Understanding Craft-Based Inquiry in HCI

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ABSTRACT
Over the last decade, a number of craft-based approaches to research have emerged within the field of Human-Computer Interaction (HCI). In this paper, we examine the roots of crafting as they apply to these approaches, which blend analog crafts with digital technology, and we outline three defining characteristics: the integration of analog and digital crafting processes, the creation of highly refined products, and the creation of a deep and embodied knowledge. Moreover, we demonstrate how Richard Sennett's tripartite deconstruction of the crafting process can be applied to support analysis of the types and processes of knowledge generated in craft-based approaches to HCI.

Author Keywords
Hybrid Craft; Digital Craft; Technocraft; Tangible Computing; Wearable Computing; Human-Computer-Interaction; Research Methodology; Knowledge Creation; Craft; Craft-based research.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Recent years have seen a growing interest in craft-based approaches within research in the design and use of interactive systems. Craft-based approaches offer new ways of thinking about both the process and outcomes of research and design. They resonate with the overarching topic of diversity at this year's DIS conference by expanding the field in terms of understanding of what digital artifacts are and could be, how these artifacts are perceived and put into use, and how we create new insights and knowledge. These approaches represent an emergent and evolving field, and as of yet we do not have a clear overview of the field, neither a common language for presenting and discussing the different strands that form the field.

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While there is a growing appreciation of novel, craft-based approaches, there are therefore also ongoing discussions about which practices constitute the field, which types of knowledge are generated through them, how they fit into research on designing interactive systems, how they fit into pre-existing paradigms of inquiry, and by which standards should we evaluate them.

To move towards a better understanding of these approaches and the potentials they hold for research into Human-Computer Interaction (HCI), we address two interrelated research questions in this paper:

1) What are the defining characteristics of craft-based inquiry in HCI?

2) How can we understand and analyze the types and processes of knowledge creation that they entail?

To address these questions, our objective is to first offer an overview of craft-based approaches to designing interactive systems, and to identify their key characteristics. We demonstrate that insights from craft research [1, 15, 28, 33, 43, 57], with a particular focus on Richard Sennett's work on crafting and his tripartite deconstruction of the crafting process into questioning, localizing and opening [57], can form the basis for understanding knowledge generation through craft-based HCI. We argue that craft research has much to offer in terms of understanding digital craft-based approaches in HCI, since this field has historically had a strong focus on the interrelation between the crafting process and knowledge production. For instance, Nimkulrat asserts that craft is a way of thinking through the senses, a method of knowing which is deeply entangled with the crafting process: "craft practice in a research context can facilitate the reflection and articulation of knowledge generated from within the researcher-practitioner's artistic experience" [43]. For Adamson crafting is "a way of thinking through practices of all kinds" [1 p.7], whereas Gray and Burnett defines crafting as "a dynamic process of learning and understanding through material experience" [28 p.51], and Sennett describes how "thinking and feeling are contained within the process of making" [57 p.7].

The intended audience of the paper is twofold. Firstly, researchers and practitioners who integrate craft-based approaches in their work, for whom both the overview of the field and the deeper understanding of the epistemic value of these processes as modes of inquiry may be of value. Secondly, researchers engaged in the ongoing debate about forms of knowledge and knowledge generation in HCI, e.g. [22, 30, 67]. We consider our work here an open invitation to the community to develop the discourse on craft-based approaches to knowledge creation in HCI.

STRUCTURE OF THE PAPER

Our main objective is to examine and articulate knowledge creation that result from emergent craft-based approaches to HCI research. To position and frame our work, we first offer an overview of the literature on craft-based approaches in HCI, namely Hybrid, Digital, Computational and Technocraft. We then identify and analyze the distinguishing traits of craft-based research in HCI through an array of examples from the existing literature from the field, supported by observational studies and interviews of practitioners engaging in these practices. Since craft approaches in HCI research are relatively new phenomena, there are yet no integrative frameworks by which to analyze their knowledge generation processes and outcomes. However, the realm of traditional craft research examines these issues [1, 57]. We therefore use craft research to understand these modes of inquiry. Here we in particular found Sennett's tripartite deconstruction of the crafting process fruitful for achieving a deeper understanding of the value of crafting processes within HCI. We therefore extend the three core components of Sennett's deconstruction of *localization, questioning*, and *opening,* into three guiding questions for evaluating craft-based research inquiries in HCI. We subsequently use these questions to analyze three examples of craft-based HCI research, the *Bamboo Whisper* by Flanagan and Frankjaer, *Stiching Worlds*, by Kurbak and Posch and the *Hamefarers Kist* by White. We have chosen these examples due to a) their diversity, representing a wide range of craft-based approaches to HCI, and b) the availability of the authors' descriptions of their creative processes, which are necessary for the particular forms of in-depth analysis we carry out in this paper.

We consider this a contribution to the ongoing discussion in the HCI community to explore if and how design-oriented research approaches can contribute to academic knowledge generation. This is evident in the emergence and development of e.g. Research through Design [68] as a legitimate research approach, and of novel formats for representing and communicating research outcomes, e.g. in the shape of Pictorials [9]. However, as pointed out by several recent contributions e.g. [3, 16, 26] many central issues regarding designerly knowledge production in HCI are still contested and not fully developed. In this light, we will end the paper with a discussion on how craft-based approaches provides opportunities to explore novel forms of knowledge creation within HCI.

