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Milou Voorwinden
Delft University of Technology, Netherlands

Savanne Klop
Delft University of Technology, Netherlands

Holly McQuillan
Delft University of Technology, Netherlands

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Designing a toolkit to explore the design space of woven textiles

Milou Voorwinden*, Savanne Klop, Holly McQuillan
Delft University of Technology, the Netherlands
*Corresponding author e-mail: m.voorwinden@tudelft.nl
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Abstract: Driven by the potential of smart textiles, shape-changing structures, living textiles, and sustainable manufacturing methods, designers are pushing the boundaries of weaving. However, most existing industrial technologies are designed for mass-producing simple, flat fabrics. This has narrowed the collective understanding of weaving's design potential, thereby restricting the development of complex, three-dimensional, and animated textiles. We present a toolkit, developed through an exploratory workshop and focus group discussion with academic and industry-based designers, that enables exploration and expansion of the design space for woven textiles. The card deck and canvas provide a shared language to externalise and interrogate existing ways of thinking, while a modified frame loom enables hands-on exploration of new possibilities. The toolkit demonstrates how combining analytical reflection with hands-on making offers both techniques and a vocabulary for unconventional textile design, while enabling critical examination of production systems.

Keywords: Textile Design; Weaving; Woven Textile-forms; Design tools; Workshop

1. Introduction

Researchers and designers of textiles are increasingly exploring the potential of weaving to move beyond conventional flat fabrics towards textiles that embed form and complex material behaviours. While the rich history of weaving demonstrates a wide range of machines, techniques and materials capable of producing such diversity, contemporary weaving practice is largely shaped by industrial production systems that prioritise speed and standardisation. As a result, many innovations in weaving technologies remain confined to specialised research or industrial niches. Although both emerging and historical techniques offer significant potential, designers are often unaware of these developments or have limited access to the machines and expertise required to experiment with them. This is particularly relevant as emerging applications such as textile-forms and smart materials require more complex and integrated textile structures than conventional weaving typically supports.

Designers can play an important role in identifying and shaping future applications for materials and techniques. As noted by Stappers et al. (2023) "Designers, more than classically trained researchers, aim to find or create possible (desirable) futures, rather than precisely understand past or present for its own sake." Within design research, this future-oriented perspective often requires the use of prototypes to materialise and explore phenomena that do not yet exist. Prototyping is particularly important when working with underdeveloped materials (Barati et al., 2019), when collaborating in interdisciplinary teams (Benabdallah et al., 2025), or when the design research is situated in a specific material-practice (Giaccardi, 2019) such as textile design (Igoe, 2021). However, textile designers frequently work in interdisciplinary teams, and due to the complex interdependencies between materials, weave structures, and production methods, textile designers may find it difficult to communicate the creative and technical variables that shape woven textile design. These challenges highlight the need for tools that support designers in both exploring and communicating the design space of woven textiles beyond existing industrial constraints. In particular, tools that combine analytical reflection with hands-on experimentation can help designers externalise tacit weaving knowledge, discuss design variables with collaborators, and explore new textile constructions.

In this research, we aimed to develop tools that support designers in exploring unconventional woven textile constructions and communicating weaving knowledge across disciplinary boundaries. The toolkit we present in this paper consists of two complementary components: a card deck and canvas that help map key weaving variables and provide a shared language for discussing textile constructions, and a modified frame loom that enables hands-on experimentation with these variables through prototyping. The toolkit was developed based on our previously developed design space (Voorwinden, 2025b) and research project exploring weaving with a variable consumption and take-up (Klop, 2024). In the following sections, we describe the development of the toolkit through an iterative research through design process, and present findings from an exploratory workshop and focus group with academic and industry-based designers who tested and evaluated the toolkit. We conclude by reflecting on how combining analytical tools with material experimentation can support new approaches to textile design practice and contribute to discussions on material exploration and sustainable production systems in design research.

2. Related work

In the context of the contemporary environmental crisis, the potential of creative design-driven solutions is recognized (McQuillan & Karana, 2023). However, textile designers can struggle to exploit their hands-on knowledge-making skills when promising technologies are developed in engineering contexts, as these are often not available for creative design experimentation. This dilemma lies at the intersection of textile fabrication and technological innovation, the role of making and prototypes in textile design practice, and the tools available for understanding and learning in the domain.

2.1 Novel textile techniques and technology

Many research projects that use textiles employ them as substrates with minimal structural variety; however, there is growing interest in developing complex woven textiles (Buso et al., 2022; Devendorf et al., 2022a) that leverage the sustainable fabrication and/or the interaction potential of these techniques. Researchers use these complex structures to create smart woven sensors (Pouta & Mikkonen, 2022; Sun et al., 2020), explore the use of biomaterials in interactive textiles (Guridi et al., 2024; Zhu et al., 2024), and embed solar cells (Van Dongen et al., 2022). Other researchers create animated textiles that change colour (Berzowska & Skorobogatiy, 2010; Devendorf & Di Lauro, 2019), shape (Kilic Afsar et al., 2021; Kizuka et al., 2025), and texture (Meiklejohn et al., 2022; Ojala et al., 2025; Walters et al., 2024).

Some researchers expand the design space of these textiles and processes even further and explore how the simultaneous construction of textile and form can provide new design potentials for interaction and sustainable fabrication (McQuillan & Karana, 2023). Through multilayer jacquard weaving, designers create textile-forms (McQuillan, 2020) that can transform from a flat to a 3D shape (Walters & Kapsali, 2023), to create soft interfaces (Buso et al., 2023; Meiklejohn et al., 2023; Zhu et al., 2023) and zero-waste garments (McQuillan, 2020; Shi et al., 2024; Voorwinden & McQuillan, 2025). Some researchers have also begun exploring woven manufacturing techniques outside the norm. Examples such as partial weft weaving (Meiklejohn et al., 2024; Olde, 2022; Voorwinden et al., 2025b; Buso, et al., 2025), reed variations (Cnaani & Sterman, 2023), creel and take-up systems for shell weaving (Chen et al., 2024), and 3D weaving (Harvey et al., 2019b; Shi et al., 2022), or combining knitting and weaving (Rosato et al., 2023), provide new affordances for the creation of form.

2.2 Industrial and 3D weaving

While many textile designers intentionally work within and against the constraints of the (traditional) weaving loom, industrial textile technologies are rarely the focus of critical reflection in textile design processes (Walters, 2022). When designers explore the boundaries of these technologies, they can encounter limitations imposed by the paradigms of flatness, efficiency, speed, and uniformity for which these technologies were developed.

