



Design Bookkeeping: Making Practice Intelligible through a Managerial Lens

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ABSTRACT

As DIS researchers increasingly describe design as an emergent and material engaged practice, many are embracing different approaches to design documentation that capture the breadth of these practices. This pictorial contributes to these efforts by shedding light on a kind of managerial work that emerged when creating a complex e-textile installation. Specifically, we reflect on our project through the lens of “design bookkeeping” to describe documents that embody managerial knowledge and describe what these documents make intelligible about our practice. We surface findings and cross-cutting themes that bring attention to these practices in relation to broader understandings of project documentation. We then speculate on how the DIS community could circulate this knowledge within, and beyond, academic publication venues.

AUTHORS KEYWORDS

Material Driven Design; E-Textiles; Documentation Practices; Weaving; Collaboration

CCS CONCEPTS

- Human-centered computing~Human computer interaction (CHI)

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DIS '24, July 1–5, 2024, IT University of Copenhagen, Denmark

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ACM ISBN 979-8-4007-0583-0/24/07. <https://doi.org/10.1145/3643834.3660754>

INTRODUCTION

Among the many programs of research taking place within DIS, there is growing momentum around programs that describe design as an open-ended process of “traveling” alongside materials [18]. Characterized in different contexts as “emergent” [17], “nomadic” [36], “material driven” [26] or “digital craftsmanship” [2,25], these approaches share a commitment to the role of the designer as a negotiator among human and non-human agencies towards non-random, but non-certain outcomes. They also surface challenges in documenting and sharing this “situated, embodied and partial” design knowledge [36,37], often looking to document in a more holistic manner: turning away from singular narratives of success to also attend to the value of failures, samples, or design paths-not-taken [19,20,22,28] though formats such as stories, workbooks, and design journals.

In this paper, we approach the challenge of documenting situated, embodied, and partial design knowledge from the perspective of collaborators producing an e-textile. In our practice, a significant amount of work is devoted to understanding how a given set of instructions to a weaving loom might give rise to different 3-dimensional structures, or how we might be able to move a very brittle material through a cloth in a way that keeps it from breaking, or simply how keep our machinery in good working form. Alongside the samples and ideas we produce, we also produce “managerial” techniques and ad-hoc solutions for dealing with the complexity posed

by the many materials and resources of the project. Put another way, alongside our work cultivating a design imaginary through sketches and samples, we also must cultivate our practice as design bookkeepers to make the production of those samples possible.

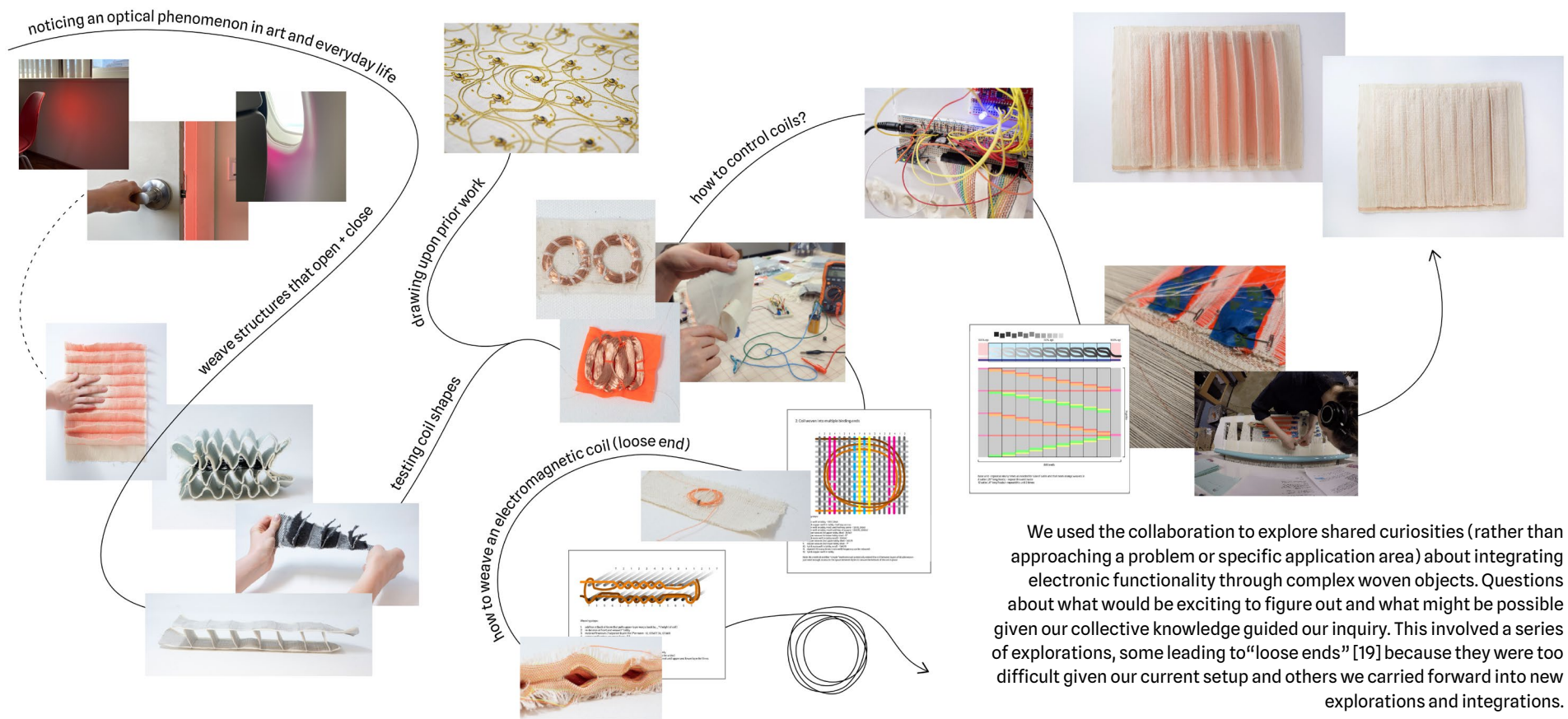
We use first-person retrospection to reflect on our collaboration through the lens of “design bookkeeping”, framing design artifacts in progress generating essential entries, or documents, within a final ledger, the artifact. We present and analyze six collections of entries to draw out how, and to whom, these managerial forms of knowledge become intelligible. These cases illustrate how the documents produced through design bookkeeping take an active role in the creative process—emerging from sense-making and challenges that emerge when working with complex materials. Additionally they address topics and concerns that intersect multiple projects, and rather than documenting a single path taken, they are best read non-linearly to inform other practitioners or inspire new design directions. We conclude by surfacing themes in the production and use of design bookkeeping documents that differ from normative understandings of documentation and tutorials. We also offer this term and the features it illuminates about our practice to DIS to bring attention and value to this managerial element of design research and to advance calls for more open, flexible, and holistic design documentation.