BACKGROUND: HYBRID, DIGITAL, COMPUTATIONAL AND TECHNOCRAFT

Several definitions have been attempted in this nascent field, which spans a wide range of practices from digitally assisted design of physical artifacts [9, 33, 46, 52], fashioning of computational physical artifacts and materials using traditional craft practices [12, 33], production of digital artifacts, e.g. code [8], merging of digital and physical media and practices [27, 33, 63] as well as artifacts emerging from within Maker and DIY culture [3, 53]. Terms such as Hybrid Craft, Digital Craft, Technocraft, and Computational Craft are used to describe this somewhat fuzzy area often used interchangeably, sometimes describing distinct areas. The ambiguity in HCI of what precisely constitutes Hybrid, Digital, Technocraft or Computational Craft, seems to at least partly stem from discrepancies of the definition of craft itself, which is at times interpreted as denoting traditional, i.e. pre-industrial fabrication methods [12], sometimes as signifying any kind of physical making, extending to simple manipulation and reassembling of physical objects [27], application of software in the fabrication process [46], to constituting a particular methodological approach and way of thinking in a creative context [23]. These discrepancies also mean that it is hard to establish a common frame of reference. We are well aware of the heavy female bias in the field, the analysis of which lies outside the scope of this paper, as our focus here lies with the possibilities for knowledge creation inherent in craft-based processes within HCI.

Hybrid Craft

Golsteijn, van den Hoven, Frohlich and Seller define Hybrid Crafting as "everyday creative practices of using combinations of physical and digital materials, techniques or tools, to make interactive physical-digital creations" [27]. In spite of the broadly encompassing definition the authors' focus lies with the incorporation of digital audio-visual media, e.g. movie, image, and audio files into interactive physical constructions, where craft denotes "making [anything] which is novel in that context" [27]. Buechley and Perner-Wilson use the term Hybrid Craft as denoting the integration of electronics with traditional, low-tech crafts in what they describe as Blended Practices, e.g. painting. One of their many projects, the Living Wall can be seen in fig. 1a. Buechley and Perner-Wilson place great importance on the activity of constructive making of electronics framed specifically within a certain craft context. Different craft methods and their inherent materials provide different affordances, which shape the expression and construction of the technology, diversifying not just the possible outcomes within the crafts themselves, but also the types of engaging with practitioners and public reach [12].

Digital Craft

Another prominent term, Digital Craft, is generally applied to denote the design and fabrication of physical artifacts by the use of digital tools, such as CAD, digital clay, 3D printing and CNC laser cutting, as shown in fig 1b. These tools merge the traditionally distinct practices of design generation and fabrication. In this context crafting signifies material selection, fabrication methods and assembly logic, not the fabrication process in itself [46]. Similar use of Digital Crafting can be observed coming from within traditional craft practice when embracing the use of digital tools [13]. In contrast, Nitsche et al., discussing approaches

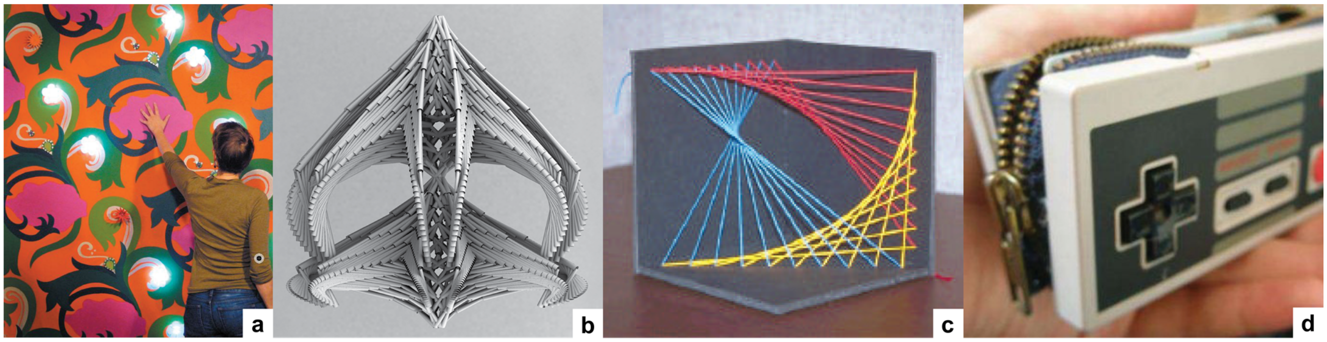

Figure 1. Hybrid, Digital, Computational and Technocraft, image examples from a.[12] ©Leah Buechley, b.[46] ©Neri Oxman, c.[8] ©Glenn Blauvelt, d. [24] ©Zenilorac.
The various terms are often used interchangeably, with divergent definitions.

within university and design school curricula to Digital Craft, define it as the combination of digital media, physical computing, and traditional craft approaches [44]. Jacobs et al. apply the term Digital Craftsmanship very broadly, encompassing computer-aided design, electronic crafts, procedural design, and hybrid human-computer digital fabrication [33]. Exploring digital fabrication methods in the production of ceramics, Rosner, Ikemiya and Regan use Hybrid Craft and Digital Craft interchangeably as the use of computational resources within and around traditional modes of craft activity [53]. Likewise working with ceramics and digital fabrication techniques, Zoran and Buechley, explore the inherent incompatibilities and possibilities of crafts and digital fabrication around the notion of artifact uniqueness. Here the authors suggest the notion of Hybrid Reassemblage, i.e. repairing broken handcrafted artifacts with 3D printing techniques [69].

