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Knowledge-creation Processes in Crafts-based HCI Research

Introducing a Sympoietic Framework

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ABSTRACT

Crafts-based approaches in Human-Computer Interaction (HCI) blend analog crafts and materials with digital technologies. In addition to introducing novel ways of creating artifacts, they also present us with alternative modes of inquiry and knowledge creation but we still lack frameworks for understanding the forms of knowledge created through them. We therefore introduce a *sympoietic* framework for articulating and analyzing knowledge generation in crafts-based research projects in HCI, which integrates concepts from craft theory with HCI. The framework extends from knowledge processes in the making of an artifact to encompass the wider research process. This includes processes that occur within the 'lab', e.g. research question articulation and experimentation, as well as what happens when an artifact is deployed in and enters into dialogue with the world. We exemplify the potentials of the framework with analyses of two cases, a photonic fabric and a kinetic wearable.

CCS CONCEPTS

• **Human-centered computing~Human computer interaction (HCI)** → HCI theory, concepts and models

KEYWORDS

Crafts-based HCI, Knowledge creation, Intermediate level knowledge, Exemplary knowledge, Craft theory, Research through Design, Research processes, Sympoietic research processes.

1 Introduction

Crafts-based inquiry is increasingly gaining interest in HCI and design research. Until now, the majority of contributions in this domain have explored the possibilities of injecting tools, techniques and materials from analog crafts into digital contexts and vice versa e.g. [4, 6, 10, 22, 29, 30, 34, 44].

With the growing body of crafts-based HCI research, investigations into the epistemologies of these inquiries have emerged, questioning the types of knowledge they generate, their place in existing paradigms, standards of evaluation, and how they can provide methodological frameworks to inform and guide technology development [10, 15, 42]. While the introduction of crafts-based approaches is relatively new to HCI, there is a rich body of prior research into crafts [3, 21, 28, 31, 32, 36]. A series of recent contributions draw upon this legacy to articulate and understand the seemingly fuzzy processes that unfold within crafts-based inquiry in HCI. Buechley and Perner-Wilson argue that using a soft, i.e. crafts-based, approach has the potential to diversify technology development [10], Wilde and Underwood build on Ingold to explore how materials with new capabilities prompt us to consider new ways of approaching design [42], and Frankjaer and Dalsgaard apply Sennett's model of the crafting process to analyze how crafting processes in HCI unfold and, of particular interest to us in this paper, how knowledge is created through the making of an artifact [16].

In contrast to these contributions, which are mainly concerned with the knowledge generated through process of crafting the digital artifact, our objective in this paper is to *expand the perspective on knowledge creation processes in crafts-based HCI* to encompass the entire research process, including testing, application and dissemination. We take this wider perspective for two reasons: Firstly, because these conditions have a strong impact on the knowledge created, both in terms of guiding initial inquiries and hypotheses and in terms of evaluating and further developing artifacts based on how it is received and interacts with the domains into which it is introduced. Secondly, because we see a strong need for researchers in crafts-based HCI to better articulate how these processes, which can appear disorganized, in fact follow discernable patterns and rely on methodological processes that can generate forms of knowledge and artifacts that can enrich and diversify the field of HCI and design.

In this paper we introduce a framework with which to understand and analyze the many threads of these research practices. As we demonstrate, the processes in crafts-based research are *sympoietic*, i.e. they are created and organized collectively. *Sympoietic* (from ancient greek: sym = together; poiesis = creation) processes are signified by deep entanglements, lack of distinct boundaries and ensuing synergy between the various elements – human and nonhuman – that are at the core of a particular creative or research outcome.

We base the framework on craft theory, HCI, and practical explorations, and exemplify the framework with two cases, a photonic fabric and a kinetic wearable. The *sympoietic framework* speaks to a rising interest within the design community to develop new approaches to design that go beyond human-centered design and towards more complex understandings of the interplay between the material and the immaterial, the human and the nonhuman, which has developed in recent years as part of broader posthumanist discourse in academia. Despite the many different and divergent currents within posthumanism, they ”all have in common that they seek to undermine traditional boundaries and recognize the significance of the nonhuman contribution to the human life-world in form of nonhuman and material capacity for agency” [14].

Moreover, the two exemplary cases, consisting of a plant-controlled installation and a wearable that reflects insect living conditions in our surroundings, demonstrate the potentials and challenges of designing interactive products that takes co-existence with the natural world seriously, imminent in a time of multiple planetary crisis.

The paper is mainly theoretical, with the two cases introduced to demonstrate the presented theory. The research contributions are twofold:

1. to show the extent and complexity of open-ended, *sympoietic* research situations that unfold in crafts-based HCI research,

2. to introduce a framework based on craft theory as a tool to analyze these complex research situations.

Our intended audience is researchers engaging with crafts-based approaches to inquiry in HCI and design, for whom the proposed framework may be of epistemic value to understand their own work or that of others, as well as researchers engaged within the ongoing discussions about knowledge creation in HCI and design. Our intent is to add to the conversation about methodological implications embedded within crafts-based approaches to inquiry, and so contribute to the growing body of research solidifying the theoretical foundations of this emergent field.

2 Background

Our work in this paper addresses the wider debate in HCI about knowledge generation in design-based research approaches, such as Constructive Design Research [24] and Research through Design (RtD) [43]. It is by now acknowledged that such approaches constitute productive modes of inquiry and knowledge generation, albeit there are ongoing discussions about how to articulate, communicate, and evaluate the forms of knowledge they result in e.g. [12, 16, 36]. Moreover, there is a continuous development and refinement of the methods and the means of communicating their outcomes. Our research is motivated by these discussions, including those that pertain to legitimating crafts-based research, and as such it echoes the recent call from Höök et al [17]:"We need to develop both better ways of capturing the specificity and richness of design processes beyond anecdotal evidence, and better formats for communicating, contesting, and developing this knowledge in academic fora".