When exploring new materials and applications, emerging weave technologies that depart from traditional flat-weave design and production norms have the potential to transform the industry. Design researchers are therefore reflecting on the aesthetic and technical limitations that conventional industrial weave technology presents (McQuillan et al., 2023) and are also developing their own tools and methods to explore the aesthetic and technical potentials that emerge when the technology setup is changed (Shi et al., 2024). Meanwhile, there are many innovations and new processes invented in the industrial and technical textile domains. Examples of process innovations for medical textiles (Li et al., 2013), automotive applications (Buesgen & Ehrmann, 2015), and the creation of composites (Gries et al., 2022) have potential beyond the domains in which they were developed. However, it is rare for these innovations to be explored outside of their niche.

2.3 Role of making and prototypes in textile design

Textile Design is traditionally rooted in hands-on material-driven approaches, where making serves as a mode of thinking (Manning & Massumi, 2014). Through direct engagement with materials and making, the design processes these makers engage in generate more than just a final artifact; they also produce valuable knowledge about materials, techniques, and systems (Redström, 2017).

When designers experiment beyond established industrial norms, their work is often positioned in the realm of craft rather than recognized as a site of innovation with industrial potential (Nimkulrat, 2012; Philpott, 2012). Yet, making can serve as a tangible means to interrogate and critique the systems that shape textile production, what von Busch (2022) calls material activism: the use of hands-on practice to challenge the power structures embedded in dominant modes of making

Through material exploration, designers can question assumptions around efficiency, scale, labour, and sustainability, and open conversations about alternative production logics and futures. In this sense, making becomes a form of inquiry, one that exposes the limitations and embedded assumptions of current systems while articulating new possibilities that challenge dominant paradigms.

Prototypes and material samples developed through such exploratory practices can act as triggers for further thought (Wiberg, 2022), prompting reflection, discussion, and collaborative envisioning of alternative futures (Ehn et al., 2014). Within material- and making-centric fields such as textiles, this research approach demands deep disciplinary knowledge and often benefits from collaboration among practitioners, manufacturers, and researchers. To support this, researchers have developed tools and frameworks that facilitate learning about and engaging with textile materials and processes, which we discuss next.

2.4 Tools for learning and understanding textiles

Learning to weave complex textiles requires extensive practice since it involves understanding the relationships among many variables. To help designers learning to create woven textiles, researchers have developed tools to assist in this process, such as design spaces (Voorwinden, et al., 2025b), weave tools that teach weaving in an embodied way (Devendorf et al., 2022b), digital tools that support the creation of complex (Devendorf et al., 2023), and 3D woven textile structures (Wu et al., 2020). Researchers have identified that access to complex (digital) jacquard looms that allow for skill-building is important and have therefore also developed inexpensive tools that support this process (Albaugh et al., 2021; Ooms et al., 2020).

Toolkits and workshops are developed for specific applications, for example, to encourage harnessing the potential of textiles in serene experiences (Parisi et al., 2024). In the context of three-dimensional textile-form design, researchers have also conducted workshops to learn how to embed and utilise contrasting material behaviours (Walters, 2021) and teach textile-design students textile-form design methods using a diverse set of aids and tools (Drews et al., 2023).

In addition to developing design skills, textile designers frequently collaborate with others, which requires effective communication regarding weaving potential and the processes involved. It has long been recognized that involving textile designers is important in the development of materials and textile-based products (Marr & Hoyes, 2016); however, there is still a lack of resources to support these processes. The challenges that often occur in interdisciplinary collaborations are both in communication and ‘different ways of knowing’ (Pouta et al., 2022). An interesting example of researchers bridging these gaps is through collaborative hardware (loom) assembly (Speer et al., 2025). Furthermore, researchers have experimented with involving weavers as technical collaborators (Devendorf et al., 2020), and some textile centres aim to support knowledge exchanges by facilitating collaborations (European Textile Network, 2025; Lottozero, 2025; TextielLab, 2025). The growing number of tools, workshops, and collaborations in the last decade demonstrates a desire to mutually benefit from knowledge exchange among stakeholders within and connected to the textile domain.

While the examples in this related work have expanded the technical, conceptual, and aesthetic boundaries of weaving, most work in design remains focused on developing new material capabilities or showcasing individual experimental artefacts, while technical innovations and unconventional weaving techniques are rarely integrated into the field. Furthermore, there are few examples of tools that enable designers to systematically explore the design space of weaving beyond current industrial limitations. In other words, while we have evidence of what is possible, we lack methods that help designers identify, interrogate, and reconfigure the underlying assumptions that shape their own textile design practices.

To address this gap, we present a toolkit designed to support designers in critically examining weaving norms through the practice of making. We aim to support exploration how weaving can be stretched beyond its current industrial limits; there is significant potential to leverage innovations from technical domains and designers' creativity to reimagine these techniques for future sustainable processes. Unlike previous approaches that focus on artefact design and production, the toolkit aims to explicate design inputs and decisions, encourage both structured and opportunistic engagement with weaving variables, and foster reflection via hands-on exploration of alternative configurations of these variables to challenge dominant textile paradigms.

3. Methodology

The gaps outlined above are mirrored and deepened through our experience as designers and design researchers working in and with the woven textile industry for more than 10 years. So, this research addresses the following two challenges. First, as new machines and techniques for technical textiles are developed, these innovations tend to remain within their specific niche, and so designers are often unaware of their existence. Additionally, even if designers are aware of these novel technologies, they may have limited or no access to them. Second, when working in interdisciplinary teams, textile designers may find it challenging to communicate the creative and technical variables and interdependencies of their design process, leading to misunderstandings and hindering collaboration.

The objective of this research was to develop tools that enable (textile) designers to better integrate cross-domain practices and theory, thereby unlocking weaving's potential and opening pathways for collaboration on industry challenges. We utilised Research through Design (Stappers & Giaccardi, 2017) in two ways. Informed by previous research on weave variables, the card deck and canvas were developed in iterative rounds with user testing. The loom add-on was developed using a “designerly way of research”, in which the process of designing the loom parts played a formative role in generating knowledge about weaving and weave design, which contributed to the structure of the workshop and the wider findings.