MAGNETIC REVERBERATIONS

We illustrate the practice and resulting objects of design bookkeeping as they formed during the creation of *Magnetic Reverberations*, a textile installation that emerged at the end of a three-month collaborative exploration of weaving and electromagnetics. In an effort to push ourselves we integrated as much of the textile and electronic functionality into the woven structure as possible. The cloth is woven in one piece made of multiple layers that are cut apart into flaps. We inserted individual neodymium magnet disks into pockets woven within the base cloth and integrated hand-wound electromagnetic coils into the under-side of the flaps during weaving. All the wires were hand-routed through the cloth during the weaving process as well. After removing the piece from the loom, we manually attached the loose connecting wires to a hand-woven ribbon cable made of cotton and silicone coated stranded wire via hand-sewing. We connected the other end of the ribbon cable to the hardware controls via standard pin-based connections. The entire assembly is mounted to a thin acrylic supporting sheet and additional magnetic discs are placed within the acrylic to hold the cloth steady and upright for viewing. We used an ESP32 microcontroller to enable communication between a web-based interface and the electromagnets in the cloth.

Magnetic Reverberations is an interactive textile reimagining electromagnetic actuators through the lens of soft goods and hand-operated Jacquard weaving. Woven in one piece, magnets and copper coils embedded in the fabric's layers enable eight flaps on its surface to be individually controlled through a web interface. This creates an experience where viewers can play with the cloth, opening and closing the flaps, revealing or hiding the warm glow of neon yarns hidden inside.





SITUATING OUR DESIGN COLLABORATION

We approached design as an emergent and open-ended practice and each member in our collaboration brought a slightly different perspective. Elizabeth is a weaver and led the project as the experimental weaver-in-residence [8,9] within Laura’s research lab. In this role, Elizabeth had time and budget to support three months of ideating and exploration in the build up to a final exhibition piece. Laura and Irene identify as design researchers, both with interests in the integration of textile and electronic systems. Elizabeth and Laura were co-located during the collaboration and, having worked personally

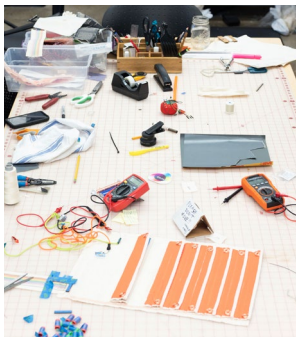
as well as in collaboration with Laura on a similar topic previously, Irene participated virtually through weekly meetings and feedback sessions. As a product of working side-by-side in a shared setting, Elizabeth and Laura had the opportunity to follow each other’s practices, observing how they approached, organized, and managed the work. Laura was specifically impressed with Elizabeth’s clever ad hoc solutions to common challenges. In weekly meetings, most of our discussions focused on strategies that might facilitate the next phases of the inquiry. Our focus on sharing techniques for accomplishing the project gave us an opportunity to think through tasks we

usually performed in isolation, together, and to take up and exchange bits of practice. It is these “bits of practice,” referenced in our conversations and embodied in Elizabeth’s organizational workflows, that inspired this pictorial. While publications and project documentation from other artists and researchers informed what we believed to be possible, we wanted to draw attention to the work of adapting those ideas to our local context. Furthermore, we saw Elizabeth’s documents as a form that could be shared among practitioners while also providing inspiration for designers more broadly.

Why Design Bookkeeping?

When reflecting on our collaboration and the value each of us found in our collaboration, we kept returning to moments where we devised clever methods, practices, or strategies for producing the work. Put another way, we focused more on process over idea, learning from each other's ad hoc approaches to common e-textile challenges. We characterized these moments as “managerial” and “mundane”, among other terms. The metaphor of design bookkeeping emerged to capture these qualities and to frame them as a thread that exists in parallel to design ideation or design visioning.

Equipped with this metaphor, we used a method of first-person retrospection [7,40] to look back at our collaboration while asking where and how “bookkeeping” work took place, what form did it take, and how did it come to be? What knowledge, in what form, circulated through the project at any given time, and how would someone look back at our “books” so to speak to draw a narrative of what took place? Methodologically, the use of first-person methods, and an embrace of one's subjective position, has been a common strategy when reflecting on material practice (e.g. [18,19]) because it turns away from the idea of universals to, instead, locate value in the individual discoveries and “ultimate particulars” [27] that emerge through a design process. These first-person narratives may be communicated in the form of stories [29], design journeys [4], comics [13], booklets [6], annotated portfolios [3,19], recipes



Entries into our design bookkeeping ledgers aim to bring insight into the messy work that takes place to produce a polished exhibition piece.

[1,5,39], swatchbooks [23,30], zines [14] or workbooks [10,16,34]—each form offering a different method of reading and interpretation by the audience. Digital systems, and tools like the Process Reflection Tool [5], further extend the formats and modes of capture and engagement in project documentation. Here we most closely build on the portfolio style of Goveia da Rocha et al. in [19] with a snapshot of techniques and strategies we used to manage the complexity of our project.

Seeing the Artifact as Ledger

Through the lens of design bookkeeping, we see the *Magnetic Reverberations* final exhibition piece as a ledger that brings context to an evolving series of questions and experiments. The entries in this ledger take the form of concrete external representations of the practices required to complete an experiment in connection with the project. These include instructions, diagrams, notations, choreographies, labeling strategies, databases and repositories (and so on). The production of entries was built into each of our respective practices and in many cases, their production was simultaneous with the work of planning and carrying out each iteration or keeping a record of the process for a personal reference in the future. Here documentation didn't feel like a choice, but a necessity for production and sharing within and beyond the collaboration.