In order to delimit and clarify our aims in this paper in relation to this prior work, our focus is on crafts-based approaches, specifically in terms of understanding the dynamics and processes in the research process that encompasses not only the immediate crafting of an artifact, but also the things that influence the practitioner-researcher in this work, and those that unfold in the encounters between the artifact and the world. Following Frankjaer and Dalsgaard, we define crafts-based HCI as practices that integrate analog and digital crafting processes and create highly refined products, as well as deep and embodied knowledge. We are aware that this is one of many approaches and there are other equally valid definitions, each reflecting the historical discrepancy surrounding the term craft [16].

Moreover, we will focus on how intermediate-level knowledge [18] is articulated through the process. Here, we refer to intermediate-level knowledge as knowledge outcomes that reside in between the level of specific, concrete instances of crafting in practice, and the level of generalizable theories. Intermediate-level knowledge can take on different forms, and a range of these have been explored in more recent contributions to HCI and design research, such as strong concepts [18], bridging concepts [13], annotated [9], and conceptual constructs [38].

With the growing body of exemplary research in crafts-based HCI, more analytical inquiries into these kinds of processes and their potentials for knowledge creation have emerged, blending craft theory with HCI and RtD. By using models of inquiry and frameworks from crafting these inquiries seek to understand and guide crafts-based HCI research processes, that combine digital and analog materials, techniques and tools, from the perspective of craft [16, 42]. Craft theory asserts that craft is a way of knowing through the encounters that take place between the senses and the affordances of the materials at hand, performed as constant reflection, evaluation and recalibration [3, 21, 28, 31, 36]. Sennett describes the crafting process as a time-based rhythm of action - rest/question - action, a continuous process containing the ability to *localize, question,* and *open up.* Whereby, "*localizing* makes a matter concrete; *questioning*, reflects on its qualities; and *opening* expands [on] its sense" [36 p. 277]. In *Understanding Crafts-based HCI,* Frankjaer and Dalsgaard apply Sennett's tripartite model as a method for analyzing and evaluating crafts-based inquiries in HCI and demonstrate how the model can be extended to include digital materials and technology [16]. Wilde and Underwood on the other hand take a less deductive approach. In *Designing Towards the Unknown*, they describe their research method as "crafting RtD". Taking their cue from Ingold's understanding of creative processes as *wayfinding*, Wilde and Underwood stress that creative agency extends beyond human actors and include both materials, and relationships formed between humans and non-humans, animate as well as inanimate, and that to design towards unknown outcomes requires engaging in open-ended processes [42].

In order to position and demarcate our contributions in this paper, we consider Sennett's model of *localizing, questioning, opening* as applied to crafts-based HCI, proposed by Frankjaer and Dalsgaard [16], to provide a useful tool for understanding knowledge created through crafting artifacts in HCI research. Although we found this model useful to articulate our own research practice, we also find that crafts-based processes unfold

far beyond the creation of the artifact and formulation of research questions. The framework we present in this paper extends the established tripartite model based on Sennett by Frankjaer and Dalsgaard to include these processes.

3 Methodology

The main contribution of the paper is theoretical in nature, however the research presented and discussed is practice-based, i.e. rooted in practical experimentations as demonstrated via two examples of crafts-based HCI research projects presented in the section *Exemplary Cases.* Specifically, our intent is to develop and present a framework that meets the following criteria for understanding knowledge creation in crafts-based HCI: It must be *operational*, so that it can support researchers in articulating and analyzing knowledge creation in concrete projects. It must take into account the *complexity of craft-based HCI* practices and the heterogenous forms of empirical data that it generates, including subjective and tacit forms of knowledge. It must provide researchers with a *shared frame for comparing and discussing different projects*. It must *take into account the multiple forms of agency* that can influence a crafts-based project.

To analyze the often complex and extensive processes that characterize crafts-based HCI, we propose Situational Analysis mapping [11] as a core component of the framework. Situational Analysis (SA) is a method originating from within Grounded Theory (GT), which has been discussed in-depth in relation to HCI in e.g. [27]. The maps generated in SA are continuously evolving and as relations become apparent, they inform further research. We found the flexibility and dynamic nature of SA mapping, in conjunction with the recognition of nonhuman agency, to be a useful tool for reflecting on the constructive processes in craft and practice-based research, as we find parallels between the analytical process of SA and the knowledge-creation processes that occur in craft. Craft has a particular way of deep and thorough engagement with materials, whereby the notion of materials moves beyond the mere physical and encompasses any form-giving factor, e.g. material constraints and opportunities, practitioner intent, and contextual frictions. Comparably, SA is signified by its ability to encompass a broad array of continuously emerging heterogenous data in a research situation, viewed as equals in the analytical process. Furthermore, the knowledge-creation processes in craft are deep, embodied and often tacit, a "way of knowing though the senses" as materials interact with a maker's artistic intelligence [16]. Similarly, SA acknowledges the researcher as a research instrument, constituting an integral part of the reflexive analysis, i.e. the researcher acts like a focal point for the different kinds of data in the analytical process [11 p. 85].

As the theoretical cornerstone of the framework, we propose Sennett's model of *localizing, questioning* and *opening* as further developed in crafts-based HCI by Frankjaer and Dalsgaard [16]. This offers a model to understand how knowledge is generated via artifact crafting in HCI. However, in this paper we propose that the tripartite model of *localizing, questioning* and *opening* can be extended beyond artifact creation as proposed by Frankjaer and Dalsgaard, and applied as an analytical tool to understand and articulate the entire research process, including the processes that occur within the 'lab' and in the interaction between the artifact and the world(s) that the artifact enters into.

4 A Sympoietic Framework for Articulating and Analyzing Knowledge Creation Processes in Crafts-based HCI

At its core, the framework is thus informed by craft-based HCI and craft theory, and it builds directly on Sennett's concepts of *localizing, questioning* and *opening* [36] as further developed by Frankjaer and Dalsgaard [16]. Moreover, it is informed by the notion of *wayfinding* as introduced by Ingold [20] to draw out the landscape of crafts-based research processes.