Three iterations of the toolkit were developed and tested in two rounds. The first iteration used the research team's experience to translate the existing design space (Voorwinden, 2025b) into a card deck and canvas. This was then user-tested with an expert textile designer and a novice student to explore how different levels of base knowledge affected the usefulness of the cards and the canvas. The collected data informed a second iteration of the card deck and canvas and triggered the development of the frame loom, which comprises the complete toolkit. The frame loom sought to simplify and scale down loom mechanisms explored in earlier work by the authors (Klop, 2024) for use in the (off-site) workshop. The research team iteratively developed and prototyped proposed designs conducted internal testing of their functionality and generated woven samples to utilise in the workshop as demonstrators. The second version of the card deck and canvas, along with the first iteration of the frame loom, was utilised and evaluated in a workshop with 16 participants from academic and industrial backgrounds and included a focus group discussion.

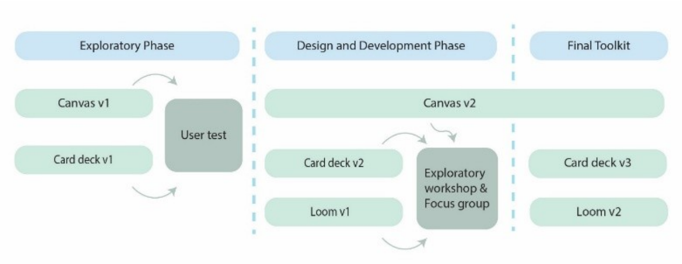

Figure 1 Development phases of the toolkit

During the study, we employed various data collection methods, including documentation of the design process (Fig. 2), observation of activities, direct questioning of participants for contextual feedback, and documentation and analysis of the workshop results, such as the samples developed during the workshop and photos of how the participants placed the cards on the map. In a focus group discussion, participants were asked to discuss their experience using the card deck, canvas and frame loom, potential use contexts, usage challenges and future developments. Their answers were recorded and transcribed, and the discussion data was thematically analysed, combining In Vivo coding and focused coding (Charmaz, 2014; Lungu, 2022). Pictures of the final samples on the frame looms were taken after the workshop (Fig. 5) for analysis.

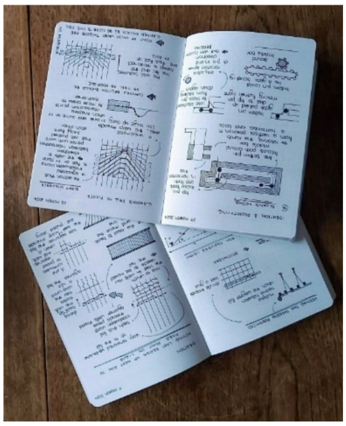

Figure 2 Design sketchbook pages from Savanne Klop (second author) documenting some of the development of the frame loom.

4. Toolkit development

4.1 Objectives

Building on our work in weaving design spaces (Voorwinden et al, 2025b), and woven textile-forms (McQuillan, 2020), as well as existing toolkit examples and research in design practice, we aimed to develop a toolkit that allows (textile) designers to explore unconventional weaving techniques as part of their design activities. To do this, we wanted the toolkit to offer a structured framework for reflection, analysis, and ideation, while remaining adaptable to facilitate iterative improvement, a generative participatory approach, and accommodate diverse design contexts.

Therefore, we proposed the following objectives for the toolkit:

- The toolkit should support designers in analysing existing samples.
- The toolkit should facilitate comprehension of the design space and its opportunities by providing example applications, analysis, and mapping canvases.
- The toolkit should inspire and support designers to experiment with unconventional loom configurations.
- The toolkit should provide a modular, flexible structure that remains adaptable across different design contexts, balancing systematic and open-ended design approaches.
- It should enable simple, hands-on experimentation with unconventional loom configurations.
- The toolkit should be accessible and easy to reproduce.

4.2 Toolkit development

The first version of the toolkit consisted of a card deck (Fig. 4a) and a canvas (Fig. 4b). The cards in the card deck were divided into 5 categories: process, ingredients, structure (warp), structure (weft), and form. These categories and the variables used in the card deck are based on previously published research, and in-depth explanations on the categories and their variables can be found in this publication (Voorwinden et al, 2025b). Each card has a prompt and a graphical representation of a variable from the design space. To support the use of the cards and highlight interconnections among variables, we developed a canvas to facilitate analysis of existing samples and generate new directions for further exploration.

During participant testing in the exploratory phase (Fig. 1), it became apparent that the canvas we initially developed was too complex, prompting us to develop a simpler, more organised overview. Participants also suggested including space for notes and drawings. Additionally, based on their feedback, we added descriptions to each card to provide further guidance and clarify the meaning and context of each variable, especially when participants are unfamiliar with them. We next developed a frame loom (Fig. 4c) for the toolkit to enable hands-on exploration of lesser-explored variables and interconnections in the design space, and to experience their impact on the weaving process and textile outcomes. The first version was a modified, ready-made, simple frame loom with adjustable sectional warp and fabric beams, allowing uneven consumption and tension of warp yarn. In addition, we developed a selection of weaving accessories (Fig. 4d) such as a fan reed, straight reed, comb, weaving needle, and yarns. The frame loom and tools provided the means to explore two main variables: warp consumption and weft length (Fig. 3). For an in-depth explanation and examples using these variables Klop (2024). This version of the frame loom was utilised in the exploratory workshop with participants.

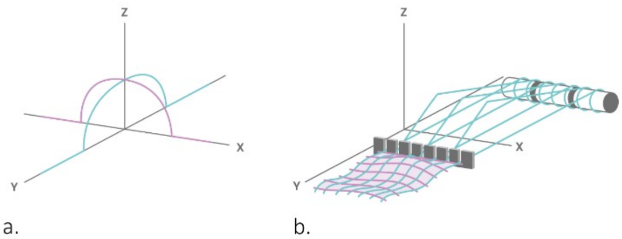

Figure 3 (a.) The frame loom add-on in the toolkit allows weavers to explore the potential of weaving beyond the X and Y plane. (b.)The sectional warp and fabric beams enable the consumption of more warp in the Z direction, while the additional tools allow for more weft in the Z direction.

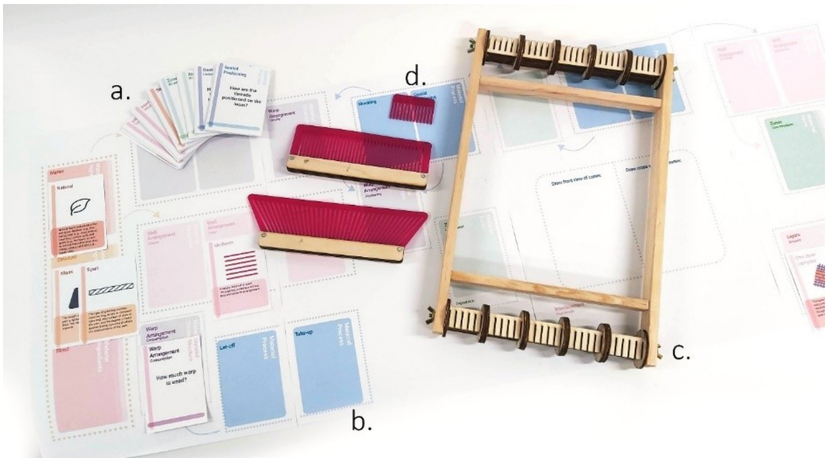

Figure 4 The toolkit showing the (a) initial card deck, (b) initial canvas design, (c) frame loom with sectional warp and fabric beams, (d) weave accessories.

