Teaching Digital Craft

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Abstract
At the overlap of maker culture, ubiquitous computing, critical making, and novel interfaces, digital craft emerges as a new research and teaching domain. It offers new opportunities in interaction design but it also poses particular challenges to academic curricula. This paper first discusses the value and challenges connected to digital craft. Then, based on our experience with exploring digital craft in a research university's teaching environment, we highlight viable approaches and teaching practices in this new field. It closes with a discussion of the prototype results achieved in those classes.

Author Keywords
Interaction design; craft; higher education

ACM Classification Keywords
H.5.2. User Interfaces: Prototyping. D.2.2. Design Tools and Techniques: User Interfaces.

Introduction
Digital craft grows in relevance as computational media invade material design. It builds on interdisciplinary approaches emerging from an ongoing debate between craft and design in digital media. This debate covers technologies, practices, histories, impact, critical approaches, even research methodologies. The term is

used both to describe production of digital artifacts (such as code) as well as in reference to digital production and prototyping methods. The tacit knowledge of handwork meets digital creation. Attempting a definition, Malcolm McCullough claims we need an inclusive idea of digital craft in the computer age. He sees craft expanded by digital media "that could reunite visual thinking with manual dexterity and practiced knowledge" [13]. Likewise, craft researchers widened their view from a traditional making practice to "craft as knowledge that empowers a maker to take charge of technology" [6]. Examples for digital craft practices are found in speculative design [7], education [9, 5], or innovative media design [16]. A driving factor of digital craft is its combination of new technology with physical hands-on experience. Such a "thinking through craft" [1] philosophy is closely related to "critical making" [14]. Both emphasize – in their own ways – the experiential qualities rooted in craft that make it a valuable access points for interaction design. An in-depth education and development of such a craft-based approach is needed to support this evolution in HCI and support interaction designers and crafters alike. But not unlike other approaches to interaction design, the interdisciplinary origins provide a creative challenge to research and education. This paper addresses possible answers to these challenges through a look at the authors' experience with taught digital craft courses.

Challenging Digital Craft as an Approach

Digital craft's application onto interaction design is not a simplification but a creative complication that produces friction. One point of tension arises from the fluidity and speed of the digital. Analogue craft practice is a matter of partial resistance to the flow of commodities through our lives according to Adamson [2]. One difference is in inherent production speed: craft slows down whilst the digital is characterized by speed. Another friction point is knowledge distribution: while craft facilitates dispersed authorship through the appropriation and displacement of skills, traditional craft teaching practices are based on masters teaching apprentices directly and seem to clash with distributive digital knowledge approaches. Furthermore, Adamson argues that craft requires proximity and skill with physical materials, whilst the digital inaugurates a completely new spatial logic. Adamson refers to the analogue as walking and to the digital as teleportation lacking spatial coherence. Production is losing the notion of proximity due to digital technology synthesizing components built in disparate places. "Objects are increasingly brought into being through disconnection, not despite it" [2]. Likewise, digital instruments do not have the ease, simplicity, and range yet that hand tools afford. As an example Adamson refers to the "depressing stylistic homogeneity of digital craft objects" [2] limited to topological layers, accumulated blocks and point-to-point morphs.

This friction between craft and the digital is also the root for a dialectical discussion between the two. For example, Adamson's perspective on the flow of commodities in the world shows resemblance to Borgmann's notion of the 'device paradigm' wherein the presence of things is replaced with the availability of commodities. A thing (like a woodstove) in Borgmann's argumentation, "brings with it bodily and/or 'social engagement' with the thing's world (which can be burdensome). In this sense a thing necessarily brings with it more than any single commodity it may make available." [18] Commodities "are highly reduced entities and abstract in the sense that within the overall

framework of technology they are free of local and historical ties. Thus they are sharply defined and easily measured." [4] Borgman continues by stating that we move away from "things" toward "devices." These devices (such as a furnace) serve to make a single commodity highly available while concealing the characteristic way its commodity (such as warmth) is procured. The device, then, disburdens us of both social and bodily engagement of the thing, leaving only the commodity (warmth) in evidence. Transferring this to interaction design, mapping one on the other can create a break where the digital device – the computer, the app, the interface – meets the craft thing – the stove, the clay, the multi-layered tool. The optimization of a device and how easy it is to use can create a disturbance in the tacit, the social engagement and proximity that are crucial to craft. If we look at digital craft as a field to be taught, then this necessary disturbance prevents any simple application of craft. Craft is not an easy way to include material discussions into design but it demands a critical re-thinking.