Computational Craft

Blauvelt, Wrench and Eisenberg use the term Computational Crafts to describe the then nascent field, exemplified with computer generated patterns for realizing handcrafts as seen in fig. 1c., but also recognize the notion of Computational Crafting to suggest a certain way of approaching immaterial computational production [8], as explored thoroughly by McCullough in [41], representative of the general understanding of Computational Craft in HCI today. In contrast, Vallgårda and Redström speak of Computational Composites, referring to combining physical and digital materials [63], albeit not necessarily in a craft-based context.

Technocraft

The term Technocraft, emerges from craft practice with relations to Maker culture, taken loosely to mean a crafting approach to digital technology, i.e. crafting with technological objects, e.g. repurposing old gaming console controllers, as seen in fig. 1d., or integrating craft with digital technology [4, 24, 37, 58, 64]. At first glance, this usage reflects common understandings of technology as something of a modern or contemporary nature, usually electrified and/or digital, and craft as analog and preindustrial applied practices. We are however somewhat partial to the notion of Technocraft, due to its allusion to the word technê, the etymological stem of technology. Although often translated to mean mere skill or craft, technê is not merely applied practice, but denotes a state were knowing and making are inextricably linked. Techné reveals the ontological status of a thing through the disclosure of its epistemic value [25 p.23]. The focus on process, skill and knowledge as inseparable components as part of craft practice is what we explore in this paper, more so than referring to the involved materialities, i.e. analog/digital/hybrid, or a particular material outcome, such as the creation of novel products. As Hamilton notes in a response to Nitsche et al. in Teaching digital craft "[the] focus on creating alternative input devices or output devices points to a narrow definition of craft [that] fits well with current cultural pre-occupations with small-scale production, but not with the larger, much older questions about craft as a matter of process, epistemology, and conversation between form and content" [Hamilton in 44].

METHODOLOGY

To arrive at a coherent understanding of craft-based research approaches to enquiry in HCI, we have carried out a situational analysis mapping [16] of 1) examples of craft-based research, 2) observational studies of the work processes of the Connected Textiles research group which is part of the Design Research Lab at the Berlin University of the Arts, in the area of e-textiles and smart clothing, and 3) semi structured interviews with an array of experts within electronic textiles and wearable technology. Situational Analysis creates analytic maps of heterogeneous data by using principles from grounded theory, where analysis, coding, and memo writing begin at the same time as data collection. Theoretical sampling then guides further data collection. As a qualitative method, in Situational Analysis the researcher is seen as a 'research instrument' [16 p.85], hence, the resulting analysis is strongly reflexive and informed by a number of different types of data. Our analysis resulted in three main characteristics: *1. Combining, aligning, and integrating analog and digital crafting techniques and processes. 2. Creating highly*

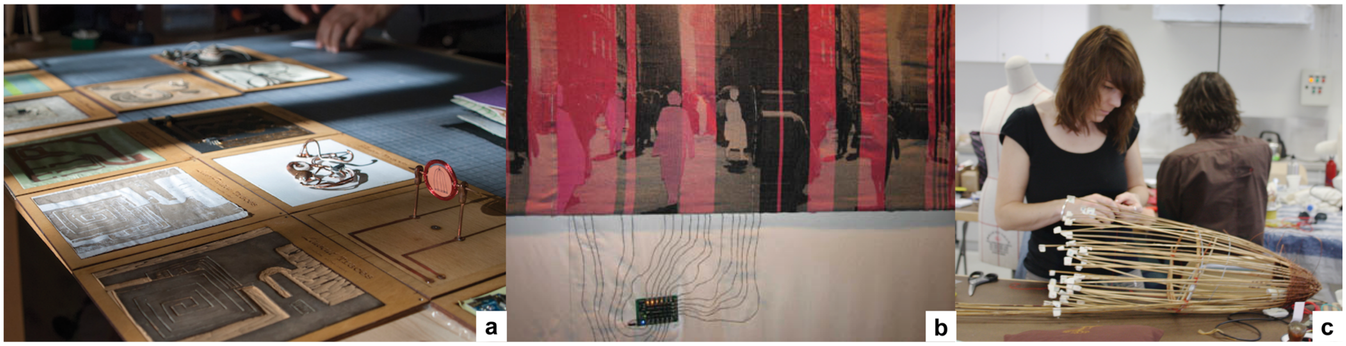

Figure 2. Illustrating the three characteristics from 1 -3. a. Various handcrafted circuit samples by Perner-Wilson exploring an array of materials and crafting techniques ©Raune Frankjaer, b. Krakow, a color changing printed tapestry ©XS Labs, c. Frankjaer in the process of crafting the Bamboo Whisper ©Nick Ashby.

refined artifacts, defined by attention to detail and aesthetics. 3. Creating knowledge through deep, embodied engagement. We then examined these three characteristics through theoretical sampling, i.e. observations and further readings. We will describe our analysis in more detail below, keeping in mind that due to the intertwined nature of these practices the characteristics are closely interrelated, e.g. the integration of analogue and digital crafting techniques both influences, and is in turn influenced by, the creation of knowledge through embodied engagement, which again is both result and driver of the creation of highly refined artifacts.

At this point we wish to stress that we do not see our work here as exhaustive, but rather as proposing common definitions and methods of analysis for furthering research in this field.