4.3 Exploratory Workshop with Participants

After the evaluation and further development of the toolkit, we conducted an exploratory workshop with the second version of the cards and canvas and the first version of the frame loom, involving 16 participants, including students and design professionals from academia and industry. The exploratory workshop lasted 3 hours and was held at a textile conference hosted by Aalto University in Finland, which has a strong textile research community. Participants were provided with components of the toolkit in two consecutive activities as outlined in Table 1 (in the supplementary materials). The workshop activities were designed to introduce the toolkit, assess how designers would utilise it, and aimed to understand how it informed their knowledge and approach to weaving.

The workshop had two key activities. The first activity involved using the card deck and a canvas in teams (2-4 people) to explore variables in weaving and to analyse and document the variables participants have employed in previous projects. Participants used woven textile samples they had developed earlier in their practice or that were a source of inspiration for this analysis. With this activity, we aimed to familiarise the designers with the design space and identify potential additional variables that could be added. In the second activity, we asked the same teams to use the modified frame loom to explore how alternative combinations of variables might create unexplored weaving pathways, revealing new design opportunities for future research.

5. Workshop Findings and Toolkit Iteration

Following the workshop, we conducted a focus group discussion exploring the usage and challenges of the toolkit, and the participants' responses were analysed. The participants appreciated the systematic separation of weave variables through the cards and canvas. They pointed out that the cards helped them to communicate and find “common ground” (p. 2). Most participants agreed that the cards and canvas are a great way to analyse samples for research purposes. Furthermore, the participants discussed different contexts in which this toolkit could be useful, depending on their experience in the workshop. One participant noted that they would like to use it in the future to explain variables in weaving to their students, for example, at the start or midway through a weave design course. Furthermore, they noted students could use it in “thesis writing as a guideline to analyse their own samples” (p. 2), to kickstart the writing process for example. One participant, who had never woven before, appreciated the combination of weave variables with hands-on work, noting that “it follows the logic of studying the fundamentals, the types that you can apply and then get hands-on” (p. 10).

5.1 Generating New Ideas

In a professional textile design practice or research context, the focus group noted that the toolkit could be used to generate new design ideas. For example, through randomizing the cards, or selecting cards with variables you haven’t explored before, as an exercise to “challenge yourself” (p. 6). Many participants noted that traditional weaving methods often limit the use of unconventional materials, and adjusting the loom setup could address this. However, they also mentioned that altering the loom configuration is not typically considered a variable under designers' control. One participant even noted, “It makes me almost angry that I can't do it there.” (on the industrial loom) (p. 3). They expressed that the workshop piqued their interest in, for example, advancing different sections of the warp for a diverse range of reasons, not only for the potential to create 3D shapes. However, the more experienced textile designers in particular stated, that they did not see mapping out the variables as a design activity. For example, one participant noted it might “complicate the process of trying to work on the machine” (p. 7) because this would add an intermediary tool between the designer and the machine.

5.2 Hands-on Exploration

The woven materials (Fig. 5) display the outcomes of the workshop's weaving activity. Some participants clearly utilised the two variables we encouraged them to explore, such as (Fig. 5b), where the participant combined partial weaving with advancing the multiple beams installed on the frame loom. Another interesting example is the sample at the centre of figure 5c, where the participants created an extra layer shaped with the fan reed. Or the sample at the right bottom of figure 5c, where materials were added locally, and a pleat was created through advancing the warp.

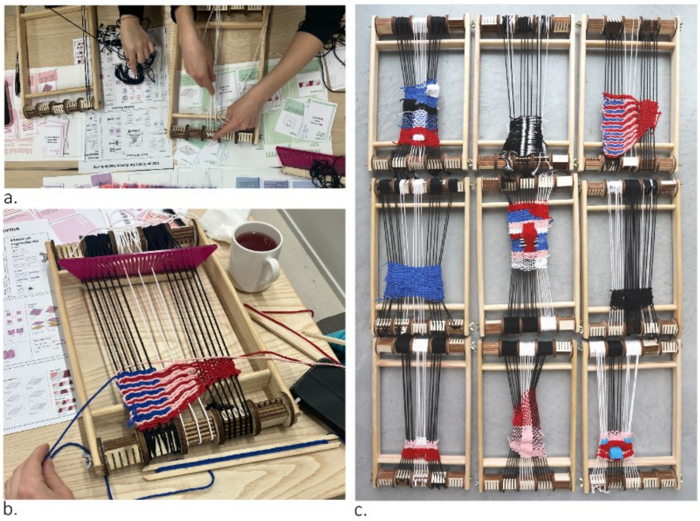

Figure 5 (a) Participants are setting up the loom during the workshop. (b) Weaving in progress during the workshop, (c) Overview of the final weave results

5.3 Usage challenges

The participants also noted some missing pieces and challenges. For example, they noted it would be helpful to include physical textile samples as examples of uncommon variables to "understand what is meant and what the actual differences are" (p. 4). One participant noted that they did not know how the variables would combine to form a textile they were envisioning, and therefore assumed it was too complex. Furthermore, the participants noted an important difference between industrial and hand-woven samples. They showed more interest and excitement in working with hand-operated looms, as they have "different variables that you can actually impact" (p. 9). A suggestion for a future version of the toolkit was to add post-processing variables, such as fabric finishes, which can "greatly affect the sample" (p. 6).

5.4 Developing the Toolkit in Response to Participant Feedback

In response to participant feedback, the card deck was kept as presented in the workshop, while the canvas required minor changes to improve clarity of categorisation language. The frame loom was further developed to add new functionality in response to participant-reported limitations caused by the woven fabric being kept under tension between the sectional warp and sectional fabric beams. Therefore, version 2 of the frame loom replaced the adjustable fabric beam with an alternative fabric take-up system that better enabled form-making on the loom. Additionally, based on observing some challenges with weaving samples on the handlooms in the workshop, we also decided to make some changes to the loom setup (see Fig. 5 and 8).