Fig. 1 illustrates the *sympoietic* framework, which we will now describe in greater detail before demonstrating it in the two cases. In the framework, *localizing, questioning* and *opening* are spaces wherein key activities

take place. These activities unfold in an experimental loop centered around the creation and encounters of an artifact. The core activities related to the artifact pertain to *manifestation* of the artifact, the *interaction* between the artifact and the world into which it is introduced, and *reflection* upon the knowledge generated through these processes.

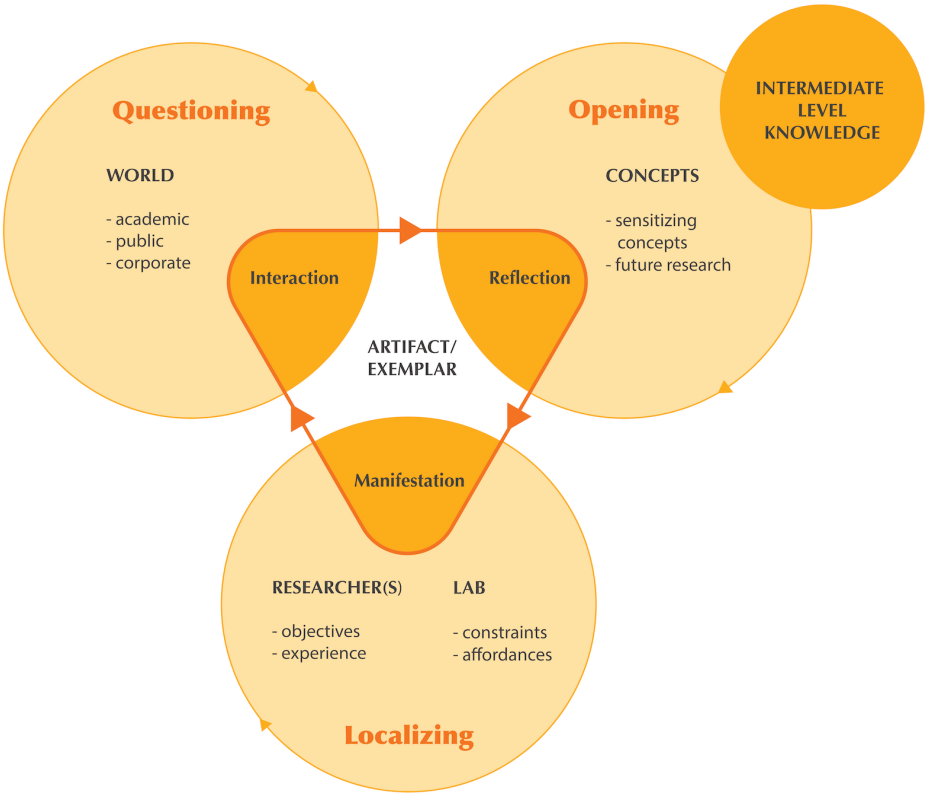

Figure 1: The *sympoietic* framework for articulating and analyzing knowledge creation processes in crafts-based HCI, which encompasses the entire research and knowledge creation process. Grounded in craft theory and crafts-based HCI, the model shows the *wayfinding* movement through the spaces of *localizing*, *questioning* and *opening* within the research landscape.

Localizing: Sennett describes *localizing* as the capacity "to specify where something important is happening" through the analysis of sensory input, i.e. "where a material, a practice, or a problem is of matters [36 p. 278]. Applied to the framework, *localizing* is where the practitioner- researcher(s) come together in the *lab*, broadly understood as a framing situation such as an institutional setting, a studio, or in some cases in a temporary dedicated space 'in the wild'. The practitioner-researchers have certain *objectives* which may or may not be conscious or articulated. These *objectives* will be shaped by the skills, ideas, sensitivities etc. that the researchers bring into the situation as formed by past *experience*. The *lab* offers certain *constraints* and *affordances* emerging from e.g., the lab culture, a given timeframe, available tools, materials and funding. In our framework, *manifestations* e.g. artifacts or materials, emerge as a result when the *objectives* and *experience* of the researchers meet the *constraints* and *affordances* of the *lab.*

Questioning: Sennett describes *questioning* as "a matter of investigating the locale", where the experience of curiosity "suspends resolution and decision, in order to probe" [36 p. 279]. In our framework, *opening* describes the space where the manifested artifact or material encounters and *interacts* with the 'outside world' i.e. *publics,* e.g. exhibitions audiences, test persons or media; *academic*, e.g. colleagues in local research environments, conferences or literature; or *commercial,* e.g. industry, local business or policy.

Opening: Sennett describes *opening* as "intuitive leaps", specifically drawing "unlike domains close to one another and to preserve tacit knowledge between them" [36 p. 279]. In our framework, elicited responses are *reflected* upon, leading to formation of more or less articulated *sensitizing concepts*, which may be theoretical or practical. In GT and SA, *sensitizing concepts* are instruments of inquiry that rest on a sense of relevance and suggest directions along which to look, yet are not definite, i.e. lack precise reference or identification [7]. These insights are then integrated into the project, leading to further experimentation. Or, having reached a sufficient state of maturity, experimentation ceases and the *reflection* is conceptualized and defined. The outcome is then channeled back to the world, in the form of e.g. publications, exemplars, media coverage, i.e. as *intermediate-level knowledge* [18]. Whilst the research outcomes to an extend are finalized as published documents and/or built exemplars, the generated knowledge, skills and developed sensitivities become part of the researcher's repertoire and influence *future research* as past *experience*, which, whether articulated and conscious and/or as tacit or unarticulated knowledge, are brought into the *opening* space by the participating practitioner-researcher. This means that any research process constitutes an ongoing process without distinct temporal boundaries.

4.1 Moving through the Landscape of the Crafts-Based Research Process

We draw on Ingold's understanding of creative processes as processes of growth, and place the maker from the outset as a participant in amongst a world of active materials where in the process of making, the maker 'joins forces' with the materials, splitting them, synthesizing them, bringing them together in anticipation of what might emerge [19 p. 21]. Ingold invokes the notion of the *wayfarer* as opposed to a navigator. In navigation coordinates are plotted onto a map, which is subsequently used to move along the predetermined route, whereby in *wayfinding* points of interest are discovered by "feeling one's way" when moving through the (material) landscape [20 p. 219]. This does not mean that the practitioner-researcher is blindly fumbling about but is in a state of anticipation, i.e. "always one step ahead of the material" [36 p. 175], a skill that lies not in *preconception* but in the ability of *seeing forward* [19 p. 69], i.e. of having developed a highly acute sensitivity and tacit understanding of the *affordances* and *constraints* of the materials at hand, [16].