Making a Digital Craft Course

Looking at Critical Making

Reviewing a selection of available syllabi on comparable courses led to a leaning toward Ratto's concept of "critical making." Ratto outlines three steps in the realization of "critical making" that serve as initial guideline: 1) review of existing work 2) jointly designing and building prototypes 3) iteration informed by conversation and critique [14]. This applies a largely studio-based teaching approach. For example, building joint prototypes demands time and continuous availability of space. Another challenge in academic institutions is the "demo culture:" the optimized to push toward a functional prototype for a hands-on demonstration to visitors, alumni, and potential future sponsors at a demo day at the end of the term. Decoupling the critical making and critical design approaches [7], which focus more on the processes than on the resulting objects, from such a demo day culture can be a culture shock at best.

Another challenge is combining craft elements with digital prototyping. The Bauhaus offered its students an introductory course with a basic education in materials and skills. Few academic research institutions can provide such a base-level introduction. Instead, it is tempting to take the material craft world for granted and focus on introductions to digital prototyping techniques. The results are numerous Arduino classes but a gaping absence of courses on welding, pottery, or woodworking. Where both are combined, as seen in some art and design schools, the balance back to critical literature review and theory appears reduced [17]. The following section outlines the set up of a course structure at the authors' institution as it tries to define its own balance of theory and practice.

Background Conditions

The following argument summarizes teaching efforts that stretched over the past 2 years and grew out of the teaching culture at the Digital Media unit at the Georgia Institute of Technology. The courses' curricula had to fit into a research-heavy public university that does not feature long-hour studio courses but is built around fixed core and elective courses. Students have full-time access to labs but little funds for additional tools or materials. Courses lead to a M.Sci. or Ph.D. in Digital Media with expertise in design, critique, and implementation of digital media at large with no particular technology preferred.

Project Studios

The courses discussed here were project studio courses that are informed by a faculty member's research but largely exploratory in their design. Students are allowed and encouraged to take multiple instances of these courses. In the courses sampled here, students tended to continue with a project studio over at least two terms, which provided much needed continuity. However, visiting students and one-term contributors were easily integrated. Courses offer 3 credit hours per week and were usually taught in single block sessions. To provide more opportunities for practical studio work, we experimented with additional not-for-credit workshop courses that were open to all students and included most of the project studio participants. Overall, the structure allows for gradually evolving courses that can carry a theme over a longer time. It also provides extra-curricular space and time for practice-based work. But it does not institutionalize this scenario, continuity and extra-curricular education are an option but not build into the system.

Course Design

The design of courses at hand included critical theory, design challenges, prototyping, and design critique. They were small (7-9 students) explorative courses of the Digital World and Image Group, led by the teaching faculty. Notably for an institution such as Georgia Tech, the courses were not framed by any particular technology. No single platform or practice was ever defined as set target. As one student proclaimed, we tried to avoid "sticking an Arduino on it." The digital material was not set but grew out of the critical engagement with existing, non-digital practices.

Teaching Digital Craft: Materials

Background

The first course created a debate on digital craft through discussions, readings, and designs that led up to the development to two larger group projects. Critical discussions of readings and of designs remained essential throughout and the resulting projects should not be misread as the targeted outcomes. They grew organically out of the debate. One project, *Paint Pulse*, will be discussed in more detail. The project originated from one student, Colton Spross', trip to Turkey where he encountered the ancient marbling technique of Ebru. As a marbling technique, Ebru is used to design intricate, flowing patterns of paint directly on the surface of water, which are then captured on paper. Ebru was developed in the 15th century but like many traditional craft practices, it was nearly extinguished by industrial competition [19]. Our goal was to connect digital elements to the craft to afford new means of expression and interrogate the practice in the digital age.