Due to the workshop's limited length at the conference, it quickly became clear that participants did not have enough time to complete all the activities. Therefore, we decided to skip the 'Identify new directions' activity outlined in the procedure; however, in the plenary focus group session, it became clear that this bridging activity should not have been skipped, because as a result, some participants (p. 2 and p. 6) did not understand the connection between the first activity (with the map and cards) and the weaving activity. Therefore, in future versions of the workshop, we recommend a full day, and we have added an updated schedule to the downloadable toolkit (below).

6. A Toolkit to Explore the Design Space for Woven Textile-forms

The final version, though still an organic design tool open to further development, is presented below and can be downloaded[1].

Figure 6 The final Toolkit for exploring the Design Space of Woven Textiles. It includes a canvas, card deck and 3D printable elements that can be attached to a frame loom.

6.1 Canvas

The canvas (Fig. 7) facilitates the separation and allocation of the card deck. It helps participants select and analyse the variables in the sample they choose. The colours correspond to those on the card deck, and it is indicated whether one or multiple variables can be chosen. The canvas can be printed on four A3 sheets, with one additional A3 print that can be placed over the middle section for the 'identify new directions activity'.

[1] https://doi.org/10.4121/b13d04ac-21a1-4bdb-802a-a96a6b30ffc6

Figure 7 The mapping canvas. It has five categories: Material Process; Material Ingredients; Material Structure (warp); Material Structure (weft); and Material Form.

6.2 Card deck

A deck of 100 cards was created, divided into five categories: Material Process; Material Ingredients; Material Structure (warp); Material Structure (weft); and Material Form (Fig. 8). Each card contains, on the front, a question the participant can answer, and, on the back, a visual and textual description of the variable with examples. The questions in the card deck aim to help the participant connect the variable to their own sample, and the explanations clarify its meaning. Additional blank cards are included in the deck to accommodate any variables designers identify as missing.

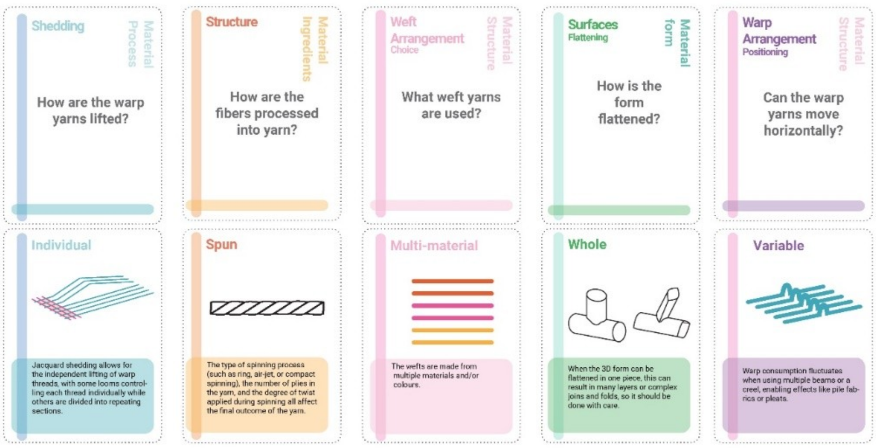

Figure 8 One card from each category. The top row shows the front of the cards with a prompt for the user to evaluate the available options or the process or properties of an existing sample. The bottom row shows the back side of the cards with more detail. The complete card deck can be found in the toolkit.

6.3 Loom and Tools

A commercially available 39,5 x 25cm frame loom was used as a base (Fig. 9). To allow participants to explore different loom configurations, we created 3D-printed sectional warp beams, a comb that holds the fabric in place as the warp is tensioned and three types of reeds that can be laser-cut and assembled before use. Other accessories that should be provided in a workshop are different types of yarns, weaving needles, and sticks.

a. b.

Figure 9 The frame loom in operation with five 3D-printed beams and a comb. Each beam can be tensioned separately, and the comb helps to keep the woven fabric in place as the warp is tightened. (a) The weaver uses a partial weft to weave additional areas. (b) After re-tensioning behind the comb, the textile forms a non-rectangular zone while the fell (last row woven) is kept straight to enable successive free-form weaving.

7. Discussion

In this paper, we presented a toolkit developed to enable designers to explore and expand the design space for woven textiles. The toolkit supports designers in critically engaging with contemporary (industrial) weaving practices by allowing them to analyse key variables, experiment with unconventional loom configurations, and reflect on how these explorations can inform the development of more sustainable and innovative textiles. In this discussion, we will reflect on the limits of current thinking in weaving theory and the role of hands-on making practices to explore how we can move beyond these conceptual limitations.

7.1 Exploring Futures

While many textile designers enjoy exploring creative possibilities within the constraints of weaving, there is also a rich history of designers, weavers, and crafters pushing these boundaries further, inventing new techniques and reviving old ones. While exploring the full potential of current weaving technology is crucial for offering near-future alternatives, it is also important to develop visions for the distant future, particularly those that prioritize social and environmental sustainability over profit and mass production.

Prototypes and samples made outside contemporary industrial norms can inspire further reflection, discussion, and the co-creation of possible futures (Ehn et al., 2014; Stappers et al., 2023). A key insight from the workshop and focus group discussion was that the toolkit's card deck and canvas helped participants make implicit decisions explicit. Participants appreciated being able to separate and articulate the different variables at play, which enabled more precise communication between peers with varying levels of expertise. This shared language, in turn, facilitates critical discussions of existing textile production methods and can give suggestions on what and how technology can be explored to challenge these. Combined with this, the workshop also showed that the hands-on making of samples on the adapted frame loom made (some) participants more critical towards conventional weaving limitations and led them to question why such things are not within their current range of possibilities.

7.2 Building skills

Designing woven textiles benefits from hands-on experience, which supports understanding of how variables like fibre type, yarn thickness, and weave interlacements interact. However, as weaving is a process, other, less tangible factors, such as timing, force, order, tension over time, and the sequence of threads, are also essential to understand. Hands-on making develops a tacit understanding of how all these elements are connected. In industrial weaving processes, it is much more difficult to develop these skills, as it is often challenging to access industrial machinery, particularly to spend enough time at a loom to develop this level of understanding. Furthermore, when testing methods outside standardized production, changing just one variable (such as warp consumption, as explored in the workshop) can affect many others, prompting the designer to reevaluate all other aspects of the textile design and its fabrication.