To exemplify, we demonstrate how the two case stories unfold within this framework, from ideation and the experimental onset, to the feedback emerging from the encounters and interactions of the created artifact with the outside world and the following conceptualization and dissemination. Our aim here is less with the projects themselves, nor in the resulting outcomes (this has been covered elsewhere, e.g. [2]), but to demonstrate how these seemingly disorganized and drawn-out processes follow discernable patterns and methodologically sound procedures, that fit existing frameworks and methods. Our intend with this framework is to provide practices, practitioners and researchers engaged with crafts-based research with tools to assess, evaluate and communicate their research as it takes place within these non-linear, open-ended and often unarticulated processes.
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4.2 Exemplary Cases

In the following we illustrate the framework as an analytical tool by applying it to two cases. To clarify, our objective here is thus not to present the cases in detail, but to exemplify the framework's potential for articulating and analyzing the knowledge creation processes they entail, i.e. the purpose of the cases in the context of this paper are explanatory. We have therefore selected cases that have resulted in concrete knowledge outcomes in the form of exemplars and intermediate-level knowledge constructs, reported on in prior publications. We refer readers to these publications for further information about these projects [1].
For the sake of clarity, in this paper, we discuss only the concepts and correlated research processes of the presented artifacts, which have led to articulated and disseminated intermediate-level knowledge, i.e. in case 2, *cyborganics* and in case 1, *agential provotyping* and *plant participation.*

The high level of complexity of these processes render the corresponding diagrams in Fig. 4 and 7 equally complex, even though the processes have been simplified in magnitude to fit into a publicizable format. Hence, we introduce the diagrams in Fig. 3 and 5 to illustrate how the *sympoietic* framework unfolds when applied in actual research situations, whereas the simpler model in Fig. 1 provides the foundation with which further research can be analyzed based on the proposed framework. In the text, we have *italicized* the key concepts represented in the diagrams.

For analytical purposes of the process, we will start within the space of *localizing*, and then move through *questioning* to *opening*. However, in practice this is not a three-step process but rather repeatedly revolves around the experimental loop as the artifact and the knowledge that springs from it is developed.

Case 1: The Photonic Fabric
This project initially commenced as an exploration into weaving programmable luminous fabric using photo-optical fibers (see Fig 2), without any preconceived ideas of the function or form of the resulting artifacts. The result was a plant-controlled interactive installation consisting of three luminous fabric artifacts and the conceptualizing of *agential provotypes* and *plants as participants, as intermediate-level knowledge* in [1, 2].

Figure 2. Photonic fabric on loom, image by author.

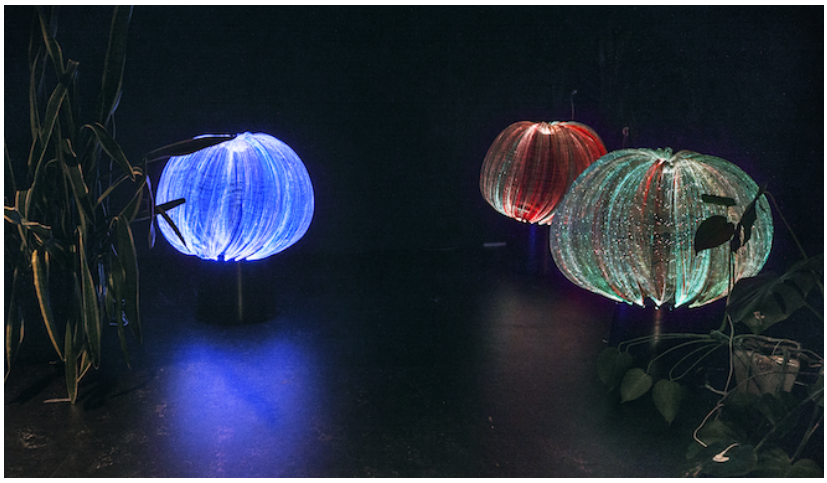

Figure 3. The photonic fabric artifacts, image by author.

Localizing

As researchers we brought with us clearly articulated past *experience* into the *localizing* phase of the research process, as our *objective* was to integrate the *photo-optical fibers into the weave* of the fabric, as opposed to adding them onto a finished structure as in an earlier knitwear-based project.

We also had *unarticulated objectives*, e.g. we expected the emerging material/artifact to contain an *interactive* or *reactive* element due to shared backgrounds in *media* and *interaction design*. This aspect only became source of discussion a while into the creative process, when we were asked to submit a proposal to a *light-art festival,* which necessitated us to define its nature and function. We decided to work with bio-electrical *plant-signaling* to control the hues emitted by the photonic fabric, largely due to a) being able to draw on past *experience* with the necessary *EMG sensor technology* and b) *environmental concerns* making the work a personally worthwhile cause.

The constraints and affordances of this project were dominated by two main factors of our *lab*, 1) available tools, materials and the non-professional setting we were working in and 2) the conditions imposed by the exhibition venue.

At the onset of the project we had access to a small university lab with a loom and left-over materials from a previous project for experimentation. Later in the process we acquired a *Rigid-Heddle Loom* and purchased *photo-optical fiber* and *LED's* via Ebay. We used other *online resources*, e.g. YouTube and Pinterest to learn how to warp, i.e. set-up, the loom and experiment with various weaving techniques. Combining cotton yarn as the warp (the strings that make up the length of a fabric) with the strands of *photo-optical fibers* in the weft (the yarn that is woven perpendicular to the warp) resulted in a piece of fabric which was very *flexible* lengthwise but, although manipulatable over the width and to some extend the length, the *brittle* photo-optic fibers snap if bent too much, limiting the achievable arrangements and shapes.