We sought perspectives on documentation and accounting within a broader range of disciplines from art restoration to workplace studies [15,21,32] to think about how knowledge transmutates through objects. Harold Garfinkle's descriptions of clinical case folders best resonated with our idea of ledgers, and also surfaced a rubric to provide additional clarity for comparing a design bookkeeping [35] entry and a more general description of documentation. Specifically, he describes how clinical records serve multiple goals: on one hand, records in a case folder serve as a contract between a patient and medical team; and on the other, they serve as an actuarial account of the ongoing coordination of care within a medical team. Where

the contractual function emphasizes performativity (e.g. demonstrating that care is taking place by classifying different treatments) the actuarial emphasizes intelligibility (e.g. maintaining a record that another practitioner can assess and make use of in their decision making) [32]. Reading creatively and in light of our interests, we considered project documentation along these lines. Many design publications or portfolio projects featuring polished visuals describing ideation and outcomes can be seen as highly *performative* (e.g. showing that research of value happened and providing inspiration within different communities of practice). DIY tutorials and how-tos attempt to bring increased *intelligibility* to the work, though, descriptions of DIY authorship offered by Wakkary et al. [38] and Tseng and Resnick [35] point to production and documentation as separate processes, which can be at odds with each other. Like clinical case records, we see design bookkeeping entries accumulating information as the work progresses. In line with these observations, we refined our question to understand the specific ways that design bookkeeping entries come to be, and the strategies they employ to bring intelligibility to our practice.

Six Exemplary Cases of Design Bookkeeping

In the following pages, we present six collections of entries from our collaboration as cases of design bookkeeping. Each case includes:

1. a title summarizing core finding that emerged from the particular set of entries analyzed
2. a specification of the the set of entries analyzed
3. a narrative of how the analyzed entries came to be
4. a narrative of what we believe the entries make intelligible about our practice to the DIS audience

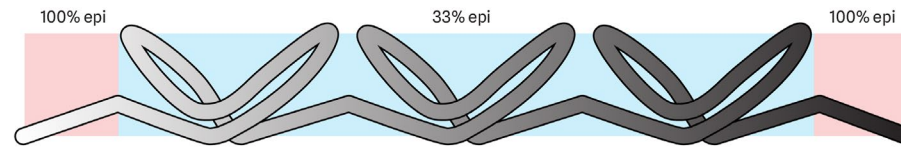
Our goals in presenting these cases, and which we address in the discussion, are to: provide the reader with a greater clarity of the practices we are referencing; to show and tell of the knowledge they hold; and to open spaces to consider how these forms of knowledge can be leveraged among DIS to advance our collective practices.

Entries emerge in the process of sense-making.

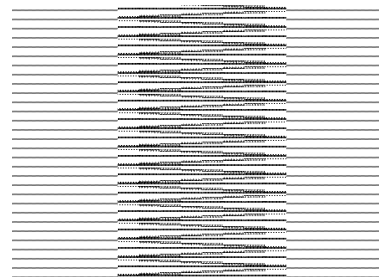
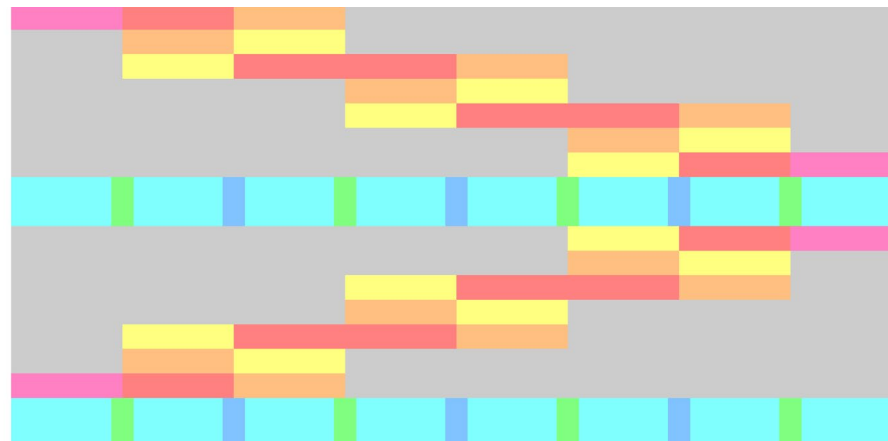
Entries: Bespoke notations used to reason through the design space of novel woven topologies

How they came to be: Our notations responded to the highly embodied nature of weaving, a process that is often (mis)represented in standard notations ④. While woven patterns are composed solely of grid cells representing raised and lowered yarns, the scope of decisions that a weaver can make at the loom is much more nuanced. Weft yarns can be pulled tight or left slack when inserted; shuttles can travel through the fabric along distinct paths, changing its final form. As a means of exploring the possibility space afforded by partial-shuttle paths in weaving, Elizabeth developed methods of representing shuttle movements that create non-linear yarn paths, using visual cues of timing and sequencing to make the choreography of weaving more legible. These representations functioned as both a graphical system for imagining and sketching yarn paths, and as a means of translating specific geometry into machine instructions to produce the piece on a digital loom.

What do they make intelligible? These entries demonstrate the active role of bookkeeping within the sense-making process, and also conversely, the active role of sense-making in the production of design bookkeeping entries. Far from documenting a “known” process, these entries highlight how a bespoke notation of choreography ①② and diagram ③ emerged to address the dynamics of human-machine collaboration at the loom ④. Photos provide process ⑤ and sample ⑥ documentation. These systems are non-standard, but within the community of practice of weavers, they show multiple representations of a similar embodied knowledge (e.g. [11]). In this way, entries create opportunities to rethink normative modes of representing materials and actions.



weft 1 - linen, 7 picks



④ Weave draft provided to the loom. ⑤ Partial-weft fabric on the loom. ⑥ Resulting fabric, woven in one piece with no cutting.

① A sketch of the path of a single weft traveling across the cloth. The color gradient represents the chronology of movements.

② Transposing weft passes onto fabric layers.

③ The mapping of color regions becomes the basis for the binary weave draft. Each color corresponds to a specific woven structure.

The primary audience of the entries is our future selves.