Which careful design, these skills can be partially developed by mimicking industrial techniques, such as adapting hand-operated looms or even a simple frame loom. As we weave, knowledge emerges through the process, also teaching us lessons that can be translated into industrial processes. Our own experiences with weaving on the frame loom and the participants' experiments taught us, for example, the nuances between yarn tension and consumption, which we aim to take forward in future work as we develop 3D textiles with creel systems.

The toolkit can benefit both advanced and novice users when building skills. Novice users described finding value in learning about weaving in this way, however, we primarily focused on recruiting experienced designers for the exploratory workshop. In the future, we would like to expand the toolkit's user testing to include more beginners to understand how the toolkit and workshop can support their learning. Expert users benefited from expanding their understanding of variables, experimentation outside of norms, and reflecting on their existing practices. Building these skills also brings independence and agency as design researchers working with industry. As most of the industry is relatively traditional, exploring new ideas can be challenging and is often met with disbelief in their viability. Therefore, developing prototypes by mimicking these processes and the knowledge they bring allows, in our experience, for a very different conversation with industry partners. That is, one framed around possibility, grounded in tangible material and process prototypes that aid in mutual understanding.

7.3 Final Thoughts

In informal conversations with some participants after the workshop, we noticed that some have continued to reflect on the limitations of the technology they use and are exploring new possibilities within the looms they already have. We are interested in how this workshop, in the long term, can actively encourage designers to take more control over their means of production and, instead of using a pre-designed loom, make changes to their tools themselves. Through making textiles and tools, the phenomena we study come into existence so they can be studied, discussed, critiqued, and further explored. Therefore, we hope this toolkit supports design researchers in producing textiles not as endpoints but as propositions that envision alternate ways of designing, fabricating, and understanding textiles.

8. References

Albaugh, L., McCann, J., Yao, L., & Hudson, S. E. (2021). Enabling Personal Computational

Handweaving with a Low-Cost Jacquard Loom. Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems, 1–10. https://doi.org/10.1145/3411764.3445750

Barati, B., Karana, E., & Hekkert, P. (2019). Prototyping Materials Experience:

Towards a shared understanding of underdeveloped smart material composites. International Journal of Design, 13(2).

Benabdallah, G., Lazaro Vasquez, E. S., Devendorf, L., & Alistar, M. (2025). "Chaotic, Exciting,

Impactful": Stories of Material-led Designers in Interdisciplinary Collaboration. Proceedings of the 2025 ACM Designing Interactive Systems Conference, 1313–1327. https://doi.org/10.1145/3715336.3735830

Berzowska, J., & Skorobogatiy, M. (2010). Karma chameleon: Bragg fiber jacquard-woven photonic textiles. Proceedings of the Fourth International Conference on Tangible, Embedded, and Embodied Interaction, 297–298. https://doi.org/10.1145/1709886.1709950

Buesgen, A., & Ehrmann, A. (2015). Engineering design and manufacturing of 3D shell fabrics for industrial and automotive applications. Proceedings of the 6th World Conference on 3D Fabrics and Their Applications.

Buso, A., McQuillan, H., Jansen, K., & Karana, E. (2022). The unfolding of textileness in animated textiles: An exploration of woven textile-forms. DRS2022: Bilbao. https://doi.org/10.21606/drs.2022.612

Buso, A., McQuillan, H., Voorwinden, M., & Karana, E. (2023). Weaving Textile-form Interfaces: A Material-Driven Design Journey. Proceedings of the 2023 ACM Designing Interactive Systems Conference, 608–622. https://doi.org/10.1145/3563657.3596086

Charmaz, K. (2014). Constructing grounded theory (3rd ed.). SAGE.

Chen, X., Lai, L. M., Liu, Z., Dai, C., Leung, I. C. W., Wang, C. C. L., & Yam, Y. (2024). Computer Controlled 3D Freeform Surface Weaving https://doi.org/10.48550/arXiv.2403.00473

Cnaani, G., & Sterman, Y. (2023). A Variable Weaving Reed for Producing 3D and Seamless Garments. Textile Intersections 2023 https://doi.org/10.21606/TI-2023/112

Devendorf, L., Arquilla, K., Wirtanen, S., Anderson, A., & Frost, S. (2020). Craftspeople as Technical Collaborators: Lessons Learned through an Experimental Weaving Residency. Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems, 1–13. https://doi.org/10.1145/3313831.3376820

Devendorf, L., De Koninck, S., & Sandry, E. (2022a). An Introduction to Weave Structure for HCI: A How-to and Reflection on Modes of Exchange. Designing Interactive Systems Conference, 629–642. https://doi.org/10.1145/3532106.3534567

Devendorf, L., De Koninck, S., & Sandry, E. (2022b). An introduction to weave structure forHCI: A how-to and reflection on modes of exchange. Designing Interactive Systems Conference, 629–642. https://doi.org/10.1145/3532106.3534567

Devendorf, L., & Di Lauro, C. (2019). Adapting double weaving and yarn plying techniques for smart textiles applications. Proceedings of the Thirteenth International Conference on Tangible, Embedded, and Embodied Interaction, 77–85. https://doi.org/10.1145/3294109.3295625

Devendorf, L., Walters, K., Fairbanks, M., Sandry, E., & Goodwill, E. R. (2023). AdaCAD: Parametric Design as a New Form of Notation for Complex Weaving. Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems, 1–18. https://doi.org/10.1145/3544548.3581571

Drews, J.-A., McQuillan, H., & Mosse, A. (2023). Methods for Designing Woven Textile-forms: Examples from a pedagogical textile design workshop. Textile Intersections 2023. https://doi.org/10.21606/TI-2023/113

Ehn, P., Nilsson, E. M., & Topgaard, R. (2014). Making Futures. The MIT Press.

European Textile Network. (2025). European Textile Network - Reports. https://etn-net.org/reports.html

Giaccardi, E. (2019). Histories and Futures of Research through Design: 13(3).

Gries, T., Bettermann, I., Blaurock, C., Bündgens, A., Dittel, G., Emonts, C., Gesché, V., Glimpel, N., Kolloch, M., Grigat, N., Löcken, H., Löwen, A., Jacobsen, J.-L., Kimm, M., Kelbel,

H., Kröger, H., Kuo, K.-C., Peiner, C., Sackmann, J., & Schwab, M. (2022). Aachen Technology Overview of 3D Textile Materials and Recent Innovation and Applications. Applied Composite Materials, 29(1), 43–64. https://doi.org/10.1007/s10443-022-10011-w

Guridi, S., Iannacchero, M., & Pouta, E. (2024). Towards More Sustainable Interactive

Textiles: A Literature Review on The Use of Biomaterials for eTextiles. Proceedings of the CHI Conference on Human Factors in Computing Systems, 1–19. https://doi.org/10.1145/3613904.3642581

Harvey, C., Holtzman, E., Ko, J., Hagan, B., Wu, R., Marschner, S., & Kessler, D. (2019a). Weaving Objects: Spatial Design and Functionality of 3D-Woven Textiles. Leonardo, 52(4), 381–388. https://doi.org/10.1162/leon_a_01780

Horváth, I. (2007). Comparison of three methodological approaches of design research. ICED'07, 361–362.