Initial Designs

Initial designs focused on various means of recreating Ebru digitally (see also [3]). They provided digital substitutes on either the input or output side of the craft. For instance one proposed design would use a robotic Ebru brush mounted on a 2D CNC-like mount that could paint automatically onto the water surface. Another example design was a performative system where the Ebru artisan's paint manipulations would be tracked by a camera, and this would alter procedurally generated "Ebru-like," patterns projected onto a nearby screen. However, our discussions in class led us to value the tacitly developed skill of the original crafter – to avoid making a "device" and instead operate on the

"thing-ness" of the practice. Simplifying or automatizing crafting did not honor this and we imposed a constraint upon ourselves to not deskill the artist or make the craft easier. Moreover, we rejected the tacking on of media additions to the practice. While craft – especially studio craft – can offer whimsical and playful results, a defining element of craft is that it answers a need [15]. Thus, tacking extra media such as sounds or visuals to an existing process that did not loop back into the earnest underlying practice's need was also rejected. We aimed to avoid "digital exhaust" that might add computational extravaganzas for their own sake instead of the craft's. As a result, we turned away from both automation and simplification to ask how we could change the substance of the craft. The craft practice already had a medium: the paint materials and tools. How could we make digitally responsive feedback loops that incorporated them?

The final concept for *Paint Pulse* evolved to make magnetically responsive Ebru paints with ferrofluids. These new paints would still work in an Ebru style but would also offer new behaviors. This led to re-designs of the traditional tools (comb and stylus) into digitally controllable electromagnets. The design concept offered a traditional Ebru artist the additional abilities of selectively also controlling pulsing responsive paints while the underlying practice stayed intact.

Into Materials

Traditional Ebru uses a special Middle Eastern gum, Tragacanth, dissolved in the liquid for the substrate in combination with horse hair brushes, ox-gall based paints, and alum coated paper. Lacking many of these resources, we rapidly experimented with several other combinations of other water marbling techniques. The standard way for recreating Ebru (using cellulose substrate and oil-paints), was overly affected by our addition of the oily ferrofluids. We spent a large part of the project experimenting with own combinations that altogether failed (at times spectacularly) until we found a similar marbling practice, the Japanese water marbling art of Suminagashi. It allowed us to combine our ferrofluid additions with the inks and still allow for proper printing and manipulation.

Into Tools

All necessary tools for the Ebru station were created by us, from the marbling water tray to the inks, to the manipulation tools. We had to teach ourselves how to make powerful magnets by tightly wrapping iron nails with thin, wire-wrapping wire, and controlling them with a SN754410 dual H-bridge motor driver. These got incredibly hot with use, so an ergonomic, 3D-printed housing was created for the magnets, which also included LED's to give visual indications of their pulsing magnetic behaviors. One of the new affordances that our ferrofluid set up supported was the addition of dynamic brush behavior.

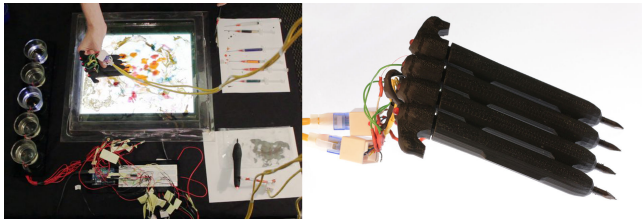

Figure 1 Paint Pulse set up (left) and one of the custom-made electromagnetic tools, an electromagnetic comb (right)

The electromagnets worked in a pulsing rhythm and the magnetism of the newly created Ebru tools manipulated

the ferrofluid ink (but not the Suminagashi inks). To maintain the Ebru artist's practice, we included a range of different activation rhythms in the form of cups with LEDs underneath that flashed in different speeds. When the electromagnetic nails were dipped into one of five cups with an electrode leading to an Arduino input, the microcontroller toggled the magnets into a new behavioral style. The entire system was controlled by a single Arduino Uno, and in order to keep the wiring organized, and to allow for rapid setup and takedown, Ethernet cables and jacks were used to connect the stylus and comb to the main system.

Figure 2 Colors at work in Paint Pulse

Paint Pulse falls short of continuous iterations. Instead of an intermediate stepping stone for the argument within a critical making course it had become more of a single standing piece, which was exhibited at Atlanta's Maker Faire and won prizes for its implementation on Instructables.com. Where it did succeed, however, was in its foundation on materials. Instead of approaching digital components of a craft as supplemental interpretive appendages, mediatization, or means for simplification, it designed the change from the basic materials up to the tools and their manipulation.

Teaching Digital Craft: Collaborations

The second approach adopted the analysis of practices presented by Keller & Keller [11]. The course analyzed their analytical stages and used them to devise a set of steps used for our own analysis. Equipped with this, each student met a local craftsperson to document their particular practice. We first concentrated on their existent practices as each student reported their crafter's practices back to the group - providing an analysis on a given practice and learning about different practices next to each other in the course.

