Combining Practices in Craft and Design

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ABSTRACT
Combining practices of craft and tangible interaction design opens up new opportunities for both domains. But structuring cross-domain collaboration between the two poses challenges. How can we set up a crafter-designer collaboration to utilize the different fields of expertise and include separate practices? We address this question through a co-design research approach that stands in context with existing work discussed. We propose a design perspective that builds on an initial distinction between the collaborators, repositions the construction of the brief, and culminates into a collaboration through the shared object. This perspective is described in a collaboration between an interaction designer and a ceramic artist. The resulting collaboration model is presented through this co-design driven collaborative case study in pottery and interaction design that exemplifies collaborative practices to improve tangible designs.

AUTHOR KEYWORDS
Craft; physical computing; design collaboration.

ACM Classification Keywords
H.5.2. [Information Interfaces]: User Interfaces—input devices and strategies; interaction styles; user-centered design.

INTRODUCTION
Craft theory and craft practices have always been a component of tangible interface construction but increasingly have become important reference points for interaction design at large. New technologies allow the inclusion of physical making practices in digital prototyping and the socio-technological history of craft offers a rich context for interaction design. It emphasizes phenomenological approaches in the social-material context of hybrid making. This is reflected in many exemplary projects that either reference craft practices [36] or present digital interventions on existing crafts [29]. Yet, the challenge remains to balance this meeting of craft and design practices in a productive way. As successful as many of the craft-related projects are, they largely present unique case studies that do not offer a model for structuring this domain encounter on a larger scale. A critical structure is needed to support a balanced practical approach. An overbearing of new technology that merely utilizes craft is as flawed an approach as a romanticized revivalist perception of craft practices to set a new agenda for interaction design. How can we structure a collaboration of interaction design and craft in the most successful and equally balanced way?

To answer this question, this paper applies an action research methodology to tangible interface design starting from a critical review, to practical exploration, to a case study example for the development of a TEI device. This paper suggests a structured collaborative practice that ultimately emphasizes the shared object in a new way.

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BACKGROUND

Craft as Reference in Interaction Design
Craft theory and craft practices have become important reference points that integrate physical making practices in digital prototyping. At that same time, the socio-technological history of craft offers a rich context for interaction design that emphasizes phenomenological approaches. Numerous tangible interaction projects either reference craft practices or present digital interventions on existing crafts.

Related Work
There are various approaches that relate craft to interaction design. For the purposes of this argument, we can divide them into three main approaches.

Technological/artistic approaches target novel combinations of crafting and digital interaction to either lead to new technological combinations or an individual project that exemplifies a certain approach through its unique expression. Projects often combine craft practices such as fiber arts or paper craft with novel materials such as conductive thread and/or ink and can lead to new technologies like the Lilypad [7] or hybrid forms such as ePaper [16]. Here, craft and prototyping techniques are combined to explore a richer technological vocabulary for designers and practitioners. They present a blended practice that combines traditional craft methods with novel materials and tools [6]. Initial frameworks are emerging – set within the frame of such a technological perspective (e.g. [37] for paper circuits, [4] for soft circuits). But the area is dominated by a plethora of individual projects that combine craft and digital components to explore individual forms of

expression. Many of these examples can be found in the demo and art showcases of conferences such as CHI, TEI, or UIST.

Ethnographic/educational approaches build on the social context of craft to explore novel practices. Scholarly work in this category looks at creative practices to inform educational and design approaches. For example, Buechley and Perner-Wilson observed 40 crafters to learn from them and inform their designs for a hybrid craft [6]. Goodman and Rosner build on their ethnographic work with gardeners and knitters to develop information technology [13]. Peppler investigates the overlap of crafting and digital media to inform novel educational approaches [24]. These works are valuable explorations of how to contextualize interaction design in existing craft traditions and practices. They probe the context of craft practices for new interaction design approaches. However, at the same time, craft itself had to adjust to new digital production techniques and this complicates such a positioning.