THREE CHARACTERISTICS OF CRAFT-BASED RESEARCH IN HCI

1. Combining, aligning, and integrating analog and digital crafting techniques and processes

Crafting in HCI can be understood as an extension of traditional crafting, in which novel techniques and processes for shaping digital technologies, i.e. embedding digital abilities into physical materials, are integrated into the creative process as means of exploration and expression. This area has been thoroughly covered by several practitioners, in particular in some of the early explorative works, of which many grew out of the MIT research Group High-Low Tech led by Buechley. Initially a response to the cumbersome, fragile and uncomfortable devices of 1990s wearable computing, as well as a way of transcending seemingly antithetical, juxtaposed worlds, such as fabrics, stereotyped as handcrafted, decorative and feminine, and computer technology, seen as mass-produced, functional, and masculine, HCI researchers such as Berzowska and Orth, began integrating traditional fiber-technology into their work [6, 7, 45, 51, 65]. Researchers such as Buechley, Pernier-Wilson and Satomi have extensively explored a wide array of analog materials including textiles, wood, paper, paints and gold, even seashells, as well as a plethora of techniques such as carving, sewing, embroidering, knitting, drawing, crochet, painting, hand-printing, and origami [10-12, 48], examples of which can be seen in fig. 2a. Here the goals are wider than material exploration and extend into the cultural and social. Blending digital technology with traditional craft fosters diversity on a number of levels, and is seen as an approach, which provides a unique and promising way to increase technological literacy and broaden technology culture, in addition to developing new kinds of devices. Expanding and diversifying the processes that are used to build electronics, naturally expands and diversifies the electronics which are created and the communities of people who build them [12]. Craft is not merely a method of working, a set of fabrication techniques but a way of thinking about and understanding the material landscape on a very intimate and refined level, which does not stop at material boundaries but transcends into computational logic. As Adamson and Csikszentmihalyi have noted, another distinct trait of craft is the small-scale undivided fabrication process [1, 18], i.e. the crafter is in control of all the elements of the process through which a given artifact is created, if not directly then through close cooperation with others. The work in the Connected Textiles research group is characterized by a remarkably low division of labor, where the designer-researchers perform tasks such as crafting, programming, inventing use scenarios, debugging electric circuits, creating analogies, searching for images online, mashing up different ideas in sketches, creating various types of models etc. on a daily basis, offering a rare opportunity to study the same actors working on very different problems, with entirely different means of work within the same project [34]. It also enables the crafting researcher to explore the meanings and aesthetics of the interaction through a unified vision even though the practitioner may not always be conscious or appreciative hereof. During one of our observations of the Connected Textiles research group, one of the groups' leaders was working with a small group of researchers on a capacitive carpet for a smart home exhibit, and almost apologetically explained they had to hand weave the sample as they did not have enough time to "have it made properly". During an interview, another researcher explained how handcrafting practice often constituted a pragmatic choice, due to production tools not being accessible or viable in small scale productions.

2. Creating highly refined objects, defined by attention to detail and aesthetics

In Sennett's view, craft enables the expression of an innate creative urge, which drives the crafter to produce the best possible work by providing the practitioner with a profound feeling of satisfaction when producing quality results [57], furthermore craft traditionally places great importance on the finish of the crafted artifact, with quality and individuality constituting two of its hallmarks [13]. Whilst this urge to perfection, may also constitute an impulse for researchers who adopt craft-based approaches to inquiry, we propose that there may be other important factors at play in explaining the researchers' choice in producing such elaborate prototypes. One of the experts, a sociologist who has studied the Connected Textiles research group extensively, deduced their practice of producing elaborately crafted products, to three main factors, 1. 'Handwerker Stolz' (eng.: crafter's pride), which relates to Sennett's notion of the desire to do a job well for its own sake, 2. developing and experiencing haptic objects being a very bodily process, 3. majority of the researchers having a background in fashion and textiles, where this is "just how they are trained". In contrast objects fashioned within HCI research are often prototypes rapidly produced as means to an end, with little regard to pleasing aesthetics or haptic. Lim et al. refer to this as the economic principle of prototyping, defined as "the best prototype is one that, in the simplest and most efficient way, makes the possibilities and limitations of a design idea visible and measurable" [40]. Going counter to the economic principle of prototyping, craft-based inquiry often produces elaborate objects, resembling works of art or finished products, e.g. the color-changing wall-hanging by Berzowska seen in fig. 2b. Characterized by their integration of materials with diverse properties, this can be seen as the explicit outcome of these approaches and in most cases, constitutes the main focus of the researchers' academic contributions and has been extensively covered elsewhere, e.g. [2, 5, 6, 45, 51].

