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Mobius Band Seamless 3D Whole-Garment Weaving Method

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ABSTRACT This practice-led research investigates the potential of eliminating cutting lines to achieve seamless, whole-garment woven apparel using the Mobius Band technique in the context of the zero-waste design thinking. Relying on the inherent advantages of knitting structure, fully fashioned knitting has been researched for producing three-dimensional (3D) apparel while reducing textile waste. However, there is limited research and practice to explore fully-fashioned woven apparel or seamless whole garment weaving directly on the loom. The conventional woven textile and fashion production systems exacerbate the division of knowledge, limiting opportunities to extend the whole garment weaving practice. This research aims to bridge the gap between loom weaving and fashion pattern-making by hand-weaving a Mobius Band zero-waste coat block - a foundational garment shape for coats and outerwear - using a digitally controlled jacquard loom (TC2). The Mobius Band technique creates a garment from a single, continuous piece of fabric incorporating an intentional twist,

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producing a seamless, reversible, and transformable design (Li et al. 2025). This unique topological structure introduces new possibilities for producing zero-waste, whole garments directly on the loom, eliminating the need for traditional cut-and-sew construction. Conventional pattern-making including most zero-waste methods, relies on cutting 2D woven textiles to construct 3D woven apparel. This rigid approach limits fashion designers and pattern makers seeking alternative approaches to reduce textile waste and rethink garment construction from the outset. This paper questions the necessity of cut-and-sew techniques in the assembly of woven apparel. It proposes an alternative approach that disrupts the conventional sequence of production. In doing so, it responds to the ongoing issue of global textile waste. By reimagining the relationship between weaving and garment construction, this method offers a potential pathway towards a zero-waste, slow fashion model for the future of the apparel industry.

KEYWORDS: Mobius Band, whole-garment weaving, zero-waste pattern design, 3D seamless weaving, fully-fashioned weaving

on technical design applications that address broader inclusive, social and environmental aspects.

Introduction

A minimum of 15%–20% of textiles is wasted in the mass-production process to produce a garment (Townsend and Mills 2013; Rissanen and McQuillan 2016). This is due to the intricate nature of the fashion design and production system, opaque business models (Ditty 2016; Fashion Revolution 2023), and the fashion industry's pursuit of infinite economic growth and expansion (Fletcher and Tham 2019; Subathra and Vijayalakshmi 2022). Zero-waste pattern cutting design has been used to reduce or eliminate textile waste in design and production (Rissanen and McQuillan 2016), however there is still insufficient progress in lessening waste impacts in conventional fashion production (Ramkalaon and Sayem 2021; Italiano et al. 2022). Because of the vast globalised scale of the fashion industry and risk-averse and benefit-first business operations, most alternative technologies addressing textile waste issues have only been utilised sparingly. Simply inserting the zero-waste pattern cutting method into the current complex liner conventional fashion production system will continually limit the potential of this practice/method to play its role in reducing pre-consumer textile waste. Moreover, pressuring financially established mass-production business models to take on the zero-waste pattern cutting techniques could overwhelm their staff and limit the industry's willingness (McQuillan 2020). Techniques that help reshape the system and identify the intersection of the front end of apparel design and production are urgently needed to enhance the utility of zero-waste pattern cutting. Therefore, a "simultaneous design approach" was used in this research to explore the intersections of weaving and zero-waste pattern design (Townsend 2003), looking into regenerate a holistic woven apparel production model for industry's need of sustainable growth.

Cut-and-sew has been recognised as an essential production process to transfer a 2D flat woven fabric to 3D apparel in fashion industry for a long time. The pattern maker begins with 2D pattern making to represent the design, cuts the fabric to match the pattern piece, and then sews the individual pieces together to form a 3D garment (Books 2013). The zero-waste pattern design relies on the shared boundary of the pattern pieces within a rectangular fabric space to minimise or eliminate waste in the pre-consumer apparel production (Rissanen 2013). Timo Rissanen summarised the formula as "zero-waste: fabric + cut + sew = garment" (Rissanen 2013). To achieve no waste in production, zero-waste pattern design, in general, is the technique for intervention in the cut-and-sew practice. However, both the conventional and zero-waste design-production processes still have not escaped the control of the cut-and-sew. Without eliminating the cut-and-sew, textile waste will continually result from this 2D to 3D transformation process, especially when producing woven-based apparel. This research questions the necessity of cut-and-sew practice in producing a garment without waste.

Fully fashioned knitting employing the looped or interlocked weft structure and flexible needle position knitting can be produced without additional cut-and-sew (Niu et al. 2020). While, there may still be a need to hand loop the seam to present a clean-finished whole garment, textile waste is extensively removed from the practice. Compared with the rapid development of fully fashioned knitting, fully fashioned and whole-garment weaving has received insufficient attention. The well-known A-POC project created by Issey Miyake and Dai Fujiwara adopted the flat tube knitted and woven fabric to design several fashion patterns in single piece cloth to maximise the potential use for the wearer(s) (Miyake et al. 2001). Anna Piper's composite pattern weaving system (Piper 2019) and Holly McQuillan's flat textile-form technique (McQuillan 2020) further enhance the intersection of weaving and zero-waste pattern cutting to pursue changes in production that remove textile waste. However, cut-and-sew practice - the origin of textile waste - is still involved. This practice-led research aims to explore the woven textile and fashion intersection specifically, to ask "can zero-waste = fashion pattern-making + fabric production to produce whole garment woven apparel?"