Craft-based approaches consist of modifications to existing crafting practices. They are often transformative but focus less on the development of new technologies and more on the application of existing ones to traditional practices and the resulting changes. Traditions of craft are challenged by personal fabrication and digital tools that often simplify and speed up processes [12], or existing trades such as jewelry making are enriched through a critical digital design dialogue toward "interactive jewellery" [36]. These tools—3D printers, laser cutters, programmable sewing machines, to name a few—are not new but their role in craft practices is still emerging which leads to a collision "and through this collision a new value for craft thinking, processes, and knowledge is beginning to emerge" [27]. In craft-based approaches, this emergence originates in the workshop not the lab [3]. It realizes in the adoption of digital technologies into existing craft practice by crafters.

Depending on the constellation of the participants, these three perspectives often overlap and allow for the development of novel hybrid approaches by individual crafter/designers (e.g. [38]). The success of such hybrid work often depends on the dual-identity of a crafter-designer or a close collaboration that is noted but its nature and structure remain largely unclear. It is this overlap that we aim to support with our own work and it is here, that we see the biggest need for a structured co-design approach: to lay out a collaborative critical practice. This notion of "critical making" [28] meets the concept of "thinking through craft." [1]. Where the practical engagement with and the individual as well as shared critical reflection on the material and the object form a collaborative practice that inherently combines craft and interaction design without conflating them.

Approach and Principles

Our approach to develop a structure for craft-design collaboration on tangibles puts emphasis on a material and critical process (like Ratto and Adamson) and it aims at inclusion of specific craft practices (like Rosner and Buechley). However, it differs in the layout of its process through a co-design informed approach. Co-design grew out of related design approaches such as participatory design and user-centered design and sees different partners "working together in the design development process" [31]. It focuses on creative collaboration processes between different practitioners and is seen as an instance of co-creation. Our approach combines this co-design focus with the "reflective practitioner" model introduced by Schön [32]. As a result, it supports a differently weighed approach to structure individual collaborations between crafters and designers.

The procedural perspective of our approach was one from the design side approaching the craft but aiming for the construction of a shared dialogue through the structure of the collaboration over time. Three key elements shaped our approach to a structured combination of craft and interaction design: creativity, practice and experience, and the role of the object itself. The creativity of the TEI designer and crafter needed support, namely through the effective combination of their practices. This led us to a new role of the object as partner in the emerging dialogue.

Approach through Creativity

Creativity is a key element not only in design but also in craft and personal creative practices of the craftsperson. It cannot be excluded from the development of a general approach in the combination of craft and interaction design [21]. Particular creative practices of crafters often define their specific engagement and the quality of the resulting work. Thus, we aimed at clear inclusion of any such personal practices and concerns.

Definitions of creativity itself vary depending on the context they are applied in [33]. Amabile's micro level looks at how immediate surroundings and social context might affect creativity and proposes a "Consensual Assessment Technique" [2] that looks at a shared assessment of creativity based on subjective criteria. We did not apply this tool as an analytical assessment instrument upfront but the consensual method is reflected in the later stages of the here-proposed collaboration. Like Amabile, Csikszentmihalyi rejects the idea of the "genius" as the single source of all creativity and explores creativity in a three layered system model of *domain*, *field*, and *individual* [9]. These provide working areas not only for an approach of the designer toward the crafter but also means to locate a possible intervention within the creative practice itself. It allows different locales where the collaborators in the craft-design arrangement enter each other's domains, where they evolve into alternating gatekeepers of their fields, and manage cross-selections of each other's ideas into a new creation.

Separate Practice

Design evolved as an own discipline from the distinction between material production and the planning and preparation processes for that production. Design thinking, the "concrete integrations of knowledge that will combine

theory with practice for new productive purposes" [5] differs from the material practices of craft that are themselves production-based. However, the relationship between the three key practices "design, craft and art can be seen to occupy an unstable territory of permanently shifting allegiances." [18] These allegiances adjust to particular practices. There is, for example, ample work on analyses of workplace practices in design research. Because we focus on experiential practice and encounter with the material, the Science, Technology, and Society (STS) informed activity system by Keller & Keller served as a useful approach to structure the analysis of different practices and their emergent relations. As a pair that includes craft practice (a blacksmith) and analytical observation, the Kellers' work mirrors the set up proposed by our model. They trace an umbrella plan from an initial brief to an experientially informed encounter with the material and emergent object design [17]. This approach informed the analytical first stage of our approach but our resulting structure ultimately differs from the Kellers'. Because we remained interested in the encounter with the material, a second key concept was that of a "surprise" encounter with these material qualities during the production process. Herein we relate to Ingold and Hallam, who outline creative practice with materials as generative, relational, temporal, and ultimately improvisational [14]. Their forward-looking concept of practice as a constant process of bringing-into-being that is shaped by in-the-moment encounters with others and with the material influenced our own design of the collaborative process between crafter, designer, and material.