3. Creating knowledge through deep, embodied engagement

Crafting is a mode of inquiry that generates knowledge as an intrinsic outcome through deep, embodied engagement. The emergence of craft-based modes of inquiry in HCI raises questions of whether this practice of high level attention to detail and application of developed skills and laborious practice, stems from a mindset inherent to the practitioners, or arises out of the agency of the applied materials, e.g. as in fig. 2c. where Frankjaer is in the process of crafting and programming the Bamboo Whisper. In their work on Hybrid Craft, Buechley and Perner-Wilson write that in contrast to the traditional crafters, the electronics makers were the only group in their study, which did not mention aesthetic nor meditative qualities as a characterizing part of their practice, in their survey results [12]. Similarly, Nitsche et al. note the 'taken for grantedness' of the aspect of material construction of physical computing in academia, resulting in "numerous Arduino classes but a gaping absence of courses on welding, pottery, or woodworking" [44]. Carter offers the concept of Material Thinking, where materials are active components in creative processes. They interact with the maker's artistic intelligence when his or her hands, mind, and eyes are connected in a creative process [15]. Posited outside the limitations of linguistics and reasoning, the creative practitioner must be attuned to an aesthetic awareness and refined perceptional sensing ability, articulated through material affordances, which facilitate comprehension and knowledge transfer inaccessible through discursive methods [26]. In a 2016 TEDx talk, Papadopoulos refers to this as the "synesthetic materiality of ideas" and explains how, as her work evolved, as she "kept weaving technology in ideas and ideas in technology", she realized that the very act of making, translating ideas into wearable artifacts, sparked a critical conversation between what materials could do, and the shape ideas could take and became a metaphor for a whole array of profound philosophical questions, inquiring to the nature, narratives, relationships and purpose of wearable technology, humans and society [47]. This characteristic constitutes the main focus in this paper. In order to better understand the processes and outcomes of knowledge generated in craft-based inquiry, we turn to craft research, with a particular emphasis on Sennett's tripartite deconstruction of the crafting process, which we apply as a lens to unfold and understand the creation of knowledge through deep, embodied engagement within HCI as shown in fig 3.

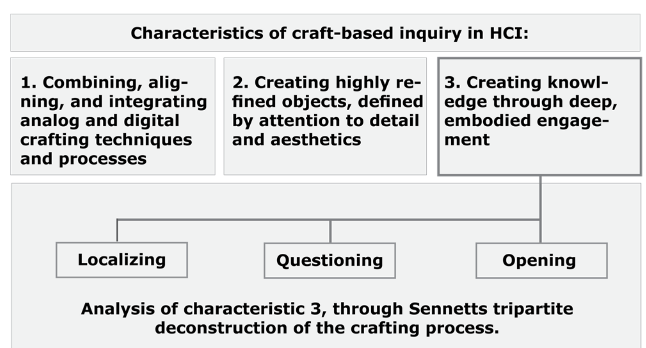

Figure 3. Analyzing characteristic no. 3, through Sennett's deconstruction of the crafting process.

UNDERSTANDING CRAFT-BASED RESEARCH IN HCI THROUGH SENNETS MODEL OF CRAFTING

Craft scholars offer numerous interpretations of the term 'craft': Risatti states that craft denotes workmanship of a refined quality [55], whereas Adamson and Csikszentmihalyi perceive a small-scale undivided fabrication process as distinctive [1, 18]. For Pye, craft is procedural and related to risk [50 p.4] and Sennett emphasizes that craft practice entails "the desire to do a job well for its own sake", which he believes to denote an innate human impulse [57 p.9]. Sennett furthermore extends the concept of craft practice to signify a condition of deep engagement, more than being bound to a particular practice. The material consciousness of the crafting practitioner, emerges from an inner curiosity of the material at hand and fuels a desire to create high quality objects, whilst striving towards ever evolving perfection [57 pp.119-120,241-242]. According to Sennett, the intimacy and dedication which characterizes the work processes of the crafter, dwell in the acts of metamorphosis and manifestation, and rests on three abilities: to localize, to question, and to open up, requiring the brain to simultaneously process visual, aural, tactile and language-symbol information [57 p.227]. As skills progress they become increasingly problem attuned, sustaining a constant dialogue between concrete practice and reflexive thought, evolving into established rhythmical thinking of problem solving and finding [11, 23]. Similar concepts can be found in the works of Schön, who, building on Dewey [20, 21] defines design as a "reflective conversation with the materials of the situation" [55]. Schön asserts that "competent practitioners usually know more than they can say" [56 p. 8] and further argues that reflection "is susceptible to a kind of rigor that is both like and unlike the rigor of scholarly research and controlled experiment" [56 p. ix]. Reflection-in-action, i.e. listening to the 'talk-back' of the situation and its materials, is at the core of 'professional artistry' where doing and thinking is seen as complementary.

In the section below, we explore the crafting process through Sennett's model of localization, questioning and opening, and relate it to processes of craft-based inquiry in HCI, with the caveat that just as with the three characteristics discussed previously, this kind of division will always be somewhat artificial due to the integration and intertwinement inherent in craft processes. Nevertheless, we have found it useful for getting a clearer understanding of how these processes unfold. Subsequently, we apply the model to three selected examples of contemporary craft-based HCI research in the section *Analyzing Craft-Based Research In HCI.*

Localization

Localization, makes a matter concrete [57 p.277]. It is the skill of identifying where something of importance is happening through the analysis of sensory input. As shown in the previous section *Understanding Craft-Based Research In HCI Through Sennett's Model Of Crafting,* localization is prompted by an inner curiosity of the material at hand by the crafting practitioner, and marks the beginning of a movement of enquiry into material properties and situational affordances [57 pp.119-120].