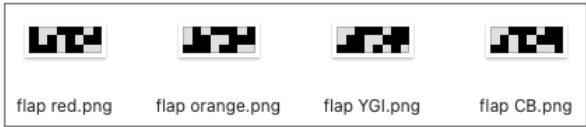
Entries: Annotated data meant to be read in relation to each other for maintenance and remaking

How they came to be: We intended for these entries to both support our ongoing collaboration and to act as explanations of the project to future audiences, including our future selves. In the design of complex weave structures, there are often multiple valid ways to resolve an intersection of yarns, and subtle differences between them may not be obvious until physical prototypes ⑤ are made. With an eye toward the intricacies of art conservation and restoration, we thoroughly documented the structure of the piece, from wiring diagrams to mappings of multi-layer wovens. In contrast to the diagrams on the previous page, which a-priori emerge from a sense-making process, these emerged a-posteriori from a desire to maintain or even recreate certain samples. Multiple formats emerge as a byproduct of the weaving process, where human-readable ideas are translated into a machine-readable fabrication file.

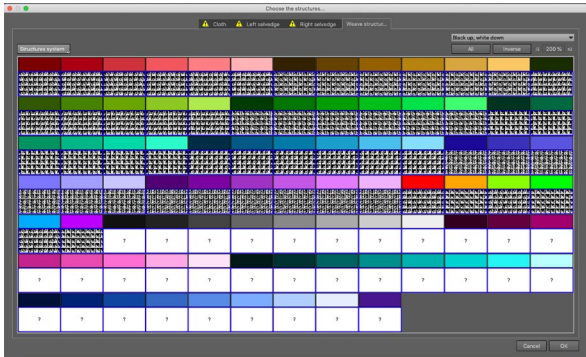
What do they make intelligible? Beyond this “exploded view” of the physical object that these multiple records provide – a multi-color diagram of the fabric ② is accompanied by a directory of weave structures associated with each color ④ and a written description of each zone ① – these entries offer multiple perspectives on a single experiment that enable a continuity of knowledge between a human designer and a fabrication machine. Documenting the feedback loop between drafting, weaving and subsequent decision-making created a narrative visual record by which we, and others with similar experience in complex weaving, could “re-understand” how the project developed in its particular way, whether we revisit it in the future to repair the original artifact, meticulously duplicate it or design a new variation.

000000	000000	000000	==	==	2nd pick of 4-pick twill	==
000001	000001	000001	==	==	2nd pick of 4-pick twill	==
000002	000002	000002	==	==	4th pick of 4-pick twill	==
000003	000003	000003	==	==	1st pick of 4-pick twill	Weaving on ends 1,2,3,4 of 5
000004	000004	000004	==	==	2nd pick of 4-pick twill	==
000005	000005	000005	==	==	3rd pick of 4-pick twill	==
000006	000006	000006	==	==	4th pick of 4-pick twill	==
000007	000007	000007	==	==	Plain weave	Floating selvage for edge of base layer segment
000008	000008	000008	==	==	1st pick of 4-pick twill	==
000009	000009	000009	==	==	2nd pick of 4-pick twill	Weaving on ends 2,3,4,5 of 5
000010	000010	000010	==	==	3rd pick of 4-pick twill	==
000011	000011	000011	==	==	4th pick of 4-pick twill	==
000012	000012	000012	==	==	1st pick of 4-pick twill	Weaving on ends 1,2,3,4 of 5
000013	000013	000013	==	==	2nd pick of 4-pick twill	==
000014	000014	000014	==	==	3rd pick of 4-pick twill	Weaving on ends 1,2,3,4 of 5
000015	000015	000015	==	==	4th pick of 4-pick twill	==
000016	000016	000016	==	==	1st pick of 4-pick twill	==
000017	000017	000017	==	==	2nd pick of 4-pick twill	==
000018	000018	000018	==	==	3rd pick of 4-pick twill	==
000019	000019	000019	==	==	4th pick of 4-pick twill	==
000020	000020	000020	==	==	Plain weave	Floating selvage for edge of base layer segment
000021	000021	000021	==	==	1st pick of 2-pick PFW	Weaving on ends 2,3,4,5 of 5
000022	000022	000022	==	==	2nd pick of 2-pick PFW	==
000023	000023	000023	==	==	1st pick of 2-pick PFW	Weaving on ends 1,2,4,5 of 5
000024	000024	000024	==	==	2nd pick of 2-pick PFW	==
000025	000025	000025	==	==	1st pick of 2-pick PFW	Weaving on ends 1,2,3,4 of 5
000026	000026	000026	==	==	2nd pick of 2-pick PFW	==
000027	000027	000027	==	==	1st pick of 2-pick PFW	Weaving on ends 1,3,4,5 of 5
000028	000028	000028	==	==	2nd pick of 2-pick PFW	==
000029	000029	000029	==	==	1st pick of 2-pick PFW	Weaving on ends 1,2,3,5 of 5
000030	000030	000030	==	==	2nd pick of 2-pick PFW	==
000031	000031	000031	==	==	Plain weave	Left edge of fringe
000032	000032	000032	==	==	1st pick of 2-pick PFW	Weaving on end 1 of 5
000033	000033	000033	==	==	2nd pick of 2-pick PFW	==
000034	000034	000034	==	==	1st pick of 2-pick PFW	Weaving on end 3 of 5
000035	000035	000035	==	==	2nd pick of 2-pick PFW	==
000036	000036	000036	==	==	1st pick of 2-pick PFW	Weaving on end 5 of 5
000037	000037	000037	==	==	2nd pick of 2-pick PFW	==
000038	000038	000038	==	==	1st pick of 2-pick PFW	Weaving on end 2 of 5
000039	000039	000039	==	==	2nd pick of 2-pick PFW	==
000040	000040	000040	==	==	1st pick of 2-pick PFW	Weaving on end 4 of 5
000041	000041	000041	==	==	2nd pick of 2-pick PFW	==

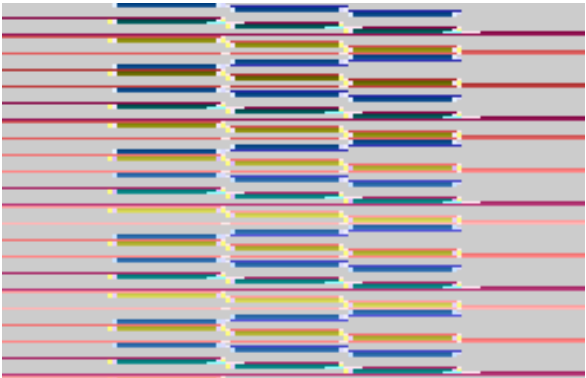
① A spreadsheet of hex codes and their meanings in the weave graphic, or color-coded diagram. Basic weave structures are grouped by hue and differentiated by value.