Igoe, E. (2021). Textile design theory in the making. Bloomsbury Visual Arts.

Kilic Afsar, O., Shtarbanov, A., Mor, H., Nakagaki, K., Forman, J., Modrei, K., Jeong, S. H.,Hjort, K., Höök, K., & Ishii, H. (2021). OmniFiber: Integrated Fluidic Fiber Actuators for Weaving Movement based Interactions into the 'Fabric of Everyday Life.' The 34th Annual ACM Symposium on User Interface Software and Technology, 1010–1026. https://doi.org/10.1145/3472749.3474802

Kizuka, A., Ueda, K., Horikawa, J., & Roth, B. (2025). Reweaving Nishijin: Parametric Design System to Shape the Future of Kyoto Traditional Textiles. Proceedings of the Extended Abstracts of the CHI Conference on Human Factors in Computing Systems, 1–5. https://doi.org/10.1145/3706599.3721170

Klop, S. (2024). Unlocking new possibilities in weaving: Defining methods for weaving 3D fabrics and exploring implementation on standard looms through use of an add-on [Msc. Graduation Thesis]. Delft University of Technology.

Li, G., Liu, Y., Lan, P., Li, Y., & Li, Y. (2013). A prospective bifurcated biomedical stent with seamless woven structure. Journal of the Textile Institute, 104(9), 1017–1023. https://doi.org/10.1080/00405000.2013.767429

Lottozero. (2025). Lottozero: Textile Laboratories. https://www.lottozero.org

Lungu, M. (2022). The Coding Manual for Qualitative Researchers. American Journal of Qualitative Research, 6(1), 232–237. https://doi.org/10.29333/ajqr/12085

Manning, E., & Massumi, B. (2014). Thought in the Act: Passages in the Ecology of Experience. University of Minnesota Press.

Marr, A., & Hoyes, R. (2016). Making Material Knowledge: Process-led Textile Research as an Active Source for Design Innovation. Journal of Textile Design Research and Practice, 4(1), 5–32. https://doi.org/10.1080/20511787.2016.1255447

McQuillan, H. (2020). Zero waste systems thinking: Multimorphic textile-forms [Doctoral Dissertation]. University of Borås, Faculty of Textiles, Engineering and Business.

McQuillan, H., & Karana, E. (2023). Conformal, Seamless, Sustainable: Multimorphic Textile forms as a Material-Driven Design Approach for HCI. Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems, 1–19. https://doi.org/10.1145/3544548.3581156

McQuillan, H., Voorwinden, M., Arts, B., & Vroom, B. (2023). The Circular Techno-Aesthetics of Woven Textile-forms: A Material and Process-driven Design Exploration. In *PLATE 2023: 5th PLATE Conference* (pp. 649-659). Aalto University.

Meiklejohn, E., Devendorf, L., & Posch, I. (2023). Making Magnetic reverberations. Unstable Design Lab.

Meiklejohn, E., Devendorf, L., & Posch, I. (2024). Design Bookkeeping: Making Practice Intelligible through a Managerial Lens. Designing Interactive Systems Conference, 35–49. https://doi.org/10.1145/3643834.3660754

Meiklejohn, E., Devlin, F., Dunnigan, J., Johnson, P., Zhang, J. X., Marschner, S., Hagan, B., & Ko, J. (2022). Woven Behavior and Ornamentation: Simulation-Assisted Design and Application of Self-Shaping Woven Textiles. Proceedings of the ACM on Computer Graphics and Interactive Techniques, 5(4), 1–12. https://doi.org/10.1145/3533682

Niinimäki, K., Peters, G., Dahlbo, H., Perry, P., Rissanen, T., & Gwilt, A. (2020). The environmental price of fast fashion. Nature Reviews Earth & Environment, 1(4), 189–200. https://doi.org/10.1038/s43017-020-0039-9

Nimkulrat, N. (2012). Hands-on Intellect: Integrating Craft Practice into Design Research Introduction. *IJDesign*, *6*(3), 1-14.

Ojala, A. E., Pouta, E., & Gowrishankar, R. (2025). Unveiling Kinetic Expression: Exploring Design Variables and Processes for Dynamic Woven Textiles. Proceedings of the Nineteenth International Conference on Tangible, Embedded, and Embodied Interaction, 1–17. https://doi.org/10.1145/3689050.3704950

Olde, M. J. (2022). Creating Auxetic Structures in Three-Dimensional Weaving. Bridges 2022 Conference Proceedings. Bridges 2022.

Ooms, D., Voskuil, N., Andersen, K., & Wallner, H. O. (2020). Ruta, a Loom for Making Sense of Industrial Weaving. Companion Publication of the 2020 ACM Designing Interactive Systems Conference, 337–340. https://doi.org/10.1145/3393914.3395815

Parisi, S., McQuillan, H., & Karana, E. (2024). Design for serene textile experiences: A toolkit. DRS2024: Boston. https://doi.org/10.21606/drs.2024.1012

Philpott, R. (2012). Crafting innovation: The intersection of craft and technology in the production of contemporary textiles. Craft Research, 3(1), 53–74. https://doi.org/10.1386/crre.3.1.53_1

Pouta, E., & Mikkonen, J. V. (2022). Woven eTextiles in HCI — a Literature Review. Designing Interactive Systems Conference, 1099–1118. https://doi.org/10.1145/3532106.3533566

Pouta, E., Vidgren, R., Vapaavuori, J., & Mohan, M. (2022, June 16). Intertwining material science and textile thinking: Aspects of contrast and collaboration. DRS2022. DRS, Bilbao. https://doi.org/10.21606/drs.2022.525

Rosato, L., Drews, J.-A., Tour, A., Bassereau, J.-F., & Mosse, A. (2023). Seamlessness and Monomateriality in Sustainable Garment Design. A Knit/Woven Trouser Prototype. https://doi.org/10.30682/diid8023j

Shi, Y., Taylor, L. W., Cheung, V., & Sayem, A. S. M. (2022). Biomimetic Approach for the Production of 3D Woven Spherical Composite Applied in Apparel Protection and Performance. Applied Composite Materials, 29(1), 159–171. https://doi.org/10.1007/s10443-021-09936-5