Active Objects

Largely building on Heidegger and Deleuze & Guattari, Ingold further proposes to look at "real" objects as constantly coming into being through relational networks wherein all participants collaborate and the human ones "follow the materials" [15] (a concept also used by Schön). He emphasizes objects not as finished constructs but as dynamic unfoldings of forces constantly at work. A thing, here, is not a proof or even a trace but an active ingredient of a larger dialogue contextualized far beyond a single manipulation. Ingold's particular focus on materials suits our approach for a material- and practice-based collaboration. It establishes the thing as an active part of a never-ending dialogue between all partners involved in the process. As the agency of the objects increases we see them becoming ever more important collaborants in a participatory design process.

That is, why this paper follows a research through design approach [11] that has found increasing traction in design research, including the combination of craft and design [19, 20]. Our approach differs from the ideal of a holistically educated crafter-interaction designer. It builds on a model that involves a designated designer and a crafter, wherein the two do not directly collaborate from the beginning to deliver a defined product, nor do they try to blend their fields of expertise into one. The emerging space for a dialogue is not a shared single practice but a dialogue and the object is a material artifact engaged in the unfolding discourse. The following will outline an example implementation of this approach as well as a discussion of results.

CERAMIC INTERFACE

The sample project started in spring 2015, in the production labs at Georgia Institute of Technology on the one hand and the ceramic workshop of the crafter on the other. It consists of a collaboration between Clement Zheng, as a designer in the field of Industrial Design, and Amy Roberson, a ceramic craftsperson. Its goal was to structure their collaborative process in a way that would harness the creative input and individual practice of both partners without diluting either one's expertise in the process. The transactions with the craftsperson evolved over the course of this collaboration, from an initial *investigative* phase to understand craft and craftsperson, to an *exploratory* phase of discussing possible collaboration opportunities, to an *implementation* phase to prototype the interactive artifact. As we will elaborate in the following, these phases manifested from the focus on creativity, different practices, and active objects outlined above.

Investigation: Mapping Craft and Crafter

The designer is trained in the fields of industrial design and interaction design, specializing in designing tangible interactive products. His practice typically involves designing, building, and programming tangible interactions. These prototypes often employ digital fabrication techniques such as 3D printing and laser cutting. Zheng had no prior experience with ceramics in his work. The first phase of the research involved an approach of the designer to the craft and crafter. No fixed product goal was set apart from the explorative encounter, which comprised of a series of informal interviews and observations of the crafter at her workplace, as well as personal encounters with the craft itself.

The Systems Model of Creativity

Csikszentmihalyi's system model [9] of creativity provides a useful approach to frame Roberson's practice as a crafter: Roberson produces craft objects within the *domain* of ceramic arts and has been a practicing artist in residence at the Mudfire Gallery in Atlanta since graduating in 2012 from a Fine Arts program in ceramics. She is personally drawn towards the three dimensional canvas of expression which ceramics offer, and is particularly interested in pottery for its tradition of producing not only beautiful objects but also objects of utility—"I love that people can use my pieces daily, rather than having them on a wall to be looked at only". This balance of form and function remains important to her practice and evident in the work that she produces. This would later emerge as an opportunity for collaboration between interaction design and her ceramic craft.

Roberson is an active contributor to the local craft scene in Atlanta, which can be seen as a *field*. As an artist in residence in a city gallery, she teaches and assists amateur and professional ceramic artists in the community. In addition,

she participates in art festivals around the city. Her work is sold through those art festivals as well as through the online craft marketplace Etsy. Within this field, Roberson has established an identity for herself, especially for her use of simple, functional forms coupled with playful and vibrant glazes.