To address the challenge of textile waste and explore alternative pathways to garment construction methods, this research adopts the Mobius Band one-piece-cutting pattern technique - a zero waste approach to garment design that uses the Mobius Band structure as a foundational form (Li et al. 2025). The Mobius Band is a one-sided surface with a continuous edge created by giving a strip of material a half twist and joining the ends (Thulaseedas and Krawczyck 2003; Guo et al. 2023) (Figure 1). This technique involves draping a garment

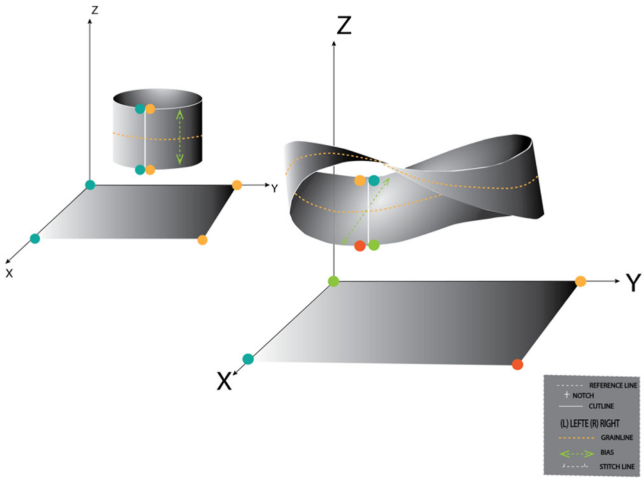


Figure 1
The Mobius Band structure, Zewei, 2025.

from a single continuous piece of fabric with a built-in twist resulting in a seamless, reversible, and transformable garment design (Li et al. 2025). Its unique topology offers new possibilities for developing whole-garment, zero-waste garments directly through weaving, which eliminates the need for conventional cut-and-sew processes. It also provides opportunities to negotiate the predetermined set up of the loom to accommodate garment shaping requirements for wearability. The Mobius Band pattern design approach challenges the conventional 2D-to-3D logic of fashion pattern-making by introducing a 3D-to-3D methodology, which approaches the garment as an inherently spatial and sculptural form from the outset.

This study utilises this 3D design concept alongside zero-waste pattern design techniques to further explore an alternative pathway for woven garment design, situated at the intersection of textile and fashion, when fabric is being developed and formed. This study primarily employs a digitally controlled jacquard loom (TC2), which allows for precise manipulation of warp selection, lifting sequences, and "weft motion trajectory" to enable 3D shaping within a single, continuous piece of woven fabric. In weaving, warp and weft refer to the vertical threads (ends) and horizontal threads (picks) on the loom, these interlace to form the fabric's structure. In this study, the warp yarns are often lifted only one or two ends per pick, allowing the weft yarn to visually accumulate and form 3D volumes that contribute directly to the shape of the garment. The concept of weft motion trajectory - the continuous path of weft movement that follows the twisted surface of a Mobius Band - is central to this approach. This trajectory creates a seamless flow across the warp threads during garment formation, working in tandem with the Mobius Band pattern design method to collectively enable the creation of a seamless whole garment coat on the loom.

Literature Review

Pre-Consumer and Post-Consumer Textile Waste

With the rapid development of fast fashion and consumers' growing demand for on trend apparel, the fashion industry now produces double the amount of clothing compared to 20 years ago (Niinimäki et al. 2020). The pre-consumer and post-consumer phases (Figure 2) are recognised to produce vast amounts of waste in the life of a textile (Vadicherla et al. 2017; Aus et al. 2021). Pre-consumer waste refers to the waste generated from production, as well as the overproduction of apparel that is disposed of before trading, and post-consumer waste refers to apparel that is not actively used or has been thrown away by consumers (Sisodia and Parmar 2022; Dhivya and Subathra 2023). Generally, textile waste exists in every stage/practice in textile manufacturing, including spinning, setting up the loom, and finishing the cloth (Dhivya and Subathra 2023). Similarly the fashion industry produces waste during apparel production stages, such as toiles and samples, cut-and-sew, unfinished and unsold apparel, and also in the consumer's wardrobe (Haq and Alam 2023).

Limiting the environmental impact of textile waste after production has proven difficult to manage. Landfilling is currently used to manage about 87% of the world's textile waste, which contributes to an increase in solid waste (Moazzem et al. 2021; Sisodia and Parmar 2022). While researchers and organisations recognise that at least 90% of the apparel dumped in landfills meets the conditions for reuse or recycling for other productions (H&M 2014; Moazzem et al. 2021), the repurposed amount is in fact far smaller. Every year, the European Union discards approximately 5.8 million tonnes of textiles, and only around 20% of these are downcycled into other products (European Commission 2022); in China, about 22 million tonnes of textile waste were produced in 2020, with a comparable recycling rate of 20% (Man 2022). The Australian Government, facing at least 501 thousand tonnes of textile waste (excluding the 940 thousand tonnes that have been exported) in landfills across the nation every year, has committed 20 million dollars of funding to help grow the country's recycling industry (Ross 2019). According to Lewis and Gertsaki's waste management hierarchy, however, reduction is the most environmentally and financially desirable outcome, followed by reuse, recycling, treatment, and disposal (Lewis and Gertsakis 2003). Eliminating textile waste from the origin helps reduce further input across the product's lifespan compared to managing its environmental impact after production.