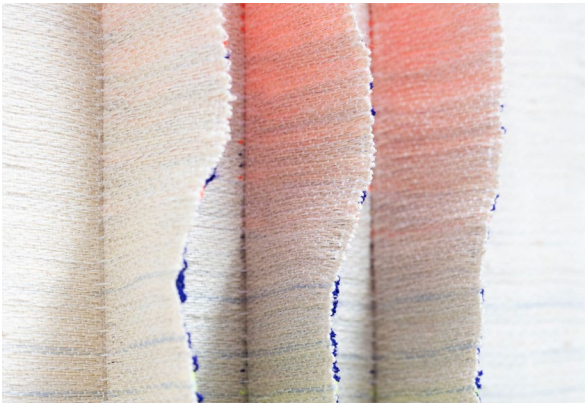
③ Custom weave structures, created based on the spreadsheet’s description of what each structure needs to do.



④ We used the weaving software Pointcarre to assign structures to colors and output machine-ready .BMP files.



② The weave graphic and its color palette grew larger with each iteration, as additional structures were needed at edges and corners to yield specific layer interactions. The graphic informs these inputs, most of which are single-use: they only function when implemented with this mapping.



⑤ This three-flap prototype was a testing ground for color effects and weave structure refinement.

Entries are often created to address critical needs.

Entries: Techniques and instructions for managing, routing, and connecting magnet wires to hardware

How they came to be: While the entries we previously discussed focus on what is possible with a given set of materials, this step looked to implement techniques we had used before with the materials in this project, specifically routing and making connections with magnet wires. This step was not a central focus of tests and explorations, but was something we just needed to solve, by any means possible, for our piece to work as we envisioned. The way this task was situated in the design process, as well as the number of components we needed to manage, made it feel like a more managerial task than others. It required us to keep track of which seemingly identical wires belonged to which electromagnet during and after weaving. Furthermore, we needed to ensure that the long, hair-thin, ends of our magnet wires could be integrated without breaking, and to facilitate a soft-to-hard connection for reliable and robust performance.

What do they make intelligible? While the routing techniques used for accomplishing this task are known mostly in our hands and in reaction to the movements of the loom, others, such as managing wire ends ①②③, labeling ④ and connecting ⑤⑥ can be learned from pictures. These features are usually hidden behind the artifact. As entries, they take center stage. They don't suggest an optimal or tested solution, but a "good enough" solution that we are confident with and that worked well for our setting. As a non-traditional evaluation of these techniques, we shipped the piece for remote installation and it was handled and installed with all connections firmly in place! This small detail may not be significant enough to occupy its own publication, but it can be a useful point of reference for others in search of reliable flexible connection techniques.



① Each wire end was paired with a boba-straw bobbin covered in painter's tape for the wires to stick to. We labeled the bobbin with its associated magnet and end (e.g. power or ground) before wrapping it with wire.



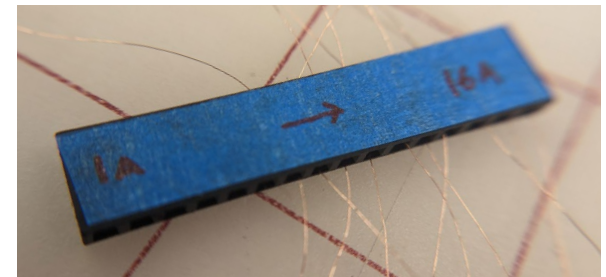
③ We routed each bundle through a weft shed and then followed new warps to the top edge of the cloth, selecting yarns that ensured that the bundle ends were spaced at the approximate width of header pins.



⑤ We wove our own ribbon cable with the same spacing as the magnet wire ends, to create a flexible connection to the fragile wires and a firmer connection to a microcontroller.



② We grouped bobbins in bundles of four, with each bundle following a single warp yarn. The weaver passed the wires under the yarn each time it was raised, securing them in place with a twill pattern that matched the base cloth.



④ We removed the pins from a pin header and used the open tunnels to hold the wire strands in order. One header held the wires to be connected to power, the other ground.



⑥ Because soldering and crimp beads broke the thin wire, we stripped the ends, twisted them with ribbon cable leads, and stitched each pair with thread. This firmly pressed the strands together and insulated them from adjacent pairs.

Impracticality leads to the production of design bookkeeping entries.

Entries: Instructions for hand-making coils of a repeatable shape, size and number of turns; craft references

How they came to be: A common theme we observed across all of our entries was how they emerged in order to address a challenge we needed to solve – and these challenges often emerged because of our embrace of impracticality. Like the critical need of routing and connecting techniques, this entry emerged as a means of accomplishing something that was required for us to realize our vision. Yet it is different in that we made a conscious choice not to use pre-made resources that would make the process easier and faster. For example, while we could have chosen to affix pre-made coils atop a simpler cloth structure, we chose to wind copper wire coils by hand and assembled complex weave structures into a sequence that necessitated constant attention during fabrication. Impracticality, for us, was understood as the high effort that a task requires; the physical dexterity or mental acuity needed to keep track of its many elements; an element of ephemerality that makes the process hard to quantify or repeat; or simply the choice *not* to use automated or industrial-scale methods or components.

What do they make intelligible? The instructions ① illustrate a process while also showing how we used common knowledge within our communities of practice to address this challenge. Specifically, we addressed the issue of counting turns in a coil by inserting a “counting thread” ②③. The use of weaving-specific equipment demonstrates a resonance between the practices of managing yarns and managing wires, a kinship that is often lost when purchasing pre-made parts from suppliers.



①



② Counting threads, a technique often used by weavers, separate yarns into bundles, tracking the total number in a warp or skein. They are temporary markers that can be removed easily (left).