Roberson's work is influenced by her *individual* interests and passion. In particular, she is attracted to the Electronic Dance Music culture, and she tries to imbue her work with the same fun and playfulness that she enjoys through her use of glaze and color. This establishes a unique signature in her work, even as she claims a much wider overarching influence of the Mid Century Modern movement in her work. In line with her attraction to playful and vibrant visuals, Roberson is also attentive to color trends. In her repertoire of tools is a set of Pantone color swatches which she refers to in choosing glazes for her pieces.

Figure 1. Left: Glazed mugs by Amy Roberson. Right: Colorful base detail at the bottom of a cup.

Exploring Process and Materials

Roberson's craft processes could be divided into two distinct methods that either fall into a relatively structured "umbrella plan" [17] that allows for more precise planning and effective performance, or into a more "improvisational" [14] crafting that specifically embraces elements of surprise as part of its production. This second method is employed for experimentation and allows a large amount of improvisation in the making process itself; "when experimenting with a new form, I like to have the clay in my hands to be able to make slight adjustments and see them from all sides." Roberson deploys this method typically when exploring a new form on the wheel or with new glazes and color combinations. The "umbrella plan" method described by the Kellers is more a top-down, linear, funneling approach. This method is typically employed by Roberson during the production of a series for a collection. It features a strong initial brief and set procedure with few improvisations or surprises allowed in the process.

Encountering the Craft

A separate vein of exploration involved a first-hand experience of the craft itself by the designer, who had no experience of working with ceramics. This was an intimate process wherein the designer experienced the basics of working with clay and pottery tools over multiple sessions working on own (mostly flawed) ceramics. This experiential approach stands in contrast to the analytical transactions with the craftsperson but was carried out in tandem with the interviews and discussions with the craftsperson.

Limited as such a preliminary encounter with the craft was, it allowed the designer to discuss basic materials and processes with the same language as the craftsperson. This experience was helpful in generating 'action' knowledge, or what Polanyi calls "tacit knowledge" [26], which heavily depends on embodiment and the ability to "interiorize" knowledge to re-apply it in practice." Even though the tacit knowledge of the crafter far outweighs that of the designer, this encounter allowed the conversation to emerge over a shared experience, albeit between an expert and an amateur. In addition, this first-hand experience increased the sensitivity and empathy one had towards the craft and process. It supported a feedback loop between the conversation with the craftsperson, and the personal encounters with the craft, and influenced the generation of ideas for potential collaborations between digital media and craft. Experiencing the practice was not meant to turn the designer into an expert potter but to encounter the material and the practices as active components to prompt questions about them. As the collaboration continued and a deeper engagement with the craftsperson was established, the flow of ideas shifted and begin to gain specificity towards Roberson's crafting practice and identity as a craftsperson. These included the insights described in the previous section, such as her use of colors and glazes, and the tensions between form and function in her work, which connected to the tacit exploration of these components at the hand of the designer.

Tensions and Opportunity

The tension between form and function is a recurring dilemma that occurs throughout Roberson's work. As a craftsperson, she creates her pieces with the intent that customers will use and interact with the pieces. This is evident in the colorful detail that she creates at the base of her vessels, a detail that is only revealed through interacting with the object (see figure. 1 right). However, many of her pieces end up not as functional objects but as display ornaments. During an interview, Roberson recounts her personal encounter of this dilemma with her grandmother, who would not use her granddaughter's pieces as she deemed them "too pretty". Roberson intends others to see and "use" her objects, pick them up, uncover hidden specifics, and manipulate them. This specific dilemma faced by the crafter stood out as a unique opportunity for collaboration; one that the brief was eventually developed around.

Exploration: Developing the Brief

If the first stage of an investigation into craft and crafter is a phase of research into craft, then the brief is the hinge which turns the collaboration to a research through craft and design [11]. As with most design briefs, it consists of a goal, constraints to work within, and is formulated between "motivation" and "creation" phases [8]. However, some important aspects of the brief stood out from our case, which we highlight below.