The fashion industry is motivated by the infinite growth of profit, with the rapid expansion of the fast fashion business model (Abbate et al. 2024), advanced technology to support online shopping platforms and convenient global transportation, all contributing to the incubation of hyper-fast fashion brands like Boohoo, Romwe, Shein, ASOS and PrettyLittleThing. Although attention to the textile waste

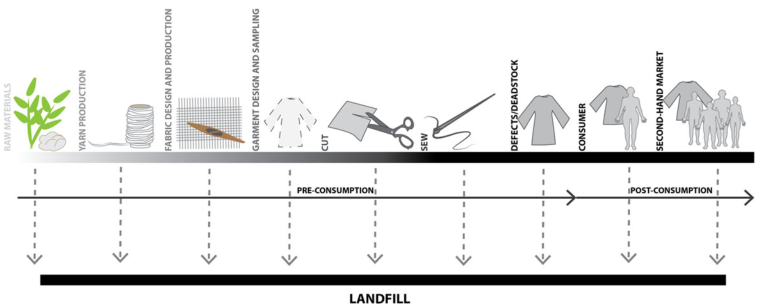


Figure 2
The entire life of the garment with textile waste embedded in a linear system, Zewei, 2025.

issue has grown globally in recent years, reducing, reusing, recycling, and treating the existing, steadily increasing amount of textile waste happens significantly slower than the rate at which new textile waste is created (Fletcher and Tham 2019). This research therefore strongly emphasises the pre-consumer phase to investigate the primary origin of the textile waste and provide a viable technique for regenerating the design and production system to reduce textile waste at the system's front end. Consequently, this research assists in regulating the environmental impact of post-consumer textile waste by intervening in the pre-consumer phase through innovative apparel production processes.

Slow Fashion Production

The current mainstream linear fashion system (Figure 3) simplifies a single department's responsibility to speed up apparel development and production to ensure the products always timely and meets the demand for the consumer (Martin 2000). Textile departments focus on fibre, yarn, fabric design and production. Fashion departments source suitable fabric while focusing on apparel design, then pattern making and construction. The fast fashion industry's reliance on this financially efficient system and business practices contribute to its vast economic success. It is fast in design, and emphasises mass produced garments that are easily assembled, cheap, low-cost, low-quality, and have a short life span (Fletcher 2010; Farrer 2011; Yang and Zhang 2018). The level of disconnection between the textile and fashion production departments increases with the speed at which fashion is manufactured (Whitty 2021; Abbate et al. 2024).

Based on a long-term accumulation of overproduction and over-consumption practices, the volume of textile waste becomes unmanageable and untraceable. With the increased number of dump sites worldwide (Roushan 2021), an innumerable amount of textile waste is now passed on to the recycling and second-hand industry with the raising awareness of circular fashion. But until textile waste is recycled, reused, and treated at a rate that surpasses that of the

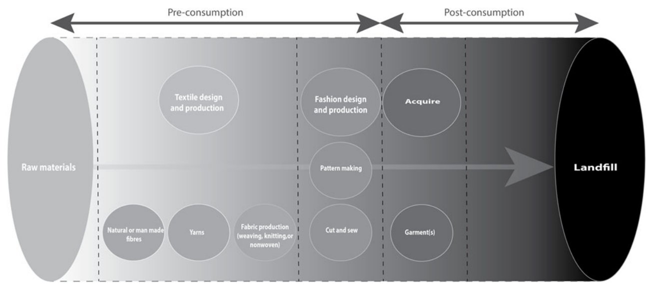


Figure 3
Fashion mainstream linear system, Zewei, 2025.

ultra-fast fashion industry today, it will continue to be a significant environmental issue. Both the second-hand and recycling industry can be considered as a temporary intervention for extending the life span of the existing garment, not a final solution or approach to creating a sustainable future. Therefore, developing an alternative approach to slow down the industry and emphasise the intersection between the manufacturing of textiles and fashion is essential to regaining control of the textile waste output.

The term fast and slow fashion influenced by the food sector, describe practices in the fashion industry that vary in scale, ethics, and environmental impact, with fast fashion likened to fast food due to its standardisation, and rapid market turnaround using low-cost materials and labour (Fletcher 2010). Since 2008, slow fashion, commonly understood as opposite to fast fashion in design and production, often refers to reducing consumption frequency and slower production speed, seen as a movement that is antagonistic to economic growth (Fletcher 2010; Solino et al. 2020; Subathra and Vijayalakshmi 2022). Slow consumption calls on consumers to exercise conscious and sustainable consumption behaviours (Cho et al. 2015), that emphasise quality purchases over quantity of purchases. To ensure quality products for long-term use, slow production is advised to prevent overusing natural and human resources (Jung and Jin 2014). This may involve a localised business model to reduce carbon footprint, made-to-order to avoid overproduction and deadstock issues, seasonless and timeless garments to reduce overconsumption, and high quality garments with lower environmental impact materials to ensure longevity (Cramer 2021). Although emerging designers and slow fashion brands have responded to current environmental issues with a variety of actions, convincing the broader industry to alter their business model towards sustainable systems is still burdensome and complex (Ditty 2016).