We also had to take into consideration that, powering the attached LED's created a large body of *wires* and shrink-tube which needed concealing to retain the ethereal quality of the fabric. Self-funding the project posed severe *constraints* onto how we could design the artifacts. They had to be *cost-effective* and we had to be able to produce them ourselves, i.e. by using materials available at the local *building supply store* and using only simple house-hold *hand tools.*

Our next concern was the venue. The exhibit was placed in a small park next to the river running through the city, which was very suitable to the nature and the quality of the project but posed substantial challenges as there was no access to *power* and the artifacts had to be removed at night due to *security* concerns. In addition, we had to consider changing *weather,* e.g. wind and rain. After much trial and error, we decided to use 6Volt

car batteries fitted inside an upturned bucket. The batteries would be able to provide enough *power* with a single recharge over the *light-art festival* and added enough weight for the artifacts to stand securely, whilst still being easily portable and providing sufficient space to conceal the electronics.

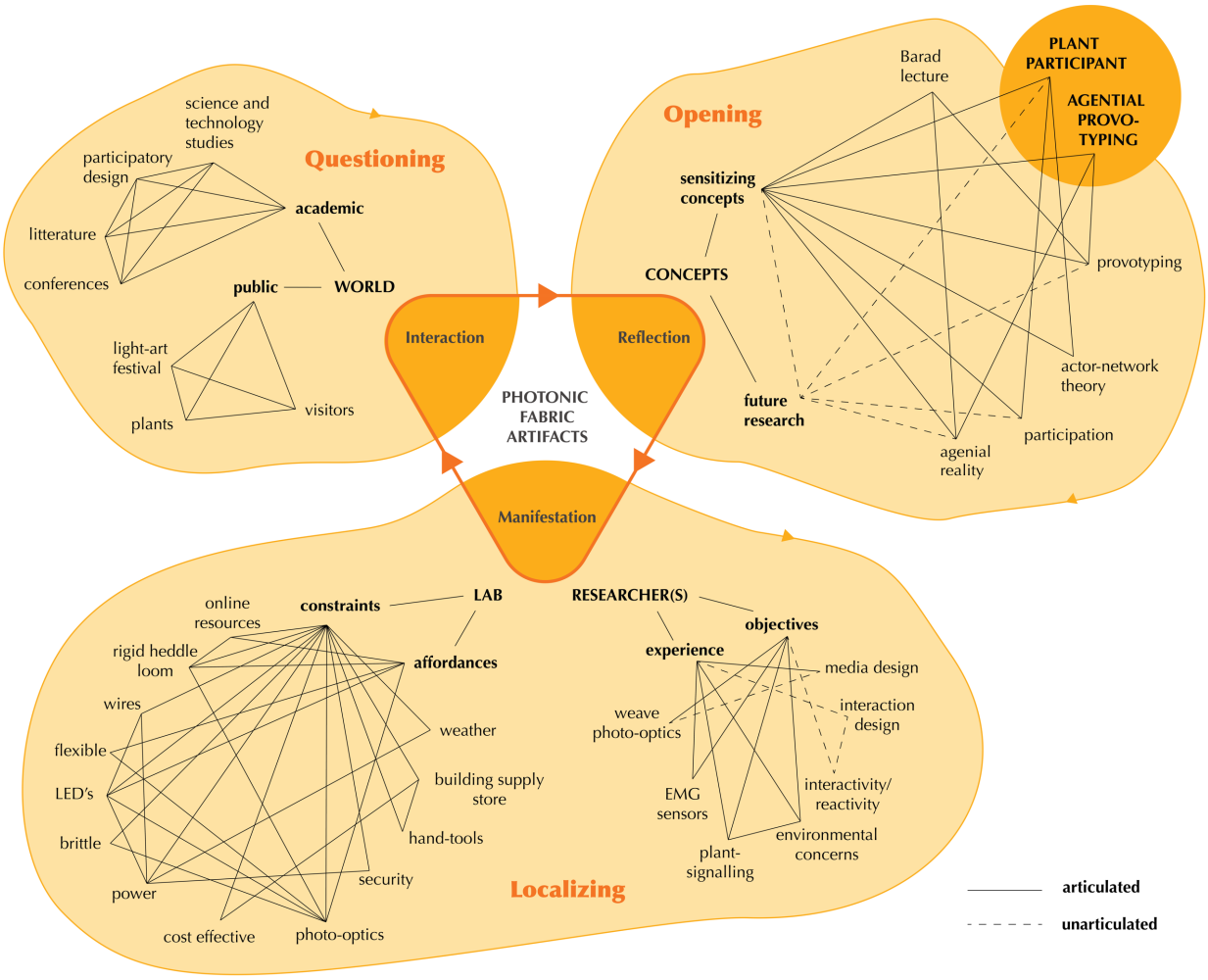

Figure 4. The research process of the photonic fabric within the sympoietic framework. This illustration exemplifies the unfolding of the research process of case 1, the photo-optic fabric, and is intended as a visual aid to support the case description.

Questioning

Once finalized the installation was exhibited over the course of five evenings from dusk to midnight, interacting with several thousand visitors attracted by the event boasting numerous large-scale media installations. During the exhibition we observed, engaged in conversations and conducted semi-structured interviews. The exhibition and the investigations are discussed in further detail in [2]. As in most research projects, we presented the project and the results to academic peers at conferences. The first was a large flagship conference in Science and Technology Studies. However, we struggled to label the work: too finished to be considered a prototype, not artwork as we are not artists, not a media-installation due to its handcrafted nature, etc. In response a fellow track presenter encouraged us to an examine 'provotyping'.

Provotypes are used to describe a certain kind of artifact, implemented at the front-end of a development process to bring- forth and reveal hidden and taken-for-granted elements of a situation, i.e. they are high-fidelity artifacts injected into a use scenario, to provoke certain reactions to be used to inform later design decisions [8, 25]. Concurrently we exhibited the installation at the Participatory Design Conference, where we, due to the focus of this field on participatory practice, took the opportunity to focus on the participatory elements between humans and plants of the installation. This approach was met with considerable resistance, not towards its expressive and aesthetic nature, but towards positioning the plants as participatory entities in the installation.