Role of the Brief

Up to this point, the perspective was that of the designer approaching the craft practice and practitioner. The brief is developed by the designer as a response, and thus as a turning point. We observed in our case that the designer stands on fertile middle ground; as an approaching amateur to craft, the designer has gained insights on the craft practice and understands the motivations which drive the crafter in her work, and simultaneously, as a professional in the design domain, the designer is conscious of his strengths and capabilities. Practically, designers are trained to integrate often diverse fields into their process (such as business, engineering, sciences) [8]. All of them shape the development of tangible interfaces in experimental as well as industrial settings. Crafters are trained on a specific material manipulation process and the set of skills that are relevant to that process. This difference of breadth versus depth training of design and craft practitioners was observed not only in our case, but also in other collaborations [34].

The brief aimed to not only bank on the opportunities identified in the previous phase, but also exploit the strengths and motivations of both designer and crafter to drive a successful collaboration. This focus on process differs from the more uni-directional client-to-designer problem statement that defines a typical design brief [8]. Our brief aimed not at a product but a shared object: a "thing coming into being," able to connect both practices and to create opportunities for craft and design in the collaborative object-making process. Besides anchoring the collaboration to a type of object, the brief also divided the work between crafter and designer on the shared tangible interface object. Neither crafter nor designer were experts in the other collaborator's domain. Consequently, the goal was to provide sufficient constraints to ensure the gradual assembly of craft and design outcomes, yet leave enough room for both, crafter and designer, to explore within their own domains.

Lastly, the brief follows Amabile's consensual assessment - evaluating the outcome based on the judgments and expectations of both crafter and designer. This differs from a more formal, criteria-driven evaluation approach found in a typical design brief [8]. The brief serves as a catalyst, and sets a new trajectory for craft and design to collaborate. Building on Ingold and Hallam's emphasis on improvisation in craft practice, we propose that the brief should afford a process, which is malleable to the "surprises" that might emerge [14]. The presentation to and acceptance of the brief marked the start of the task-driven and object-focused collaboration between crafter and designer.

Brief: Building an Interactive Lamp

In our case, the brief called for the creation of an interactive lamp. Notably, we were less concerned about the novelty of the object as a product (commercial lamps responding to touch exist) and more about the appropriate framing of the next steps in the collaboration. The nature of the lamp object relates to Roberson's personal interest in electronic dance music and her practice involving vibrant glazes as well as the playful trademark details within her ceramics. It specifies a tangible user interaction with the lamp, where physical interactions with the lamp affect the hue and color of the light produced by the ceramic lamp. It also sought to address an important personal dilemma to the crafter—the detachment of her functional pieces from any actual use. Embedding physical interactions in the object ultimately require the audience to pick up the object to engage with it. Through the brief, the interaction design answered to the crafter's personal experience and concerns regarding function.

The brief's targeted outcome (the lamp object) was not seen as a product but instead as a shared common ground for continuous critical engagement. Practically, the lamp was broken down into its various components, with the crafter responsible for the ceramic lamp body, and the designer responsible for the electronics and programming.

Implementation: Sharing Lamp Making

The third stage covered the implementation of the hybrid lamp and combined specifics of craft and design practices as well as shared and differing techniques. It is nearly impossible to embed electronics in clay that will be fired at temperatures between 1000–2400 Fahrenheit. This meant that the electronic sensing component had to be assembled onto the finished ceramic. It also meant that the ceramic needed to be constructed with this later assembly in mind. This material condition shaped collaboration and object design. The lighting component of the lamp was based on readily available RGB LEDs but the sensing system proved to be more challenging. There is a huge body of applicable work on embedding sensors to create tangible interfaces. In the implementation, this led to the choice of accelerometers to sense the interactions, as they can be connected to the ceramics without disrupting the craft process. The accelerometers in turn informed the first interaction model of the lamps—the hue, saturation and value of the emitted light are affected by the lamp's different movements. The technical benefit of using an accelerometer was that as it senses general Cartesian acceleration but allows for flexible use of that information. Different physical interactions and behaviors can be incorporated through reprogramming. This enabled the same basic electronics to be packaged in future versions of the lamp and to respond to different ceramic bodies, making room for improvisation during the implementation process. The craft-based benefit was that this interaction design addressed a key concern of Roberson with her existing objects. She had complained about the non-use of her objects as they had been deemed "too pretty" to be touched and used. The tangible interaction design using accelerometers actively addressed this problem.