For example, slow fashion has attempted to intervene in the conventional fashion system through many subtle adjustments in past years, however there are still struggles to disrupt the fast fashion system because the changes slow fashion advocates are not perceived as sufficiently deep (Fletcher 2010). Actions like sourcing and utilising sustainable-certified textiles to produce garments and other textile-based products has become a market strategy for fast fashion brands to subvert their negative image and greenwash the public or consumer (Zink and Geyer 2017). Leading viscose supplier Aditya Birla Group has provided their "100% sustainable" fabrics to H&M, Inditex and many giant fashion brands (Ringstrom 2021). The production process of viscose, from wood to pulp, fibre, yarn and then fabric, indeed sounds "green." However, the process requires the use of CS2 to transfer wood to fibre and this has already damaged the environment near the factories (Changing Markets 2017). Fast fashion's increasing use of "sustainable fabric" will not alleviate contemporary fabric waste and pollution issues and in fact, has quickly spawned new pollution locations. Slow fashion, should attempt to form a sustainable growth fashion model from different but broader perspectives (Fletcher 2010). Thus, practice-led research needs to think outside the conventional fashion and textile workflow to change the internal technical perspective to help address the system transition.

In this paper, "slow" refers to developing an alternative method to slow the speed at which we design and produce apparel, through environmentally conscious designing and crafting. By "slowing down" the speed of garment production we provide an opportunity for the environment to recover. The conventional fashion system is designed to standardise and speed up production to pursue efficiency and rapid growth. The alternative method outlined in this paper, is intended to encourage perspective change in design and production, to pursue a slow but sustainable growth model towards a balanced, respectful, sustainable future for our people, industry and planet.

The Necessity of Cut-and-Sew Practice within Garment Production

Cut-and-sew is always involved in the conventional garment production process, especially when utilising woven fabric. Regardless of whether the designer or pattern maker prefers to use flat pattern-making, draping or alternative approaches, cut-and-sew is compulsory to form a 3D woven contemporary garment. In the fashion manufacturing process, waste generated from cut-and-sew has its origins in the lay plan (marker plan) stage (Enes and Kipöz 2020), in which individual pattern pieces are carefully laid out on the fabric to maximise fabric usage and avoid financial cost in pre-consumer phases. A variety of pattern cutting approaches have been introduced in past years with an aim to eliminate or minimise the textile waste caused by cut-and-sew practices in manufacturing garments. Zero-waste pattern cutting typically relies on altering the shape of individual pattern pieces and managing the lay plan of fabric to avoid waste generation. For example, Timo Rissanen's jigsaw puzzle method emphasises that pattern-making practice could be a key approach within fashion design to reduce textile waste (Rissanen 2005). Julian Roberts' Subtraction Cutting method uses minimal cutting lines while focusing on the negative space between the cloth and the body (Roberts 2014). Katherine Townsend and Fiona Mills use an existing garment as a design prototype to develop zero-waste patterns, therefore avoiding the uncertain outcomes of the draping process (Townsend and Mills 2013).

Through practice-based research, researchers have been working to discover alternative methods that could be extremely efficient to utilise fabric with the aim to reduce the 15%–20% textile waste generated in the cut-and-sew process (Townsend and Mills 2013; Rissanen and McQuillan 2016). Deb Cumming and Holly McQuillan's project "Zero + One" uses a one-piece cutting method to ensure fabric continuity to allow reconstruction by fusing minimal cut lines for textile recycling (Cumming and McQuillan 2018). Zewei Li's previous work "The Infinity," utilised a Mobius Band structure (a two-dimensional, twisted, non-orientable surface with a one-dimensional edge) in a one-piece cutting method to provide versatile apparel with minimal cutting lines and reduced manufactory sequences (Li et al. 2025). Generally, zero-waste pattern cutting approaches play a significant role in connecting pattern-making to the fashion design stage, highlighting the importance of designing and arranging the cutting line to avoid waste. However, despite the advances of these interventions, there is still insufficient progress in lessening waste impacts in conventional fashion production as both designer and pattern maker still show reliance on cut-and-sew (Ramkalaon and Sayem 2021).

Pre-consumer textile waste is caused by the irregular shape of individual pattern pieces, the efficiency of the lay plan, and/or the numbers of the cutting lines. Designers rarely question whether it is always essential to form a garment out of cut-and-sew practices. We have been trained to use cut-and-sew to achieve the transformation from 2D flat fabric to 3D garment, therefore cut-and-sew has become an inbuilt component in mainstream garment production workflow. The launch of whole-garment knitting machines has reduced the involvement of cut-and-sew in producing knitwear (Peng et al. 2018). While the A-POC project (Kries 2001; Miyake and Fujiwara 2001) offers an early example of integrating textile and fashion design for versatility and efficiency, there remains a notable gap in weaving-based research that aims to eliminate cut-and-sew process entirely. Unlike fully fashioned knitting, which has seen significant technological advancement, weaving has yet to be fully explored as a means of forming garments seamlessly. This study responds to that gap by advancing whole-garment woven production as a purposeful strategy to address pre-consumer textile waste at its origin.

As designers, we must reconsider how we approach the design and production procedure to transition to an environmental and sustainable growth model. To address textile waste at the initial stage of the production chain, the "fundamental" principle and approach to producing garments must change. In zero-waste pattern cutting, practice design and pattern-making simultaneously reduce textile waste within the fashion design department. Could the shift in emphasis to simultaneously designing a zero-waste pattern and a weaving plan aid in bridging the gap between textile and fashion practices? Could offering an intersecting solution in fabric and apparel production address pre-consumption textile waste? This research explores the idea of removing the cut-and-sew in fashion woven garment production to form 3D apparel directly when weaving. The Mobius Band seamless 3D weaving method aims to eliminate textile waste efficiently at the stage in which the warp and weft yarns begin weaving.