When practicing a craft, this thinking locates where a material, a practice, or a problem is significant [57 p.278]. The time-consuming and laborious process of a crafters skill development leads to a state of attunement to the qualities of given material, and allows the practitioner to access tacit knowledge that exists beyond the boundaries of language [49]. When crafting with digital and physical materials this means identifying when and how particular digital technologies can form a significant focal point in the creative process, which in turn requires a deep understanding of the qualities and potentials of these technologies, as well as of the analog materials in use. Humans naturally tend to focus on 'cognitive dissonances', i.e. difficulties and contradictions. These complicated experiences can be traced directly to animal behavior, consisting of the capacity to attend to a here or this, as parallel processing in the brain activates different neural circuits to establish attention. Digital technology provides many opportunities of dissonant experiences, where naturally inert materials behaves beyond its usual capabilities as computational composites [63]. Embedding the computational abilities into the physical material in the crafting process enables the researcher to intervene intuitively at a structural level of the emerging artifact and cause the composite to emerge as an integrated whole. This procedural approach of 'feeling one's way' is one of the distinctive traits of "the workmanship of risk" as Pye, defines craft, where the qualities of the emerging artifact is continuously renegotiated throughout the creation process [50 p.4]. Buchley and Zorat [69], citing Turkle and Papert [61], refer to this kind of approach as 'soft'. A Soft Approach denotes a loose framework of tools to be deployed at the discretion of the researcher, and uses concrete forms of reasoning. Theories are constructed by arranging and rearranging, negotiating and renegotiating with a set of well-known materials. The Soft Approach stands in opposition to the Hard Approach, an analytic, engineering mindset, which by default is built in to the standard tools and techniques of electronics [61]. The Hard Approach favors intellectual planning and directing a problem before initiating action. It describes that before any action is carried out a cognitive map is assembled laying out the objects, their properties and locations as well as the relations between them, in a given environment. Ingold uses the notion of Navigation as opposed to Wayfinding [31 p.219], where upon determining the current position and desired destination, the individual navigates along a plotted route to carry out the intended action.

Figure 3. From a – c. The Bamboo Whisper ©Patricia Flanagan, Stitching Worlds ©Irene Posch, and the Hamefarers Kist ©Hazel White

In contrast, an adherent to a Soft Approach is more of a builder or assembler, finding their way throughout the process, i.e. localizing points of interests as they move through the material landscape.

Questioning

According to Sennett, the act of questioning reflects on the qualities of the matter at hand [56 p.277]. It arises out of the the experience of curiosity, where resolution and decision is suspended in order to probe. In the enquiring movement, the act of questioning signifies a moment of stillness, often too brief to be perceptible to an observer or even to the crafting practitioner, however this moment of reflexivity allows the crafter to compare the newly acquired sensory knowledge with existing knowledge, tacit as well as explicit. The process follows a time-based rhythm, where action leads to suspension whilst the results are questioned. Upon analysis the action resumes, now calibrated to incorporate the new knowledge. This rhythm of action-rest/question-action marks the development of complex hand skills. In contrast, mere mechanical activity, without the development of technique, is simply movement [57 p.279]. Ingold discerns between initeration and iteration, illustrated as the difference between the act of hand-sawing through a wooden log and the workings of a metronome. The back-and-forth motion of the saw, although seemingly constant in its repetitions much like the ticking of a metronome, is continuously adjusted to the structure of the wood, and so the movements are never identical [32]. Questioning implies a desire to understand and according to Sennett the crafting process is a way of intellectual thinking, where touch delivers unbounded data and the eye supplies framed and contained images [57 p.152]; a view in line with Dewey's, who stresses the correlation between hands and eyes, which operate both doing, and perceiving "[a]s we manipulate, we touch and feel, as we look we see; as we listen, we hear" [19 p.51]. However, only the hands can effect changes within the material world. Tallis asserts that the simultaneously perceptive and manipulative abilities of the human hand is at the core of the evolution of human consciousness, as the "instrument of transcendence required to bring us out of nature sufficiently to manipulate it beyond the kind of manipulations that are available to animals" [60 p.324]. In a craft-based approach to inquiry within HCI, questioning moves beyond adapting a process to an inconsistent material or physical landscape, and requires knowing on the one hand how the digital technology itself can be examined and inquired into; and on the other hand, knowing how a digital technology can help the crafter examine and question other components in the creative process.

Opening

Sennett describes the capacity to opening up, or solving a problem, to draw "on intuitive leaps, specifically on its powers to draw unlike domains close to one another and to preserve tacit knowledge in the leap between them" [57 p.277]. In opening, the movement of inquiry commences, adapting and appropriating the newly gained insights into the materials at hand. Problem solving generally relies on one of two strategies. The first is analytical processing, such as the standard scientific method that is adopted in many approaches to research. Another method lies with fostering insights, a key aspect to creative thought. Phenomena such as serendipity, hunches and sudden insights are often perceived as luck or mere coincidence. But rather than accidental these occurrences denote an ability to combine disparate parts. This ability is associated with a propensity toward diffuse rather than focused attention and an enhanced awareness of peripheral environmental stimuli, capable of triggering remote associations [38, 39]. The repetitive movements and tactile stimuli of any crafting process, in conjunction with the semi-focused attention necessary to produce a quality product, creates a fertile environment for exactly the kind of resting-state of mind necessary to peripheral thought processes, informed and supported by the tacit knowledge and agency communicated through the materials in use [14, 26]. In the crafting process, this means acknowledging that digital technologies are malleable and full of potential to become something else, and integrating this knowledge into the creative process so there are prompts and opportunities to see the technology in a new light, and to establish surprising connections. During our observational study of the Connected Textiles research group, we asked one of the project leaders, why she does not plan out the process and end-product before commencing the creation of an artifact. She responds with economic concerns: “That could get very expensive, there are so many things that could possibly go wrong”, implicating that the cyclical process of localization, questioning and opening to her is superior to analytical preplanning of a process, due to the many unknowns inherent to her research. As an afterthought, she adds “also if I think about it too much before I do something it would probably get very boring, most of the time the unanticipated that emerges is the exciting part”. In other words, based on her prior experience she expects that new knowledge will be created as an emergent aspect of the embodied process and material engagement.