The implementation went through iterations of divergent and convergent phases. During the divergent phases, the crafter and designer engaged in individual exploration, developing their respective components. During the convergent phases, the prototypes were assembled and evaluated for areas of

improvement and new insights in the development of the tangible interface. The end of each divergent-convergent cycle culminated in an assembled object which bears the traces of the process, and functions as a point for reflection and discussion for the next iteration.

Divergent Phases

Guided by the brief as well as insights that emerged during the course of implementation, both crafter and designer individually explored and exercised their expertise within their responsibilities during divergent phases. The housing and assembly of the electronics to the ceramic lamp body was the main focus of the tangible interface designer. Adafruit's 5V Pro Trinket was used for the micro-controller, while WS2812b LEDs were used as the light source. Prototypes iterated through initial breadboard models, to more robust packages encapsulated with a custom-made platform. Different clamping methods had to be devised to secure the electronics in response to each ceramic body. This often required work from the crafter, such as the addition of holes in the ceramic, a standard procedure in ceramic craft. A variety of digital fabrication methods were employed as fitting electronics to the ceramic lamp body became more complex. These range from laser cut plastic assemblies to 3D printed cases. A custom circuit board was eventually designed and fabricated for a more stable electronics board. The designer's iterative exploration on packaging the electronics components resulted in smaller, more robust fixtures. In addition, later fixtures were also more flexible in adapting to different ceramic body forms.

Figure 2. Electronics revision from breadboard model to custom circuit board with digital fabricated platforms.

The form, size and texture of the ceramic body was the crafter's focus during the divergent phases. The exploration began with paper sketches of possible forms the lamp might take, as a reflector of light and as a form for users to hold and interact with, but also as an object in itself with its presence in a room. A few forms were eventually shortlisted and turned in clay. These pieces were then fired with different color glazes. Different glaze and textures were tested with the tangible interactions in mind. While the crafter's past concerns with glaze and color were typically aesthetic in nature, now they had to consider the tangible user interactions (e.g. touch) and light reflecting qualities of the ceramic surface. The crafter also experimented with a variety of techniques to produce different forms which could afford different kinds of tangible interactions. A roly-poly form required the crafter to merge two turned clay parts along a narrow seam, while a faceted body was also made entirely via hand sculpting; a process significantly different from the crafter's usual process of turning clay on a wheel.

Figure 3. Different ceramic forms produced by the crafter.

Convergent Phases

The different elements from both crafter and interaction designer were assembled together and evaluated during the convergent phases. The first assembled prototype met the initial expectations of both collaborators but it also led to new considerations that emerged while the collaborators interacted with the object. The glossy and smooth texture of the glaze—which the crafter typically applied to her other pieces—raised the issue of the user's hands slipping during interaction. In addition, the LEDs were too bright to look at while interacting with the lamp. At this stage, the crafter's own preferences and the tangible interaction designer's approaches did not yet conflate but their differences became visible and critiqued by both. This critique of the prototype involved both crafter and designer and often reversed their roles. The designer would argue about the glaze and the crafter critique the light fixture. The object involved both participants in a shared reflection of the decisions made in the divergent phase and enabled both parties to engage in a better understanding of the collaboration process.

Figure 4. Assembled prototypes; first prototype (up left) to more current (bottom right).

Surprises sometimes emerged during the convergent phase, prompting improvisation on the collaborators' part. For example, the crafter produced a larger ceramic body for the second prototype (see fig. 4 upper right). The weight of the second form made it difficult for a user to interact with the lamp in the same way as the first (see fig. 4 upper left). Instead, the second prototype encouraged the user to pivot the lamp on the edge of its base, which then enables it to roll along its circumference. This new affordance required an improvisation of code optimization, which was quickly adapted to support the new interaction model.