The Fully Fashioned and Whole-Garment Methods

Fully fashioned apparel often refers to fully fashioned knitting only due to the insufficient development of fully fashioned weaving. Compared to the cut-and-sew knitwear process, which involves cutting individual pattern pieces from a large roll of fabric based on a lay plan for fast manufacturing, fully fashioned knitting takes a different approach. In this method, the fabric is knitted to meet the shape of the pattern pieces, followed by a labour intensive binding process that results in clean-finished knitwear (Peng et al. 2018; Zhao et al. 2021). Textile waste is largely controlled in this practice as the created individual pieces rely on single continuous yarn that is looped or interlocked together with flexible needle position to form the fabric (Niu et al. 2020). In 1995, Shima Seiki launched the whole garment knitting machine (Peterson et al. 2011), developing whole garment knitting technology to minimise both the cut-and-sew and binding process when knitting completely seamless 3D apparel (Smith 2013). Although whole garment knitting still involves hand looping to secure the end of the yarn and present clean-finished apparel, both environmental and human resources are largely saved in the pre-consumer phase.

For example, in Issey Miyake and Dai Fujiwara's A-POC project, according to the types of garment, various cavities were created in single pieces of tubular knitted or woven fabric (Miyake et al. 2001). The knitted A-POC eliminates the need for sewing, and a single roll of fabric can now be used to generate several garment components or variations. Therefore, consumers can cut around the designed cavities based on their needs. Comparably, in the woven A-POC, seam allowances were left around the cavities so that the customer may cut and alter the garment's appearance, though depending on the pattern's complexity, sewing may still be necessary to ensure that the garment is finished. Sewing the sleeves and body sides may not always be necessary, but cutting lines are always required to allow the sleeves to freely hang off the body. In woven production the nature of the weave structure restricts the practice to self-binding the yarn back to the fabric as knitting, therefore the raw edge of the fabric will always exist where the cutting line has been applied.

Additionally, without sewing to secure the cutting edge of the woven fabric, the garment will likely to start fray and unravel when worn. When cutting is involved in the production process, textile waste begins to arise.

Anna Piper introduced the Composite Pattern Weaving system from a textile design perspective to challenge the conventional, linear approach to garment development and production. By integrating zero-waste fashion pattern layouts directly into the woven structure, this methods enables the creation of single-piece garment on the loom, eliminating textile waste typically produced during the "post-weaving" garment assembly process (Piper 2019), with a focus on reducing cutting and sewing lines (Piper 2019). The applied weave structure considers both visual aesthetics and garment durability (Piper 2019). Different types of looms offer varying levels of control and complexity in the weaving process. A 8-shaft loom is a manually or digitally operated loom that allows the weaver to create small to medium size woven patterns using a limited number of shafts (which hold the heddles to lift and lower warp threads), making it suitable for sampling and exploratory textile work. The TC2 is a digitally controlled jacquard loom that enables precise control of individual warp threads for highly detailed and experimental weaving. A jacquard power loom is an industrial-scale machine designed for automated, high-speed production of complex woven patterns. Garment prototypes can vary depending on the type of loom used, whether a dobby loom, TC2, or jacquard power loom, Composite Pattern Weaving consistently highlights the potential of single-piece weaving techniques in addressing textile waste while considering functionality and durability.

Despite these advances, garments remain complex forms that require various shapes and measurements that must be joined together to create a functional whole post-loom. In contemporary fast fashion contexts, using flat, pre-made fabric in combination with cut-and-sew techniques has become a fast and efficient method of garment production, especially given the limitations posed by the rigid interlacing structure of warp and weft in weaving. This rigidity restricts the flexibility needed to form complex garments shapes directly on the loom, like the whole-garment knitting. To enable the creation of 3D garments, additional dimensionality, sectional and directional control are necessary. Rather than relying solely on a single set of horizontal (weft) and vertical (warp) threads, whole-garment weaving requires more structural strategies to form spatial, volumetric shapes during the weaving process.

Flat Textile-form design was introduced by Holly McQuillan to integrate understanding of existing pattern cutting methods and weaving techniques, to promote new opportunities for pattern cutting and the operation of the loom for pattern designing (McQuillan 2020). An initial step involved analysing and investigating the "space" that can be formed within the layers of weaving cloth; the existing garment is flattened and folded until it resembles a nearly rectangular shape. Since woven fabrics are usually made as flat lengths of cloth, designers must be able to transfer a 3D form (garment) into a 2D piece of cloth (McQuillan 2020). The Flat Textile-form showcases the transformation from 3D (existing garment) to 2D (folded rectangular form) to 2D (weaving multi-layer flat cloth), and cut-and-sew to create a 3D garment. Although individual pattern pieces could be woven out as a one-piece cloth, this method requires more manufacturing (cut-and-sew) steps than a standard production process. Nevertheless, McQuillan (2020) developed a stitch-less method through sliding and folding, in which the shape is woven into the fabric and released when it is cut; she believes that if the loom could weave more layers, it would be possible to omit more sewing lines. This would involve integrating existing 3D garments into 2D flat weaving forms, and utilising folding and unfolding among layers to reduce seam lines and construct new 3D garments. However, the technique presents some challenges for industry implementation. To transform flat woven textiles into 3D garments using this method, several strategic cutting lines are needed to release and manipulate layered sections of the fabric. These layers, created during weaving, can be folded or expanded to build form and volume. As a result, the fabric density (pick rate) may vary across the garment, depending on how these woven layers correspond to different pattern areas and how much manipulation is required.