In a second step, students engaged in the chosen craft form. If the first analysis was a purely technological breakdown of the process, then this second step was the experiential exploration of what it feels like to weave, knit, bake, craft. Finally, we designed digital components to transform the existent practice. Over the course of the next weeks, prototypes were built and presented to the crafters for initial feedback.

Figure 3 A collaborating crafter working at home

The close collaboration with a crafter/ artists quickly made it clear that in the actual craft practice production of an object is important but far from the only desired goal. Instead, the personal experience of the process, the personal motivation for each craftsperson, and their individual gain from the process were also relevant. One example was the collaboration with a weaver, who was also interested in bird watching. Instead of dividing these interests into two different fields, the digital intervention on her weaving practice became a proof-of-concept-prototype that controlled weaving patterns procedurally informed by an image analysis of bird photographs. Since the Jacquard loom, weaving has been controlled by some form or mechanical or digital pattern. However, in this instance the procedural patterns were driven by an image analysis of this weaver's own interest in wildlife photographs and the project became highly personal.

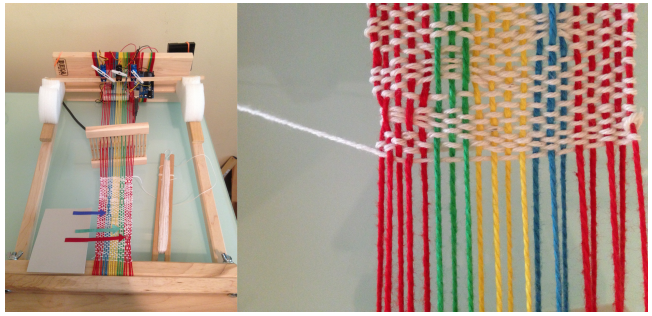

Figure 4 Student built proof-of-concept weaving loom and abstracted irregular patterns driven by image analysis

This mix of intervention upon an analyzed practice and inclusion of personal stories from the crafter informed every project of the course: the emigration experience of a baker, a knitter's experience of motherhood, the religious bonds of a group of quilters, all became key to the digital interventions. This reflects basic approaches of user-centered design but used them to change digital craft practices – not to develop new products but to find new approaches to material/ digital work.

Skill, Material, Practice, Collaboration

As mentioned, each student had to personally experience the craft practice. The challenge is that any exploration of craft practices and materials requires considerable investment of time and resources. A full exploration is not possible given the limitations of a single course – or even a single 2-4 year degree program. This was balanced in two main ways: 1) students worked with more experienced crafters and/ or artists; 2) exploration of the material was applied as an encounter of questions to it - not mastery of it. Skill, materials, practices, and objects were made part of the course's discussion and exploration.

Instead of mastering pottery, clay became a material questioning device for participants, part of the discussion in the coursework. At the same time, external crafters and artists provided additional voices and personal perspectives in the exploration of these materials. Including elements of participatory design allowed a critical engagement that did not depend on full mastery of a given practice. Collaborative work is explicitly mentioned in the description of Critical Making as an approach, but its relationship to Participatory Design that draws from different expertise and knowledge domains remains underdeveloped. In our case, the personal histories and motivations of the crafters and artists shaped the individual projects. At times, the results evolved around the person of the crafter as much as the material at hand.

Craft, and with it digital craft, is not only a field of practice that allows for critical technology production, but also one that emphasizes personal expression. That student projects formed not only around a certain craft practice but also around a particular practitioners' expressions of their history, their family status, and their interests is only logical. It emphasized that exploring digital craft is not a neutral engagement with technical knowledge but that it has to include the tacit and personal memories and skillsets on a fundamental level. It explores the elements of material production/ practice and of self-expression and personal development. Crafters – particularly as individually working artisans or in small social groups – are not machines and their personalities rightly infused the digital design process and the resulting interventions. Including this perspective through collaborations with outside partners proved essential for the course.

Discussion

Based on the courses and their outcomes discussed here, two main observations stand out for the teaching of digital craft. The first key point is the importance of "thing-ness" in any digital craft approach. In many critical making projects or craft-inspired digital works, the dynamic systems with which makers engage lean toward the digital components and their functionality. In contrast, in *Paint Pulse* much of the hands on exploration remained rooted in the complex interplay of materials in the Ebru bath and the tools at hand. Dialogue with the craft must necessarily reach beyond functionality or commodity and into material and thing-ness. Preparing the correct recipe for the materials and making all of the necessary tools led to a more fundamental engagement with the craft practice and avoided building on top of it as a "device" in Borgmann's argument would do. We argue that mediatization of craft (e.g. through sonification or visualization techniques) can be distracting at best for the area of digital craft if it fails to build on the material basis of the particular craft practice.