This emergent interconnection—the "surprise"—that emerged during the second assembly, and the improvisation that followed, gave rise to a different interaction concept. Instead of a single expert changing the material and the digital construction, the new insights were part of the literally productive dialogue between two experts on the grounds of the emerging objects. At this point designer and crafter were also more familiar with each other's process and domain. With the first two prototypes as reference, the discussion went beyond improvements of the existing models. New approaches to develop interactive ceramic lamps, as well as innovative ideas for the different lamp components were raised. The collaboration between crafter and designer continued and at this point of writing they are at the fourth iteration of the interactive ceramic lamps. Since the second prototype, more ceramic forms and interactions were explored, including the 'roly-poly' and faceted forms as well as new methods of organizing the cables and electronics with the ceramic lamp body. Both crafter and designer are now more confident of their individual roles and what they can achieve through this collaboration. In contrast to the first prototypes which was developed close to the initial brief, subsequent prototypes deviated from the initially prescribed tangible interaction. The tangible interface emerged over time in this dialogue of objects and co-designers. The crafter pushed the physical characteristics of the ceramic bodies to afford different physical interactions, while the tangible interaction design of the lamps emerged from the designer responding to these new shapes and forms. The dialogue between both crafter and designer occurred not only person-to-person but increasingly over the object as well. In our case, we read these gradual steps toward the development and optimization of a range of possible products as signs for a successfully initiated collaboration that never conflated expertise but remained active through the differences of all partners involved.

Consensual Assessment

No external assessment was conducted throughout the implementation process, rather the outcomes of each iteration were evaluated against the expectations of the crafter and designer collaborators. This follows Amabile's consensual assessment technique, where "a product is creative to the extent that expert raters independently agree upon this judgment" [2]. Such a dynamic and emerging assessment method serves our goal of establishing a collaborative practice, in contrast to developing an optimized product. The *personal* and *domain* impact of this collaboration both provided evidence in support of such an assessment technique. Roberson varied her *personal* crafting and glazing techniques in reaction to the outcomes of each iteration. As she reflected: "This rounded form is good to hold, but I want to see how an open form will change the quality of light", and "I want to try a more neutral glaze to see its effect on the different color hues." These were direct responses to the operation and design of the electronics and LEDs. They exemplify her response to and engagement with the collaboration through its objects.

Furthermore, the outcomes of each iteration catalyzed discussion and idea generation among Roberson and her peers at Mudfire gallery (her *field*) as well. Roberson reported on an impromptu discussion with her peers about "incorporating electronics into ceramics" while she was working on her part at the studio, resulting in several new ideas, one of which was a "faceted lamp body that changes the lighting effect as it rests on different faces" (The fourth prototype, see figure 4). Here, the shape of the lamp, the means of its construction, even its ideation would have been impossible for either collaborator alone but emerged from the social environment of the crafter. They were developed in absence of the designer and indicate possible extensions of the model to reach wider collaborating partners within the targeted craft *domain*. Given that crafters often have highly individualized skillsets, this would allow for a larger range of expertise and indicate a wider reach. It also responds to our initial interest to build a model that supports further collaboration and participation across domains as these contributions are indicators for a discussion that reaches not only the single collaborating crafter but her peers as well.

The collaboration's impact on the crafter's practice motivated her to continue the partnership months after the original project had ended. Even prompting discussions on pushing the collaborative outcomes beyond experimentation and refining them for the marketplace. A critical and/or financial success of such a new product would indicate that the *field* acknowledges the success of the collaboration.

DISCUSSION

This sample project describes a long term collaboration between crafter and designer (one and a half years at this time of writing). It stands in contrast to shorter term "workshop"-style collaborations between crafters and designers that start off as product-oriented, such as the research carried out by Tung et al. [34], as well as other educational approaches [24]. We observed numerous challenges emerging from this long term collaboration and reflected on the process to meet them. The focus was on the role of shared object, as well as the involvement of differing yet connecting practices.

Iterative diverging-converging process

Compared to the co-prototyping process employed in the workshop conducted by Tung et al. which tightly coupled designer and crafter for short term engagement, our practice-based co-design study revealed a need for periods of individual exploration leading to subsequent assembly and evaluation. As the designer noted in reflection: "I am accustomed to specifying every aspect of a 'product', from measurements to materials to color and texture. For this collaboration however, I felt like I was designing a system to work with the craft"—speaking about an adjustment of his work to the practice as such instead of to the resulting object. Such an approach leverages the separate fields of expertise of both crafter and designer as distinct and often

asynchronous practices; both crafter and designer had to schedule this collaboration around their separate practices. This cyclical process of co-investigation, individual exploration and assembly may prove to facilitate a longer term craft-design collaboration beyond a single project. The assembled object in our case study serves not as an answer to the brief, but rather as "a method of collecting and preserving information and understanding" [19] as Mäkelä argues; a trace in the shared process that assembles both practices over the evolution of the object.