The above examples demonstrate the difficulty of embedding one-piece weaving into fashion pattern-making. In conventional weaving, the fixed grid created by the warp and weft threads constrains how fabric can be shaped, as well as the length and width of the fabric produced. This rigid structure limits flexibility and tends to pre-determine both the garment pattern lay plan and the sequence in which the fabric is woven (weaving plan) (Piper 2019). Thus, cut-and-sew remains deeply engrained in contemporary fully fashioned weaving approaches when there is need to transform a 2D fabric to assemble into a 3D garment. The simultaneous design practice in zero-waste pattern cutting and fully fashioned weaving indicates a new possibility in reshaping apparel production. However, to efficiently minimise textile waste in both the weaving and post-weaving stage and reduce construction off-loom, the fundamental principle of fashion production needs to change to allow in-depth interaction among textile and fashion designers and knowledge domains. The Mobius Band seamless 3D whole garment weaving method, put forward by the research undertaken and articulated through this paper, aims to challenge the necessity of cut-and-sew in woven apparel production. By applying the Mobius Band's continuous 3D form as a design framework, this method enables thinking of the weft yarn as infinite and in continuous movement, or as motion trajectory, to shape the garment as it is woven. This offers greater opportunity for creating zero-waste, seamless garments directly on the loom, supporting a slower apparel production model.

The Mobius Band Pattern Design Thinking

Within this study, Mobius Band pattern design thinking refers to using the shape and properties of the Mobius Band as both design inspiration and a structural model for creating woven garments. Unlike conventional pattern-making, which starts with flat 2D shapes laid out on a surface, this approach encourages designers to think in 3D from the beginning. The continuous and seamless form of the Mobius Band offers a new way of designing garment that avoids cutting fabric into separate pieces, thereby reducing pre-consumer textile waste (Li et al. 2025). It helps reimagine the process of making garment as one that is more fluid, and which provides a pathway to reconstruct the rigid cut-and-sew process in woven apparel design and production.

Woven fabric in general is considered as a 2D, flat surface with two orientations (warp and weft). The pre-determined orientations of warp and weft on the loom have limited the exploration of 3D seamless whole-garment weaving with the table loom and the digital jacquard loom, as the 3D weaving of garments requires a multi-orientation yarn set-up. Unspun, an apparel brand, developed and utilised the world first 3D weaving technology- the Vega 3D weaving machine - to design and manufacture 3D woven pants. Individual tubes for leg pieces were created separately to meet the wearer's measurements, then assembled together to form the garment (Morison 2023). The tubular shape generated by the Vega 3D weaving machine allow yarns to cross, overlap and spiral up at angular directions, however, to date this 3D weaving technology is still within the scope of fully fashioned apparel. The efficiency of minimising pre-consumer woven textile waste by this technology is evident as the pants are composed by two tubular shapes. Further research and technology is needed for other types of garment, including garments with long sleeves or those that involve complex fashion pattern pieces.

By contrast, Mobius Band pattern design thinking allows an integration of 3D form with 2D weaving practice through utilising the one-dimensional edge of the Mobius structure. This edge supports a seamless weft motion trajectory that joins garment components into a unified whole. Figure 4 visually demonstrate this concept by illustrating how the weft yarn moves along the Mobius path, looping across the structure in a continuous, non-interrupted flow, to form a seamless garment shape directly on the loom. This contrasts with the conventional way of flat cloth formation. The non-orientable features of Mobius Band include its fluidity, mobility, and malleability compared to the two orientations of traditional weaving practice. Thus, seamless 3D whole-garment woven apparel can be generated without fundamentally changing the set-up of the jacquard loom, and therefore is an accessible and resource-saving method for designers and companies to apply on their own digital jacquard loom. To minimise pre-consumption woven textile waste, Mobius Band pattern

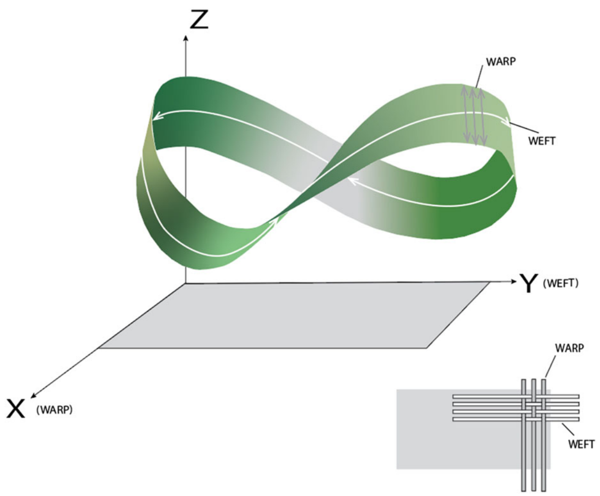


Figure 4
Mobius Band structure in relation to weaving, Zewei, 2024.

design thinking also develops an holistic method to combine fundamental textile and fashion knowledge and techniques. For example, this approach simultaneously considers weft insertion (the process of interlacing horizontal threads through vertical warp threads to form fabric), the 3D garment form, the weaving plan (a detailed guide that determines how the threads will interlace to create the fabric structure), and the apparel pattern (the template used to cut the fabric or form the garment pieces). This integration allows for a holistic design process that treats the cloth and the garment as one interconnected system.

Methodology

Action research is the approach used in this practice-led study to provide new possibilities for action outside of the designer's ingrained fashion design experience and viewpoint. By using "reflection in action and reflection on action" (Swann 2002:50), action research is a way for the designer to respond to challenges, ambiguities, or uncertain situations. Within this study, action research was applied to a design practice at the juncture of textile and fashion, as the practice was being developed. By reflecting and critically evaluating the practice experience, the designer was able to integrate a heightened knowledge of action, practice, and purpose (Reason and Bradbury 2001) to improve their understanding of weaving. The potential benefits of simultaneously thinking about design and practice include integration of textile weaving techniques, apparel pattern-making and construction.