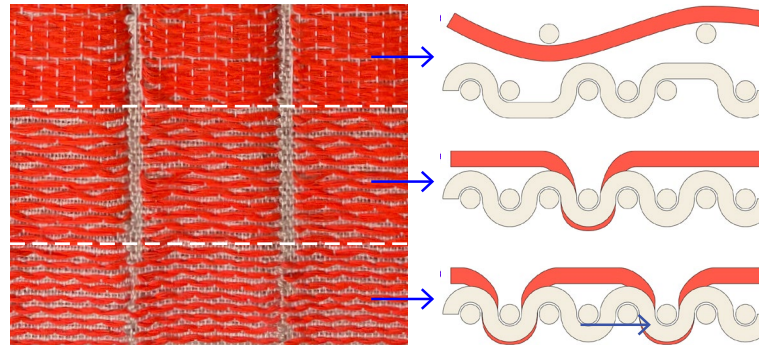
③ We used this technique when winding coils (right) to limit the crossing of wires and maximize the electromagnet’s power. In our case, the thread is both a counting device and a permanent structural element.

Entries honor paths not taken.

Entries: Photos and experiment logs for refining woven flap structures

How they came to be: We often iterated over elements of our design that were central to our vision and curiosity several times. For example, designing a woven flap structure was a task with clear criteria: flaps must be opaque white on one side, and saturated orange on the other side, so the action of flaps opening to cast a neon glow is a surprise to the viewer. The flaps must also be able to open and close easily, which became increasingly challenging as we worked with increasingly stiff materials. Elizabeth would work back and forth across the loom and design files, adjusting the design while at the same time, clearly documenting the nature of the change as a woven cross-section diagram. Each iteration was assigned a unique number that linked to a folder of associated diagrams and notes to explain the approach and outcomes (relating back to entries for our future selves). Notably, every stage in the design process is honored with documentation, not just the final outcome.

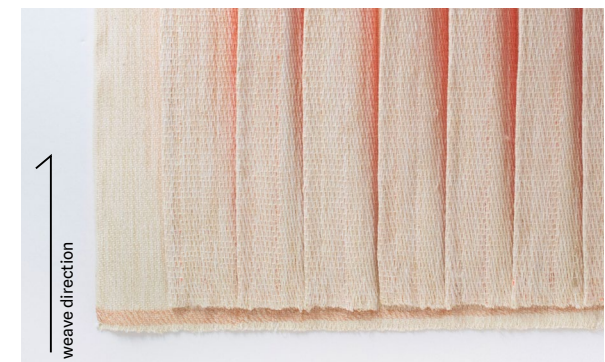
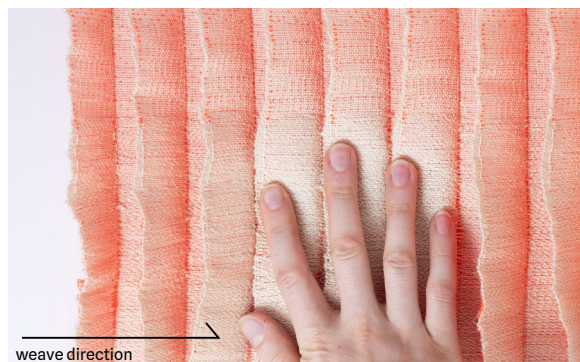
What do they make intelligible? While each experiment looks to optimize for specific concerns, looking across the experiments reveals more general themes that may emerge across multiple practices, such as spreading out interlacements on two layer cloth to aid packing ① or turning the design 90 degrees to adjust the mechanics of the movement ②. For a weaving novice, this entry highlights woven cloth as having a “grain” like wood, bringing recognition to the livingness of the materials. The ability to generalize themes across experiments is enabled by equal documentation devoted to the paths-not-taken as those we did ③, which provides equal resources for someone interested in adapting the techniques to suit their materials and visions.



① The sampling process began with variations on doubleweave to maximize the coverage of orange yarns on the surface, during which we found a structure that allowed them to lay flat and parallel rather than deflecting into a wave. The first full-size sample is a document of these slow improvements, with horizontal bands representing each time a file was updated and brought back to the loom for testing.

② Written notes summarize the results of each experiment, pose questions and air frustrations, encapsulating what was known and unknown to us at each stage of the project. Administrative in nature, these logs serve as a record of incremental changes, dead ends and pivotal decisions.

- Ends that are transitioning from the sparse to the dense layer should be lifted on the
- Ends that are transitioning from the dense layer to the sparse layer should be lifted
- v4 - base structure is 1/2 twill instead of PW, selvages are 1/5 twill instead of 1/4 twill. Done
- Floating selvages for neon need to float above the base structure too - choose 2
- 1/8" margin area of the flap shouldn't have any dropped ends because they're not
- Leftmost and rightmost flap need a floating selvage along the bound edge too, not
- v5 - same as v4 but with 2/2 broken twill base, every 6th end dropped
- v5.5 - just has improved selvages, floating selvage is 2px wide and 2px away from flap
- v5.6 - rotates dropped ends every 16 picks instead of 8
- floating selvage rotates at same pace as dropped ends - this means entire graphic
- Didn't change Pointcarre file, just graphic.
- v5.7 - added 2 end wide PW "selvages" at both edges of each base section & flap ends
- Can neon orange cross through layers just beyond the hinge? If so, it's not
- v5.7 fixed (in same psd file) - fixing neon floats at first and last bound edge & neon peeking
- Neon continues weaving 2px beyond where it normally would turn around at hinge
- v5.7 fixed 2 - re-fixing neon floats at last (right side) bound edge
- final fix: add 2 pixels of floating-over-everything to right side of each blue section



③ Later in the design process, we realized the stiffness of the fabric was oriented along the wrong axis, limiting its actuation potential. Rotating the woven design by 90° required significant reworking of the on-loom choreography; in addition to producing new fabrication files, we captured on video and in writing how the previous samples didn't perform as expected.

Entries evolve across multiple ledgers.

Entries: Past entries, future entries: Examples of past entries that moved into the current ledger ①② and entries from the current project that moved into a future ledger ③.

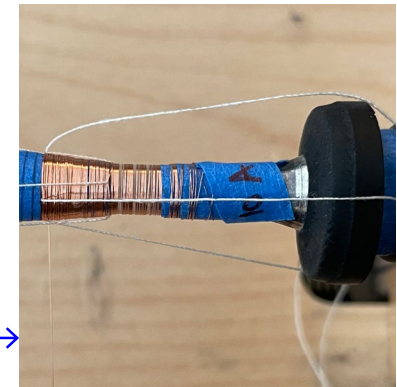
How they came to be: Referencing prior work is a core part of any design practice. At various points in our process, we became perplexed at how to accomplish a given task and looked for answers in older material or other publications. For example, when making electromagnetic coils, we relied both on Irene's prior work [31] and project documentation [33] ① and implemented roughly 25 different designs based on prior publications such as [12] to learn, for ourselves, how the author's findings would behave in our context. We also repurposed the circuitry and webcontroller interface ② from one of Laura's previous projects to bring interactivity to the project. In other cases, sampling during the project gave rise to the beginnings of side projects and investigations. Specifically, a lattice structure developed in an early sample from this ledger began a seed of exploration within Laura's research practice ③.