Shi, Y., Taylor, L. W., Kulessa, A., Cheung, V., & Sayem, A. S. M. (2024). Re-engineer apparel manufacturing processes with 3D weaving technology for efficient single-step garment production. iScience, 27(8), 110315. https://doi.org/10.1016/j.isci.2024.110315

Speer, S., Yankova, N., Huang, J., Rosé, C., Peppler, K. A., McCann, J., & Orta Martinez, M. (2025). Designing Looms as Kits for Collaborative Assembly. Proceedings of the 38th Annual ACM Symposium on User Interface Software and Technology, 1–18. https://doi.org/10.1145/3746059.3747765

Stappers, P. J., & Giaccardi, E. (2017). Research through design. In M. Soegaard & R. Friis Dam (Eds.), The encyclopedia of human-computer interaction (2nd ed., pp. 1–94). The Interaction Design Foundation.

Stappers, P. J., Visser, F. S., & Keller, I. (2023). The role of prototypes and frameworks forstructuring explorations by Research Through Design. In P. A. Rodgers & J. Yee, The Routledge Companion to Design Research (2nd ed., pp. 310–326). Routledge. https://doi.org/10.4324/9781003182443-28

Sun, R., Onose, R., Dunne, M., Ling, A., Denham, A., & Kao, H.-L. (Cindy). (2020). Weaving a second skin: Exploring opportunities for crafting on-skin interfaces through weaving. Proceedings of the 2020 ACM Designing Interactive Systems Conference, 365–377. https://doi.org/10.1145/3357236.3395548

TextielLab. (2025). TextielLab Tilburg. https://textiellab.nl/en Van Dongen, P., Britton, E., Wetzel, A., Houtman, R., Ahmed, A. M., & Ramos, S. (2022). Suntex: Weaving solar energy into building skin. Journal of Facade Design and Engineering, 10(2), 141–160. https://doi.org/10.47982/jfde.2022.powerskin.9

Von Bush, O. (2022). Making Trouble: Design and Material Activism. Camden: Bloomsbury Voorwinden, M., Andersen, K., & McQuillan, H. (2025a). Multistable Leno Woven Textiles.

UbiComp Companion ’25,. International Symposium on Wearable Computing, Espoo, Finland. https://doi.org/10.1145/3714394.3750710

Voorwinden, M., Buso, A., Karana, E., & McQuillan, H. (2025b). A Design Space for Animated Textile-forms through Shuttle Weaving: A Case of 3D Woven Trousers. DIS ’25, Madeira, Portugal. Designing Interactive Systems Conference, Madeira, Portugal. https://doi.org/10.1145/3715336.3735741

Voorwinden, M., & McQuillan, H. (2025). Woven Textile-Form Design: A Method to Design Woven 3D Form. Journal of Textile Design Research and Practice, 1–43. https://doi.org/10.1080/20511787.2025.2567765

Walters, K. (2021). 2D to 3D workshop: A method for teaching form-generating processes through the exploration of contrasting material combinations. 3rd Interdisciplinary and Virtual Conference on Arts in Education. https://www.divaportal.org/smash/get/diva2:1596770/FULLTEXT01.pdf

Walters, K. (2022). Emergent behaviour as a forming strategy in craft: The workmanship of risk applied to industrial-loom weaving. Craft Research, 13(2), 327–348. https://doi.org/10.1386/crre_00082_1

Walters, K., Devendorf, L., & Landahl, K. (2024). Animated linen: Using high-twist hygromorphic yarn to produce interactive woven textiles. Dis ’24. https://doi.org/10.1145/3643834.3662146

Walters, K., & Kapsali, V. (2023, September). From boxfish to twistbox: Developing a woven textile hinge through bio-inspired design. Textile Intersections 2023. https://doi.org/10.21606/TI-2023/108

Wu, R., Zhang, J. X., Leaf, J., Hua, X., Qu, A., Harvey, C., Holtzman, E., Ko, J., Hagan, B., James, D., Guimbretière, F., & Marschner, S. (2020). Weavecraft: An interactive design and simulation tool for 3D weaving. ACM Transactions on Graphics, 39(6), 1–16. https://doi.org/10.1145/3414685.3417865

Zhu, J., El Nesr, N., Simon, C., Rettenmaier, N., Beiler, K., & Kao, C. H.-L. (2023). BioWeave: Weaving thread-based sweat-sensing on-skin interfaces. Proceedings of the 36th Annual ACM Symposium on User Interface Software and Technology, 1–11. https://doi.org/10.1145/3586183.3606769

Zhu, J., Winagle, L., & Kao, H.-L. (Cindy). (2024). EcoThreads: Prototyping biodegradable e textiles through thread-based fabrication. Proceedings of the CHI Conference on Human Factors in Computing Systems, 1–17. https://doi.org/10.1145/3613904.3642718

About the Authors:

Milou Voorwinden is a PhD candidate Faculty of Industrial Design Engineering at Delft University of Technology. Her research in textile design seeks to rethink woven textile methods and processes to support textile-form design and fabrication.

Savanne Klop completed the MSc Integrated Product Design at Delft University of Technology in 2024 with a thesis on designing an add-on that enables the creation of 3D and non-rectangular forms on a standard hand-operated loom.

Holly McQuillan is Assistant Professor in Multimorphic Textile Systems at TU Delft, co-founder of DREAM, and a pioneer of zero waste fashion design. Her research explores complex fibre-yarn-textile-form systems as a means for transforming how textiles are designed, made, and experienced.

Supplemental Materials

Activity	**Time**	**Participants arrangements**	**Description**	**Tools**
1. Mapping your project - 90 min. Participants will analyse existing 3D woven samples, objects, or sketches, using the design space to document variables and identify new directions.				
Introduction	25 Min	Plenary	Introduction to the workshop and explanation of the design space. Introduction round participants, showcase samples.	
Mapping your project	30 min	Groups of 2		Cards, Map
Identify new directions	30 min	Groups of 2		Cars, Map
2. Exploring New Configurations 90 min Through guided ideation, participants will generate alternative loom setups and experimental approaches to push beyond existing weaving constraints				
Setting up the loom	30 min	groups of 2	Use one of the looms we provided, or create your own experimental set-up to ideate loom configuration.	Looms, additional loom tools
Weaving	60 min	Groups of 2		Looms, additional loom tools
3. Focus group discussion- 30 min. Participants will exchange insights, refine new methodologies and expand the design space collaboratively.				