This paper outlines the creative process undertaken, including descriptions on making and reflection in and on action, leading to a self-evaluation that serves as a foundation for further work. The following were aims and crucial aspects which directed the study:

- Minimising pre-consumption textile waste and wasteful manufacturing procedures
- Focusing on the garment shapes directly generated by weaving
- Focusing on creating spaces between various separated cloths without cutting lines
- Awareness of the continuous weft motion trajectory and individual warp lifting capacity to allow seamless whole-garment weaving
- Activation of "Mobius Band pattern design thinking" to ensure seamless integration of 3D fashion patterns with 2D flat loom weaving technique.

Overview of Work Undertaken

In this study, a simultaneous design approach began with the designer's established understanding of creating zero-waste apparel patterns combined with experimental weaving on an 8-shaft loom. Initial experimentation and textile sampling focused on understanding the behaviours of single, double and triple cloth structures. These foundational trials were conducted on a 8-shaft loom, which allows control over grouped warp threads through a limited number of shafts. Subsequent sampling was undertaken on a TC2 Jacquard loom, which enables precise, individual control of each warp thread. This greater level of control allows for more flexible control of warp lifting and weft insertion to create spatial shaping, making it particularly suited to developing seamless whole-garment woven forms. The first sample woven was a $^1/_4$ scale Mobius Band zero-waste pattern, which tested the process of converting a fashion pattern into woven cloth to enhance the designer's knowledge of textile production. Additional experimental sampling was then undertaken on an 8 shaft table loom to further investigate the behaviours of the warp and weft yarns, the rigid loom setup, and the weave structure in relation to cloth density.

This early stage weaving practice was carried out with the ultimate intention of minimising post-loom production processes while exploring fastenings, such as button, zips or ties, which are one of the key components of apparel construction, allowing garments to be worn, adjusted, and secured on the body. In considering apparel functionality, the capacity to use the space created between warp threads whilst weaving (i.e. the shed) was investigated from the standpoint of fashion pattern-making. This enabled adequate space to be built into the garment to ensure ease of bodily movement when wearing. Further to this, CLO3D, which generates pattern alterations on digital garments and fits these to specific avatars, was used to provide real-time visualisation of fashion pattern making and to reduce the textile waste in initial physical sampling. The resulting 3D simulation visually presents a Mobius Band coat on avatars, while the $^{1}/_{2}$ scale and full-sclae coat was crafted on TC2 to showcase the Mobius Band seamless whole-garment weaving method.

From Mobius Band Zero-Waste Pattern to Cloth - TC2 Loom Weaving

As a fashion designer and researcher it is necessary to approach textile design with new questions, such as how woven structures can accommodate garment shaping without cutting, and practices like integrating Mobius Band zero waste fashion patterns directly into the weaving process. These explorations work towards eradicating pre-consumer textile waste at the intersection of textiles and fashion.

During initial experimentation, the possibility of integrating the Mobius Band pattern in weaving was the primary focus. A Mobius Band zero-waste pattern to test out the process of converting a pattern to a woven cloth was used. The pattern was chosen by considering its complexity, including cutting lines of different lengths, directions, curves and straight, to provide a comprehensive picture of the pattern-converting process. The Mobius Band fashion pattern was re-edited in Adobe Illustrator (AI) to allow width (seam allowance) to the cutting lines. To prepare the file for jacquard weaving on the TC2 loom, the design was then imported into Adobe Photoshop (PS), where different weave structures and colours were applied to cutting lines (Figure 5). This required the creation of a weave structure library, a collection of pre-defined weave types (such as plain, twill, satin) coded as black-and-white patterns in PS. The purpose of this library was to assign distinct weave structures to specific zones within the pattern, allowing varied cloth behaviour and colour contrast without changing the warp yarns. To achieve this, the Mobius Band zero-waste fashion pattern was separated into multiple PS layers, with each layer representing a different weave structure. This layering enabled precise control over how the garment would behave in different areas once woven. Consequently, garment variations could be achieved through the variation of weave structures and weft yarns (colour and material), rather than relying on cutting and sewing to form complex shapes and forms.

The $^{1}/_{4}$ scale sample (Figure 6) was woven on the TC2 loom, within the limitations of the existing off-white 20/2 Ne mercerised cotton warp set-up, the warp width was 30 cm, threaded through a 120/10 reed (12 dent/cm), with 2 warp threads per dent theortically. This sample results in 45 ends (warp threads) per inch, which determines the fabric's density and texture. This $^{1}/_{4}$ scale toile, shown in Figure 6, demonstrates the potential of directly converting the Mobius Band zero-waste pattern into a single-cloth woven fabric. The sample was created without using a conventional garment lay plan, which helps to avoid pre-consumer textile waste generated by lay plan and cutting. Figure 6 illustrates how the woven cloth