The many independent variables of the pigment, the substrate, the ferrofluid, the electromagnets, container material and shape, and the paper type formed a rich dimensional space for experimentation, tactile experience, and play. Tweaks in any of these attributes had large effects on the plethora of necessary dependent interactions: buoyancy of the pigment, reactions of the pigments, working time (some of the inks quickly froze when placed into liquids), magnetic responsiveness, chemical reaction between the water and the paint, adhesion of the surface pigments to the paper, and the workings of the color on the paper. There were too many permutations of these variables to empirically test in the time span available in the course's final stage (4 weeks). More importantly, the aesthetic criteria for gauging success were too subtle for us to easily develop a set of heuristics. But it was the thing-ness of these problem fields that shaped the hands-on digital practice and exploration.

Within this exploration, we had to rely on a rapid approach where we sought to develop as much tacit knowledge as possible between the many different materials we could combine at our disposal. This is akin to the approach of research scientists in other fields depending on situated practices when they develop an intuition over their domain before forming a specific research question for refined experimentation. In digital craft, the situatedness includes the materials used for a particular practice. While a mastery of these material is

impossible to achieve in the scope of an academic course, the material itself has to remain a central theme for the theoretical and practical engagement and its physicality has to remain part of the discussion.

The second point learned is that the practice itself cannot be seen as neutral. Craft often includes personal expression, development, quirks. Revivalists such as Morris made it a core argument for a necessary resurgence of craft. "We do most certainly need happiness in our daily work, content in our daily rest; and all this cannot be if we hand over the whole responsibility of the details of our daily life to machines and their drivers." [17] Alienation and ugliness have to be countered through handicraft, able to produce things of beauty through personal engagement of the crafter. Crafting, here, is as important for the practitioner as it is for the product. While an unreflective revivalist's perspective is just as misleading as a purely technological approach, the infusion of personal expression into the practice cannot be brushed aside.

This is particularly true in the current role of craft in many societies, where it has largely been replaced as a form of necessary product production and instead re-emerges as a form of self-development. Material, object, and practice are often directly informed by personal choices that are not driven by functionality or process optimization but by personal taste and individual history. Few students will have such a fully developed background. To include this in a course on digital craft, we suggest elements of Participatory Design in a collaborative setting with experienced crafters. This copies approaches from Critical Design and Critical Making. Introducing craft through the art of another collaborator also avoids a too individualistic approach that might take any part of the digital craft for granted. The craft and the personal stories connected to it have to be encountered anew during the course to remain critical and to help participants recognize the connection between the two. That is why the only student who had practical experience with the Ebru craft in the *Paint Pulse* project had to heavily adjust his initial ideas throughout the course before we reached the final design of the prototype. Sometimes, familiarity can cloud the problem space.

Digital craft combines digital media, physical computing, and traditional craft approaches. It does not favor any single domain over another as it balances and transforms all components involved. That is why the courses and approaches discussed here were not framed by single technologies. Their educational approaches were not built around a particular technological core but on process. If digital craft is submerged into a sub category of physical computing, for example, then the necessary balance will be difficult to maintain. The courses discussed here were taught at a technical research university where it is expected that students can learn particular technologies and solve arising challenges through new approaches without much educational scaffolding. Admittedly, this might be challenging in other institutions, but the alternative seems too restrictive. Put simply: an introductory course into specific platforms with a view on how the hardware or software might operate on traditional craft materials is weighed too heavily on the technological side and might lack the openness that is needed for an experiential course on digital craft.

Our future work will continue the collaborative and material-based approaches outlined here. Courses on

digital craft will start with a focus on a single material, its production, and handling in collaboration with material scientists and crafters. Once again, this points back to the Bauhaus tradition. The ideal of a "digital Bauhaus" has been evoked and debated at numerous occasions [8, 10, 12]. However, reaching this goal depends on experimental course designs and teaching approaches – just as the curriculum of the Bauhaus did. The here outlined approaches hope to contribute to and inform this experimentation.

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