Objects to think with

Seymour Papert describes "objects-to-think-with" as artifacts in which there is "an intersection of cultural presence, embedded knowledge, and the possibility for personal identification" [23]. He referred to such objects in an educational context but we observe that our ceramic lamps took on the same role. They provided a platform to connect the asymmetrical expertise and practices of crafter and designer. Through the process of co-design, we observe crafter and designer working less on following a strict product goal, but instead responding to the prototypes built.

Figure 5. Left, Middle: nudging the lamp to increase light intensity. Right: resting the lamp to dim it.

The crafter adjusted crafting process and techniques to respond to new understanding of the sensors and electronics. Most notably, the third 'roly-poly' form marked a significant leap from the initial plan for the crafter, as she sought to imbue the ceramic bodies with more playful affordances for tangible interaction capable to be sensed by the accelerometer. On the other hand, the designer began to develop new tangible interactions responding to the physical characteristics of each new ceramic body. The designer describes his approach to later ceramic pieces as a case of asking the piece "how would I want to interact with you?" allowing the tangible interaction design to emerge from physically handling and exploring the potential of each form. Interactions for the 'roly-poly' body were developed from such an object-led approach: forcefully nudging the roly-poly will increase the intensity of the lamp's light, while resting it gently on its side dims the lamp (see fig. 5). Such a reflection and implementation process would be difficult for an interaction designer, or even a designer-crafter hybrid practitioner. It is a process facilitated by the dialogue fueled by the difference between practitioners of craft and design collaborating over the making of an object. It continuously leverages the role of the object as object-to-think with. In our case, the reflection continues to inform the tangible interaction design.

Digital fabrication's supportive role

Digital fabrication has been applied to craft-technology research from many different angles. In their work *hybrid reassemblage* and *hybrid basketry*, Zoran et al. employed digital fabrication to explore the tensions between hand-crafted and digital manufacturing [38, 39]. In another collaboration, 3D printing was used as a rapid prototyping tool to conceptually explore craft possibilities [30]. Digital fabrication processes have also been imagined as embodied craft in which humans replace machines [10]. From our case study, we observe that digital fabrication is employed as a pragmatic means of interfacing the craft outcome with the sensing system for tangible interaction design. In many ways, this use of digital fabrication resonates with Gershenfeld's prediction of the technology fulfilling a "market of one" [12]. It was employed in unique production runs to support the tangible interaction design in response to unique ceramic forms produced by the crafter. At no point of our project did we ever consider to replace the crafted component with a personal fabrication-based one as this would have intruded into the dialogue we had established between designer and crafter through separate practice.

OUTLOOK

Combining craft and design remains an ambitious goal with much promise. "Design intervention is an interface between tradition and modernity, and calls for matching craft production to the needs of modern living. It can, and has been shown to, play a role in empowering the disenfranchised and the marginalized." [35] We cannot claim such an impact but present an emerging practice for a constructive collaboration between the two domains that does not attempt a direct merger but a critical dialogue. Thus, it proposes an inherently inclusive and additive approach for emerging participatory and collaborative practices. Through our case study, we observe enabling mechanisms that support craft-design collaborations. Our collaboration leveraged the role of "objects to think with" to inspire improvisations in individual practice where collaborators respond to each other's work. Evaluating each outcome through consensual assessment also created space for critical reflection that catalyzes and steers subsequent making efforts. We observe the importance of the experiential and investigative initial approach from design to craft and craftsperson in establishing empathy and uncovering opportunities for collaboration. This paper presents a process-based and co-design inspired 3-step approach that allows the objects to become active components in the critical development. In our model, the collaboration ultimately does not center on a single component, but it uses the divergence and convergence between experts, materials, and objects over time to structure a dialogue that, we hope, helps to informs future TEI design processes that combine craft and interaction design.

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