ANALYZING CRAFT - BASED RESEARCH IN HCI

One of the signifiers of craft practice is the intense engagement with the artifact by the practitioner. This aspect of craft on the one hand facilitates the formation of deep embodied knowledge, on the other hand this trait can become problematic in a research context if the artifact and its visceral qualities assume such importance that they become goals in themselves and the research objectives subsequently become secondary. The desire for a job well done which according to Sennett drives crafting practice as a motivator for the investment necessary to produce great results, has the potential of obsession. Sennett invokes the somewhat drastic example of the creation of the atom bomb as a cautionary tale, where the pride of creating an outstanding product overrides the implications of the developed artifact, “They [the creators of the bomb] had taken pride in making something that, after the work was done, caused many of these makers great distress” [57 p.295]. Granted, most HCI today is far away from creating weapons of mass destruction and craft-based-approaches in particular are generally centered around ‘soft’ aspects of technology; still we feel it should be of concern in the evaluation of these kinds of research, whether the visceral bias towards high quality finishes distracts from actual research results. One approach for evaluation we have found useful is to apply the tripartite model of localization, questioning and opening, extended into three leading questions encompassing the digital technology with which to approach and analyze craft-based inquiries as presented in table 1, and exemplified by three examples: the *Bamboo Whisper* by Flanagan and Frankjaer; *Stiching Worlds* by Kurbak and Posch; and the *Hamefarers Kis*t by White. We have chosen these three examples due to their diversity and the availability of the authors’ description of, and focus on, their creative processes. Below we briefly describe the three projects and our analysis based on Sennett’s deconstruction. of the crafting process, extended into three guiding questions, which can be seen in table 1.

Example 1: Bamboo Whisper

The Bamboo Whisper, pictured in fig. 3a. is a headdress fashioned of woven Bamboo Reeds. The device reacts to sonic input by agitating the protruding brim-sticks. The project found its shape through an unfolding process of exploration of possible percussive expressions, achieved by running a vibrating motor attached to the emerging artifact during the crafting process. Different algorithms, in conjunction with the qualities of the bamboo reeds bound in a particular weave structure, engendered expressions of varying characteristics [26]. The most interesting effect, the artifact ’talking back’, emerged from an unanticipated delay in the code. Instead of correcting the delay caused by the structure of the algorithm, the authors instead allowed it to question the desired qualities of the artefact and consequently used the glitch as a shaping material [26].

2: Stiching Worlds

In the *Stitching Worlds* project, pictured in fig. 3b., Kurbak and Posch attempt to build a handcrafted computer, thereby questioning how computing technology would unfold if approached through crafting, rather than from an engineering mindset, i.e. the project “questions whether ‘what’ we make is really more important than ‘how’ we ‘what’ we make is really more important than ‘how’ we make things” [66]. Electronic components such as resistors, capacitors, inductors are created through knitting, weaving, embroidery and crochet, based on the premise that the patterns used in these practices are equal to digital code, as they can be saved, copied, distributed and manifested as textiles, at differing times and places, in unlimited numbers [66]. Equating fiber-based, domestic crafts with computing logic may at first seem controversial, however it is interesting to note that modern computing has its origin in fiber craft. The first modern computer is generally accepted as to a punch-card loom, constructed by Joseph Jacquard in 1804 [29 p.45], and in the 1960s, NASA used Rope Core Memory, handwoven computer programs, constructed of rings and string fitted inside metal tubes, to guide the Apollo missions [42].

Example 3: The Hamefarers Kist

In Handle with Care, White describes the process of creating the *Hamefarers Kist*, pictured in fig. 3c., a wooden ‘memory box’, for sharing online photo streams with distant, aging relatives, who do not use digital devices [62]. The finely crafted wooden box contains an array of small knitted cushions of differing patterns, each symbolizing a certain person. Placing the cushion on a special shelf inside the box connects to a photo stream created by the associated person, displayed on a screen on the inside of the lid of the box, which is actually a concealed iPhone. White, citing Dunne, describes the device as a genotype, i.e. as the embodiment of an idea, created by a hybrid design and crafting process, where material and technical explorations produce speculative objects that can suggest how the physical world can be used to access the digital world. The craftsperson, according to White, “pulls out particular qualities of a material, whether that is through knitting or a smartphone…taking the huge mass of technological possibility and taking a small sliver of it to create meaning through evocative objects” [62 p. 83].

Crafting Process	Opening	Questioning	Opening
Guiding Question / Example	When and how can/does the digital technology and physical materials form a significant focal point in the creative process?	How can/does the digital technology help the researcher examine and question digital and physical components in the creative process and vice versa?	What are the potentials of the physical technology and physical materials to establish new and surprising connections?
Bamboo Whisper Explores how wearable technology could unfold if crafted from organic materials.	Different algorithms, in conjunction with the bamboo reeds bound in a particular weave structure, engendered expressions of varying characteristics.	Instead of correcting the unintended delay caused by the structure of the algorithm, the authors used it to question the desired qualities of the artifact.	A glitch can be used as a shaping material, i.e. the prototype was molded around the affordances of both the code and those of the bamboo reeds.
Stitching Worlds Examines ‘crafted logic’, by fashioning embroidered computers.	The patterns used in fiber-based crafts are equal to digital code.	How can computing components be created through various fiber-based crafting techniques.	Computing and fiber crafts are closely related, original computers were based on fiber technology.
Hamefarers Kist Explores the use of physical artifacts to share online content with populations devoid of digital skills.	Extracting one single technological function from a multifunctional device and making it meaningful through its physical embedding.	How can traditional artifacts be used to allow aging populations to operate digital devices?	Old, traditional knitted patterns can be used as a filing system.