Opening

The *provotyping* concept seemed fitting with regards to revealing hiding aspects of a situation, in this case the sentience of plants, however the artifacts were not intended to inform future design decisions but to question commonly accepted beliefs of the vegetal world as inanimate. Here, post-humanist theory, offers several solutions, e.g. *agential realism,* introduced by Barad, who understands reality as agential, i.e. dependent on the 'cuts' which are imposed onto the world through the apparatus' with which it is viewed and measured [5]. Attending a *lecture by Barad* at this time of *reflection*, provided an important cue towards the way our installation worked. Subsequently, we were able to conceptualize our work by drawing together *provotypes* with *agential realism*, as '*agential provotyping'*, i.e. a "readily accessible design artifact aimed at a broad heterogeneous public, that reveal the taken-for-granted elements of the human life- world through playful interaction and aesthetic experience" [2]

Case 2: Kinetic Wearable

This project emerged from material explorations into the possibilities of combining organic materials and digital technology, through basketry. The resulting kinetic and interactive head-dresses, react to insect activity in urban areas (see fig 5, 6 and linked video-file: https://tinyurl.com/rlhbge4). As intermediate level knowledge*,* the wearables have been conceptualized as *cyborganics* in [1].

Figure 4. Kinetic wearables in the lab, image by author.

Figure 5. Screenshot from kinetic wearable video-file, image by author.

Localizing

The project was carried out between two researchers, one with a background in fashion-design and fine-arts, the other from media and interaction design, with shared interests in craft, organic materials and the implications of pervasive technology, in particularly when worn on the body. Our *objectives* were at the onset vaguely formulated ideas about exploring the possibility of interactive technology and haptics in communication related to the bodily senses.

In contrast *the affordances* and *constraints* were quite clearly defined due to the context in which the experiments were carried out, a ten-day workshop on haptic interfaces. Held at a 'wearables lab', it was tacitly understood, or assumed, that the emerging artifact was in some way to be worn on the body. Material selection to a large extend took place due to availability: a sponsor had provided a large amount of scoured unspun w*ool;* bamboo *reeds* were easily obtained from a local market and the electronics were provided in part a second sponsor as well as scavenged from electronic toys. We worked simultaneously on fabricating the felt, to be sewn into a vest, commenced weaving the *reeds* and the grass into a headdress and worked on the *code* to create *movement* by agitating the reeds with a *motor.* At this point the idea had emerged to create two identical devices and translate the voice of one wearer into *movement* in the headdress worn by the other and vice versa. One of the artifacts' main features, the emitted *sound* and the impression that it 'talks back', became apparent through the creative process and was initially caused by a delay in the *code*, i.e. the incapability of the micro-controller to handle simultaneous in- and output. Time constraints and the laboriousness required in the fabrication did not allow us to finish the artifact, which was left at the lab with one practitioner-researcher to complete the material construction, while the other commenced working on the electronics and the *code.* Working across two continents we met up roughly a year later to combine the completed parts to see the project finalized, or so we thought.

Yet, the artifacts were showing unanticipated behaviors. Whilst developing the headdress we had been working on one artifact, the second, we assumed, would simply be reproduction. Instead the two artifacts entered into an independent *feed-back loop*, as the rattling *sound* caused by the *movement* of the *reeds* in one headdress would get picked up by its *microphone* and trigger the other headdress to rattle, which then again would trigger the first headdress to rattle, etc. This *interaction* between the two artifacts was further complicated by the inability of the single chip to multitask, intercepting the responses of the artifacts to each with by various delays due to missed cues, resulting in obscuring what was happening and adding a significant amount of mysterious life to them.

Sitting side-by side in the *lab*, the two headdresses seemed like some kind of very large *insects*, reacting and talking to each other - maybe even sometimes to us - without us being able to clearly discern what exactly was going on. Taking our cue from these *interactions* and the associations brought to the fore, we decided to follow the *insec*t lead and investigate into the *possibilities* which would emerge from shifting focus from human-to-human interaction to insect-to-human interaction. Initially, we envisioned using sensors to interface with the *insects*, and investigated several possibilities, e.g. measuring activity in hives or insect-

hotels in the local area[1]. This research brought us to an urban biodiversity initiative led by the city and the national history museum. During a meeting with the biologist leading the project, we learned that our understanding of insects as creatures of great numbers to be largely mistaken. Most insects are solitary and, due to their small size, impossible to measure with standard sensing equipment, particularly in an urban environment where any *sound* or *movement* caused by *insects* would get drowned out.
In response we looked to other possibilities and turned to computation to realize the project. We built in a *GPS* module to use geolocation data from the urban biodiversity project to establish proximity to diversified locations, i.e. places around the city where *insects* are likely to be present, added a cellular unit to query a *web-service* for meteorological data in order to establish whether weather conditions were favorable for *insects* to be active and a photosensor to establish if the artifact was in fact outside. Correlating these three data-sets allowed us to establish if the artifact is in close proximity to active *insects.*

Questioning

The project had many *interactions* with the world throughout the creative process, starting with a pop-up exhibit at a *local gallery*, here a visitor associated the artifact with human *echolocation*. In the second version of the, at the time of writing, ongoing project we use *volunteers* who wear the two headdresses around *city* walks in different locations. Post-walk we conduct semi-structured interviews to assess the experience and associations caused by wearing the artifact. The project has been presented in its initial version, i.e. as a device of human-to-human interaction, as well as in its current form, i.e. human-to-insect at *conferences* in various fields. One very early event was centered around the topic of the configurations of the human and the nonhuman, which we, due to our focus on technology and the body, automatically related to quantified self and augmenting technology, i.e. *cyborgs.*

Opening

The notion of *echolocation* provided us with an *early sensitizing concept* that we explored under the broader notion of *sensory displacement* together with the notion of the *cyborg*. The latter increasingly gaining strength as a defining concept for the project and conceptualized as the *cyborganic,* as a reference to the wearable's organic qualities and the implications of the aesthetic and material choices in body-worn, augmenting technology, explored in in [1]. During this process of *reflection*, we, through internet and literature research, became aware of distinct similarities of the artifacts to *ceremonial dress* used by different cultures in Africa for religious purpose, in particular in rites-of- passage, leading to the concept of *liminality,* which as a *sensitizing concept* with which to explore the project, and its implications and meanings for interactive, body-worn technology as detailed in [2].