What do they make intelligible? From this case, we learned that entries gain "respect" and validity as they travel across projects, leading to updates and refinements that often make them more robust and flexible for adaptation in new contexts. While solutions within a project may be ad hoc and personalized, over time and multiple ledgers, we see their form developed and adapted. In the specific case of the electronics and web-controller interface, the general adaptability of our electronics and interface suggest the formation of a kind of "kit" that could be useful to the community more broadly. While we have not chosen to publish or pursue this avenue, the more modest and personal elements of this practice as an entry bring attention to these opportunities.

① A video still from a prior documentation video of Irene's work became a critical resource when trying to figure out how to wind coils consistently. Where they used a sewing-machine bobbin winder, we adapted a handweaving bobbin winder to form tightly wound coils with a similar level of precision.



Video by Ulrich A. Reiterer



② The electronics emerged from two of Laura's prior projects, both of which use an ESP 32 board to enable communication between the cloth and a web-accessible interface (enabled via firebase and Angular web frameworks). Both projects generated a quickly deployable infrastructure upon which multiple areas of cloth can be actuated and/or sensed using a multiplexer, wall power, and MOSFETS.

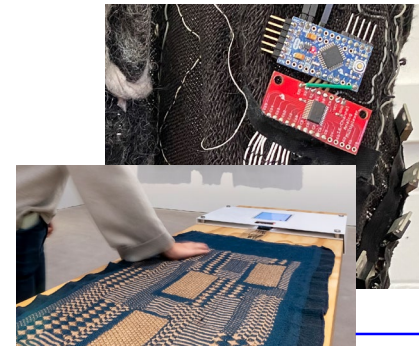
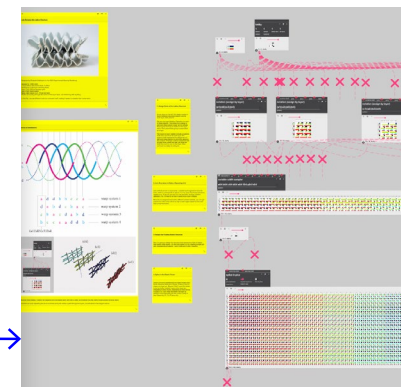
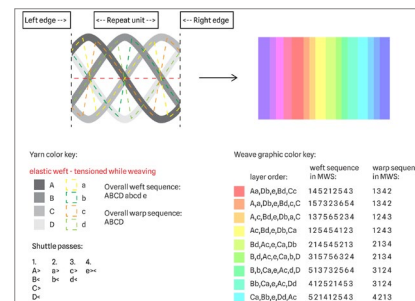
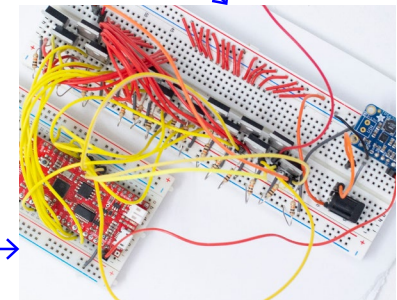


Image courtesy of CHAT (Centre for Heritage, Arts and Textile), Hong Kong



③ Diagrams of samples created during this project inspired Laura to recreate the design in AdaCAD to invite inquiry by a broader community [41]. The four-layer lattice shown here was drafted by Elizabeth as an early exploration of expanding and contracting behaviors in fabric; the initial entries enable versioning and reimplementations of the original design.

DISCUSSION

By reflecting on our collaboration through the lens of design bookkeeping, we brought attention to elements of our practice that felt more managerial in nature, while also asking what value our ad hoc, improvisational, and personal approaches to these managerial challenges might hold for a broader research audience. This inquiry has implications for how DIS might distribute and share “situated, embodied, and partial” [37] knowledge in intelligible forms, both within academic articles as well as more public resources. To develop these implications further, we reflect on the themes unique to design bookkeeping as a genre of documentation and speculate on how DIS practitioners might share this knowledge.

Cross-Cutting Themes in Design Bookkeeping Entries

The term documentation is broad enough to encompass a breadth of approaches and formats with the common goal of sharing knowledge among practitioners and broad audiences. Like literature, documentation follows different genres: from the “how-to” to the “user manual.” We see design bookkeeping as one such genre that presents knowledge as design ledgers filled with design entries. While individual entries share many features with existing modes of documentation (e.g. instructions, diagrams, etc), they, as a collection/ledger, invite different modes of reading and adaptation. Specifically, focusing on ledgers and entries gave us permission to break from temporal or linear narratives of replication to center the individual moments of discovery to be adapted into other practices. The metaphor evoked images of the gridded ledger as an equalizing mechanism, holding different bits of practice as transactions occurring through time. While held in one ledger at one moment in time, the knowledge, like funds, is free to move between accounts and ledgers. While the direct relation between currency and knowledge is imperfect, it was useful in foregrounding ideas of exchange, movement, value, and record keeping.

Our analysis of design bookkeeping entries revealed different trajectories for transmitting what we describe

as managerial design knowledge: from providing inspiration, new modes of representation, or greater awareness of the needs and challenges of designers working within this domain. These trajectories offer different readings for different communities of practice, alternating suggestions for adaptation with requirements for domain expertise. Thus, ledgers could offer a research contribution as a sum of modest entries rather than a more streamlined narrative of a project’s central focus and goal, existing in harmony alongside design process narratives. Yet, as we saw in the wire routing case (“critical need”), ledgers can never entirely replace the value of working side-by-side, nor should they strive to. By embracing their own humility and ad-hoc nature, we think they invite remaking, evolution and collective improvements as entries move through and are remade in multiple projects.

Focusing on entries, we see that the term illuminates specific features in terms of scope, audience, and the relationship to ideation.