Table 1. Three leading questions to approach analyze and evaluate craft-based inquiries in HCI, exemplified through analysis of the creative processes of the three examples.

DISCUSSION: KNOWLEDGE CREATION THROUGH CRAFT-BASED HCI

In this paper, we have chosen to examine HCI practice from a craft perspective as we believe that craft, with its strong focus on the interrelation between the crafting process and knowledge production can inform HCI into forms of insight into knowledge creation through embodied engagement. As Sennett’s three-step process of localization, questioning and opening indicates, craft practice is a complex system, moreover when extended to include computational technologies it is not a simple matter to align and integrate digital and physical crafting processes; it goes well beyond learning to code and solder, and is as much, if not more-so, a question of how the crafting researcher perceives and approaches the use of materials and techniques. In design research, the importance of experiential material engagement is widely recognized. Karana and Giaccardi suggest designing for 'materials experience'. A particular material, whether analog, digital or both, is deployed as the point of departure in the design process. The material and its unique qualities becomes co-performers, leading the way in the potential unfolding between material and practitioner [35]. Karana writes: “Materials are like words: The richer one's vocabulary (in materials), the larger is the number of design solutions that can be seen and expressed” [36] and asserts that intellectual knowledge, or acquaintance with virtual materials data is insufficient, as material engagement plays a unique role in the process of thinking and reflecting [19]. The notion of Somatic Connoisseurship, as proposed by Shiphorst, “highlights the significance of somatic facilitation” and “characterizes expertise that is developed, expressed, and passed on through the constantly refining process of practice”, which “develops expertise that can access and train experiential acuity including observation, discernment, synthesis, empathy, and focus [54]. These statements effectively mirror craft practice and demonstrate the value of bringing craft research into dialogue with HCI. We have chosen here to focus on exploring the potentials of Sennett’s tripartite model, since this offers a well-developed theoretical foundation for establishing such a dialogue, and enables us to compare and contrast craft-based approaches in HCI to craft-based approaches from other disciplines.

The deep engagement and absorbed concentration which forms the basis of any crafting process, the multi-modal perceptive abilities that time-consuming craft-based practices foster and hone, enable the crafter with an acute sensitivity to the affordances and qualities of materials and the artifacts they create. The mastery of any skill, i.e. for “complex skills to become so deeply ingrained that these become readily available, tacit knowledge” takes about ten thousand hours [57 p.127]. This is a time through which the practitioner, struggling with the properties of the chosen materials and the available tools becomes intensively attuned to the properties and idiosyncrasies of the material at hand. Merleau-Ponty describes this immersive experience as 'being as a thing', whilst Polanyi calls it 'focal awareness' and exemplifies with the act of hammering a nail: ''When we bring down the hammer we do not feel that its handle has struck our palm but that its head has struck the nail. . . I have a subsidiary awareness of the feeling in the palm of my hand which is merged into my focal awareness of my driving in the nail', to which Sennett adds that "we are now absorbed in something, no longer self-aware, even of our bodily self. We have become the thing on which we are working" [57 p.174]. In relation to HCI this means that to engage in research through craft-based practices, necessitates an appreciation of the value inherent in the time spent acquiring skills and engaging in material practices, as a prerequisite to access the tacit knowledge intrinsic to these processes.

CONCLUSION

Several contributions have argued that design is a particular paradigm of inquiry [57, 59]. One of the particulars seem to be the development of experiential knowledge, or 'first order knowledge' [17]: subjective insights and understandings pertaining to particular situations explored through craft-based approaches in HCI and the design of interactive systems. However, addressing this form of knowledge in research can be problematic. While it might be articulated and documented, this for better or worse transforms the experiential knowledge into knowledge of a different nature.

To gain a better understanding of these approaches and the potentials they hold for research in HCI, in this paper we have addressed two questions: 1) What are the defining characteristics of craft-based inquiry in HCI? 2) How can we understand and analyze the types and processes of knowledge creation that they entail?

To do so, we have provided an overview over different strands of craft-based research in HCI and highlighted three characteristics we have observed to signify approaches to scientific inquiry: *1. Combining, aligning, and integrating analog and digital crafting techniques and processes; 2. Creating highly refined artifacts, defined by attention to detail and aesthetics; 3. Creating knowledge through deep, embodied engagement*. We have used insights from craft research and in particular Richard Sennett's tripartite deconstruction of the crafting process, as a lens to understand crafting and the kinds of knowledge emerging from such processes. One of the crucial challenges for crafting as a research approach in HCI is to examine and further develop ways of addressing how, when, and why such processes of knowledge translation are viable and productive. We have introduced an extended version of Sennett's tripartite model localization, questioning and opening as an approach to understand crafting in HCI. We see our research here as an invitation to the DIS community to engage in and develop better understanding of craft-based research practices, which exhibit substantial potential to unlock tacit, embodied and material forms of knowledge.

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