[1] Insect-hotels are becoming increasingly popular in response to the drastic insect decline over the last three decades. The hotels are structures build predominantly in urban areas to provide shelter and nesting grounds for insects and usually consist of an array of materials, e.g. old logs, twigs, small pipes, broken tiles etc.

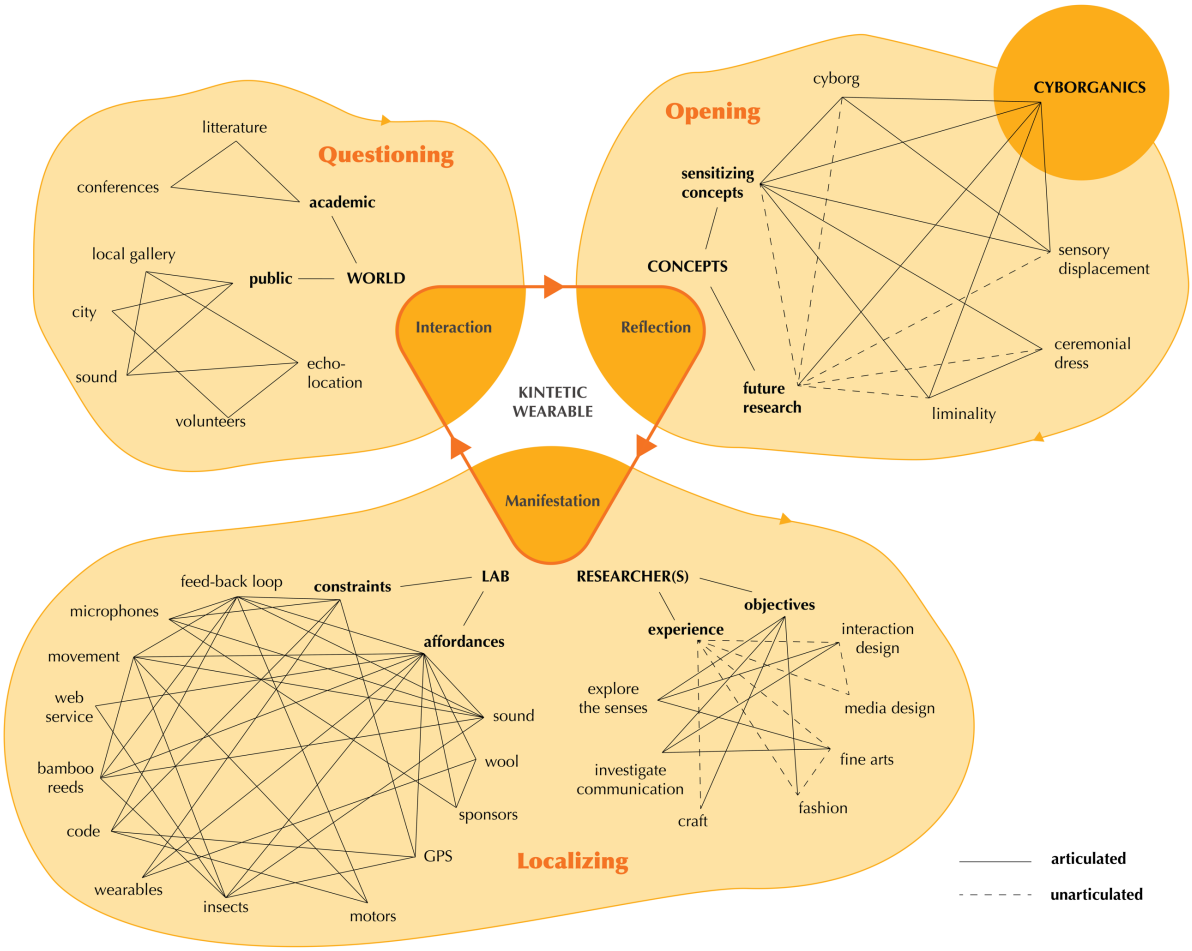

Figure 7. The research process of the photonic fabric within the sympoietic framework. This illustration exemplifies the unfolding of the research process of case 1, the photo-optic fabric, and is intended as a visual aid to support the case description.

5 Discussion

As illustrated in the two cases in the previous section, their developments as exemplars and later conceptualizations were to a large extend non-linear and shaped by an array of heterogenous external factors, e.g. plants, insects, weather, humans, materials, continents, peers, literature, conference tracks and tribal rituals, existing largely outside of our control and extending well beyond the constructive process.

Sympoiesis: Co-Creating with more than Human Actors In case 1, the photonic fabric, we entered into the research situation, i.e. the localization space, with only two predefined factors, 1) method of fabrication, i.e. weaving and 2) the main material component, i.e. photo-optical fiber. We did however bring with us quite substantial knowledge from a previous project on how to illuminate and treat the photo-optical fibers to achieve the desired qualities to disperse the light through the fabric. We also brought with us an articulated objective to integrate the fiber-optics into the material through the fabrication process, this objective constituting the initial driver of the process. We equally brought with us an array of unarticulated intentions, such as interactivity, shaped by our professional backgrounds. These four elements: 1) weaving, i.e. *method*, 2) photo-optical fibers, i.e. *material*, 3) integration through fabrication, i.e. *objective* and 4) interactivity, i.e. *functionality*, constituted our first vague *wayfinding* steps into the landscape of the research process. If we would plot these four elements onto a map as coordinates to navigate with, we would not be able to do so as too much information is missing to arrive at an intended goal. However, using *wayfinding* as means of

orientation we know that points of interest will become apparent as we move through the material landscape [20 p. 219].