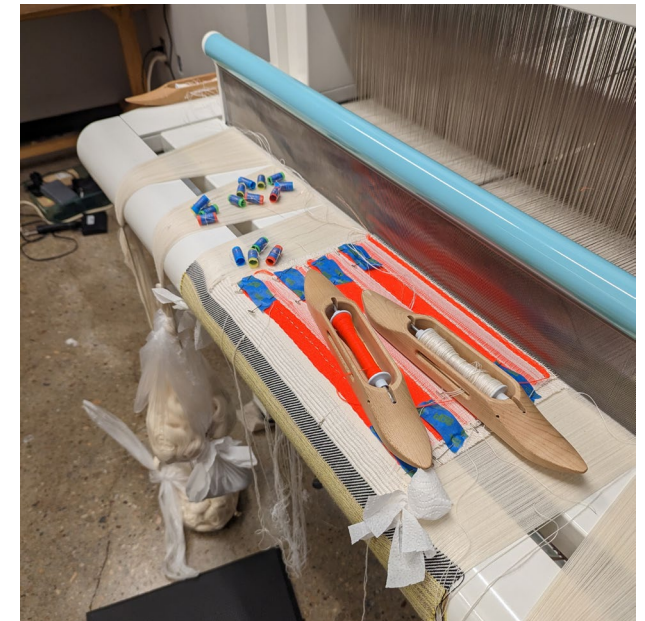
Provisional in scope: Entries embraced their perspective as provisional, “satisficing” or good-enough solutions to the problems we encountered and do not claim to be anything more. Many were not the focus of our invested efforts of optimization and analysis, but rather, the things we cobbled together to make our visions possible. As we observed in our use of connection techniques, it is through iteration, adaptation, and remaking of those solutions over time that they become more robust and flexible new adaptations.

The audience is the self: Many entries operate as a snapshot of one brain in one moment of a project. They assume the reader has a shared knowledge base and embodied experience, which is most evidenced in our diagrams and notations for complex weaving. We acknowledge that most DIS researchers will not know what to make of these diagrams, nor are we capable of explaining them fully. Yet, we believe they bring value when given to a collaborator that does hold such knowledge. By embrac-

ing this specificity, they are able to provide considerable depth. For those that do not share this knowledge, entries can inspire appreciation of the complexity of thought that is required, which has benefits in craft contexts which are often rendered to be simplistic.

Existing in a mutually constitutive relation to ideation:

The lens of design bookkeeping created space to bring our attention to activities that were directed towards understanding and anticipating the behaviors of our materials as much as creative ideas and samples they afforded. Thus, we came to see design bookkeeping as a practice that runs in parallel to, and in mutual formation with, ideation. As mutually constitutive practices, they inform one another in “correspondence” [24]. Framing these as parallel practices asserts the criticality of their role in design research and knowledge production.



The work in progress on a TC2 Jacquard loom. Hand-wound coils and magnets are woven into complex weave structures in multiple layers of the cloth.

Creating and Sharing Design Bookkeeping Ledgers

While we began the project using design bookkeeping as a lens to reflect on our collaboration, we began to see it as a practice of regularly externalizing and capturing the foundational knowledge within a project's development. We believe that designers can develop and cultivate their skill as bookkeepers along at three stages: before, during, and after a project. Before a project, designers might start by undertaking a project that is impractical and complex in nature so that the production of sense-making and archival documents is a necessary part of the process. This also suggests that certain practices (e.g. complex practices with many human, material, and machine variations available) lend themselves to bookkeeping by their very nature. During a project, designers could cultivate a practice of noticing seemingly mundane moments during the creation process and documenting them. They may actively embrace multiple documentation forms and formats and consider how they make information "human-readable" vs. "machine-readable".



A publicly available catalog documenting the making of *Magnetic Reverberations*, communicating artifact and practice beyond the academic community.

After a project, designers might consider how their documents, written partially as notes to self, might be relevant to broader audiences and to find channels with which to share those notes and documents, even if they are not totally legible to an "everyday" reader. We hope that this exploration, and the results we provided, provides one such context or example of how these insights could be shared, and acknowledged, within research publication venues.

Alongside techniques and technologies that aid researchers in their documentation and/or bookkeeping practices, we advocate for the inclusion of design bookkeeping reflections as research contributions within formats like the Pictorial. We envision publications showcasing other practitioners' ledgers as a means of building a strong foundation of practical methods upon which new visions, experiences and products can build. We believe that publications such as this would be of particular benefit for researchers engaged in complex material practices because: they would bring credit to the amounts of labor required to skillfully manipulate design materials; showcase the complexity and potential of these practices beyond normative assumptions; and create an avenue to more broadly exchange "tricks of the trade."

We also envision modes of exchange that extend beyond academic research venues, perhaps reaching audiences more strongly embedded in art and craft. Throughout this Pictorial, we have included QR codes that link to a more extensive self-published catalog of the project created to honor the work completed during Elizabeth's artist-residency. The catalog exists digitally and in a physical



book that can be exchanged and shared that ultimately honors the work and knowledge we believe to exist in our practice. The production of our own catalog, existing outside an academic publication venue, felt like an important step to simply spend more time with the ideas and materials of the collaboration. It also helps us envision alternative and perhaps DIY networks of ledger exchange. For example, what might it look like to trace a technique across practitioners and through time? How might the physical format of these texts explicitly invite exchange and adaptation?

CONCLUSION

Motivated by a desire to bring attention to the improvised and "managerial" supporting work our material-led research requires, we introduce the term design bookkeeping and apply it as a lens to reflect upon a collaboration to produce a complex electronic textile exhibition piece. We frame our project as a ledger and individual techniques and practices developed to explore the project as entries. We analyze entries in terms of how they came to be and what they are able to make intelligible about our practice to broader audiences. We conclude by framing ledgers as a genre of documentation to aid in the exchange of ad-hoc and improvised strategies developed to tackle the managerial work that underpins visioning practices. We also frame design bookkeeping as a practice to be cultivated among design researchers and envision modes of exchange within and beyond the academic publication venues.

ACKNOWLEDGMENTS

This material is based upon work supported by the National Science Foundation under Grant No. 1943109 and the Crafting Futures Lab/University of Arts Linz. The authors would like to thank the reviewers, and all the members of the Unstable Design Lab for their support during the project, especially Deanna Gelosi and Atlas Zaina. Special thanks to Hunter Allen-Bonney for photography support and to Evan Runge, who introduced Elizabeth to the term "bookkeeping" during a class on Jacquard weaving.

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