Whilst experimenting with the loom and various weaving techniques we were approached by the light-art festival to submit a proposal, which provided us with an array of constraints that helped shape the artifacts into their current form, e.g. concerns relating to weather, power and safety we needed to address. Additional constraints came from within the 'lab', e.g. available tools, materials and finances, as well as the structural properties of the photonic fabric, which in turn were shaped by the possibilities of the loom, our skill-level, the cotton yarn, the photo-optical fibers, the LED's, the technical infrastructure and knowledge distribution on social media. The last element to complete the localization phase of the research was the bigger question of what the artifact was supposed to do. This became a question of ethics and curiosity, of using the artifacts in a manner we as researchers and as people found to be both fascinating and personally worthwhile, which in turn relates back to our cultural embedding and concerns. Hence, the crafting situation is not merely a question of weaving strings and shaping fabric but denotes a coming together of an array of heterogeneous elements that co-create the research situation, bound through the interference of us, the practitioner-researchers.

This particular way of thinking, i.e. of allowing the material elements to take lead, is a prominent feature of craft, whereby in a research situation the notion of materials goes beyond the physical and encompasses any form-giving factor. , as stressed by e.g. Wilde and Underwood as they utilize crafts' intrinsic qualities to "design towards unknown outcomes", to lead the practitioner-researcher through affordances and material conversations [42].

This approach of letting the materials take the lead can also be noted in constructive design research and RtD practices in HCI. Giaccardi and Karana speak about 'materials experience' and how a particular material, whether analog, digital or both, can serve as a point of departure in a design process, leading the way in the potential unfolding between material and practitioner [23]. In the same vein, Wiberg asserts that material-centered approaches enable a fundamental design method for "working across digital, physical, and even immaterial materials in interaction design projects" [41]. He notes that although this may seem like a novel development, it signifies a return to the core of the field of design, e.g. Schön, who stressed how materials "talk back to the designer", emphasizing the dynamic and dialectic nature of the design process as it unfolds between the designer and the practical manifestation [35]. Ingold, on the other hand, opposes this dialectic between maker and materials, of thinking about making as s project which "starts as an idea of the mind and a supply of material to achieve it", finishing at the moment it has taken on the intended form. In the case of the photonic fabric, we are at this point still within the localizing space, i.e. manifesting the crafted artifact. As the research moves into questioning, the artifact enters into dialogue with the world, in this case into academic and public environments, either directly at the light-art festival or indirectly through conference presentations. These interactions foster new insights and leads to follow, e.g. theoretical constructs and concepts such as provotyping, participation, and agential reality. In GT and SA, these guiding insights are referred to as sensitizing concepts, which in opening may develop into what Löwgreen and Höök define as strong concepts and be disseminated as intermediate-level knowledge [18].
In case 2, the kinetic wearable, the incompatibility of the digital code with the analogue nature of the artifacts, caused by the material affordances of the bamboo and the embedded technology, resulted in the creation of something quite different to what we initially intended to do. Here, the materials were resisting the direction we had taken, but not without providing cues which opened up for unthought of paths of design, functionality and embedding within local socio-political urban structures.

5.1 Creating Knowledge through Sympoietic Processes

In the presented cases, finalizing the artifacts marks the beginning of the theorizing process. Where certain concepts and ideas arose through the crafting process itself, now the combined digital-analog affordances and characteristics of the artifact come into play though interactions with the world outside the lab, through

e.g. personal encounters, conference presentations and exhibitions, that prompt an array of responses and associations leading the practitioner-researcher towards sensitizing concepts to guide further research and consequent theory formation. E.g. the kinetic wearable exhibited aesthetic qualities very similar to the dress worn by various African ethnicities as part of ceremony, which led us to investigate concepts of liminality, and opened up for viewing the artifact in a new light.

In relation to the ongoing discussion taking place in the HCI community about different forms of knowledge generation, we with our work here, address how this unfolds within a specific subfield of HCI – crafting – and with a specific level knowledge generation, rooted in well-established theories from craft research that are at the same time compatible with HCI, as also demonstrated in prior contributions; a coherent framework that enables researchers to map and trace the different types of phenomena that influence and shape their own process of knowledge generation; of abstraction, namely the entire research process, rather than e.g. the specific crafting of an artifact. By doing so we aim to develop a framework to address the central processes of a means to analyze and compare knowledge generation across different cases; and a means to demonstrate that there are in fact patterns and methodologically sound processes at play in crafts-based HCI, in part a response to the misconception that these processes are fuzzy and inconsistent. Furthermore, we position our work here as an invitation to the broader HCI community to consider how the wider research process plays out in other research approaches in HCI, where some of these elements may not transparent to the reader.

6 Conclusion

The body of crafts-based HCI research is increasingly growing, introducing an array of novel ways to create artifacts as well as presenting alternative modes of inquiry and knowledge creation. To be able to explore and access the potentials for knowledge creation inherent in these approaches, we need to develop suitable vocabularies, frameworks and standards by which we can analyze and disseminate them. This can be difficult as these practices may not follow well-known trajectories and can appear somewhat disorganized, in particular in the cases in which contributions to the academic community focus on the artefact rather than on the research process and the judgments and decisions it entails.

To tackle these issues and to demonstrate that these processes can indeed build on sound methodological grounds, we introduce such a framework, based on craft theory and recent works from crafts-based HCI. This *sympoietic* framework extends the knowledge creation process from the crafting of an artifact, to include the wider research process, encompassing research question articulation and experimentation, to the encounter of the artifact with the world and the knowledge that can be generated therefrom. This framework is *operational*, that is, it can support articulation and analysis of knowledge creation in concrete projects. It can encompass the *complexity of craft-based HCI* practices and the heterogenous forms of generated empirical data, including subjective and tacit forms of knowledge, as well as *takes into account the multiple forms of agency* that can influence a crafts-based project. The framework can thus provide researchers in with a *shared frame for comparing and discussing different projects*.

We hope this will serve as an inspiration for fellow researchers engaging in crafts-based research or similar forms of enquiry, to articulate and demonstrate their approaches so that we together can advance our understanding of the potentials of crafts-based HCI to push existing methodological boundaries in interaction design and HCI research and practice.

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