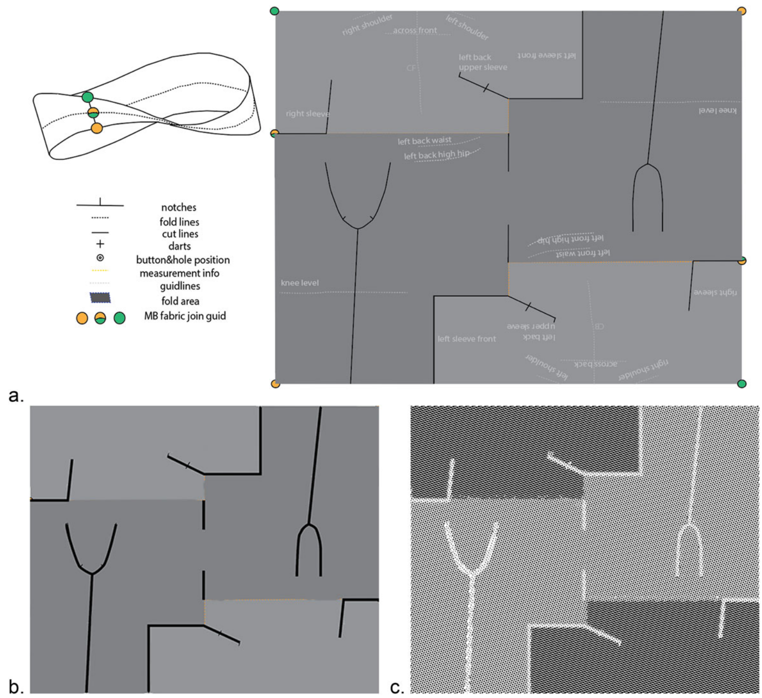


Figure 5

Development of Mobius Band zero-waste pattern for TC2 jacquard weaving: a. The original Mobius Band fashion pattern; b. Mobius Band pattern design with added seam allowances edited in adobe illustrator; c. Final weave file with weave structures assigned for TC2 output. Zewei, 2021.

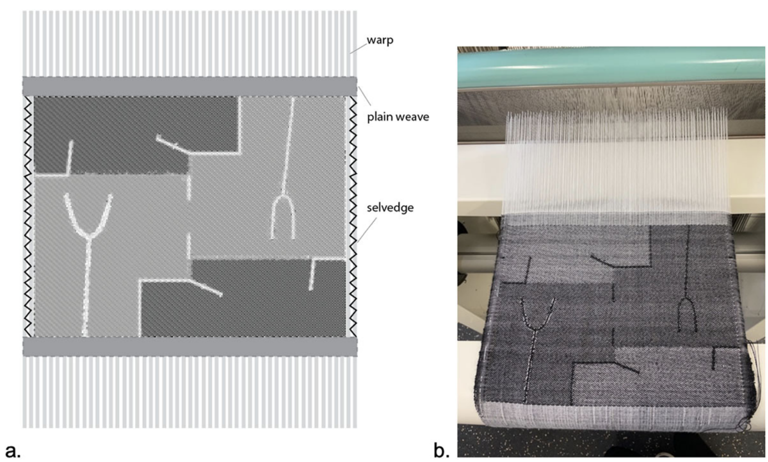


Figure 6

Mobius Band zero-waste pattern on TC2 loom: a. Extended weaving plan illustrating the relationship between the woven layout and the garment patten on loom including woven edges, selvedges and plain weave; b. Woven cloth sample showing the Mobius Band fashion pattern directly integrated into the fabric structure. Zewei, 2024.

incorporates the garment pattern directly on the loom, without requiring fabric to be cut into separate pieces.

The selvedge always exists at each edge of the woven fabric. In the mainstream lay plan and cut-and-sew process, the placement of patterns is always away from the selvedge of the fabric, which contributes to textile waste in pre-consumer woven apparel production. However, within this study, it was identified that the selvedge - the woven edge of the fabric - could function as part of the seam allowance during the post-loom construction of the Mobius Band structure. This allowed the fabric ends to be twisted and joined at the selvedge, forming a seamless loop that aligns with the Mobius Band concept and results in a clean garment finish. As shown in Figure 5, the green and yellow dots indicate the joining points of the cloth, where the selvedges are twisted and connected to realise the Mobius Band configuration. This method preserves the crucial features of the Mobius Band fashion pattern, enabling versatile modes of wearing while reducing the reliance on fashion designing with pre-existing fabric. Furthermore, several rows of the plain weave were integrated between sections to facilitate cutting the fabric from the loom. These "buffer zones" could be designed to a specific size for garment finishings and fastenings, such as hemming and binding, and integrated straps, directly within the woven pattern. In fashion, fastenings are devices or components used to secure two or more edges of garment together, allowing for easy opening and closing while serving both functional and aesthetic purpose. By integrating these elements into the weave, this approach reduces textile waste and minimises the need for additional cutting and sewing during garment assembly.

Reflections

Overall, this part of the study has shown that one-piece-cut zero waste patterns can be embedded in single cloth weaving practice. However, the shared boundary of cutting lines and predetermined warp set-up means limited ability to weave a graded pattern to fit various sizes. The fluidity of the Mobius Band fashion pattern enables a single continuous woven surface to support multiple garment shapes (Li et al. 2025). This quality allows for versatile modes of wearing without altering the woven structure. It helps to reactivate the predetermined woven fabric. The ability to simulate three dimensions and the range of avatars available in CLO3D enabled the woven garment sample, shown in Figure 6, to be tried on several avatars/wearers (Figure 7) to verify that it is suitable for a range of body types and sizes. Although the loom set up creates difficulty in weaving this Mobius Band pattern directly, the extra stitching to form the twist means the item can fit multiple wearers rather than one specific size, extending the garment's lifespan before it ends up in a landfill.

Figure 7
Mobius Band full-length dress CLO3D, same size dress on different avatars, Zewei 2022.

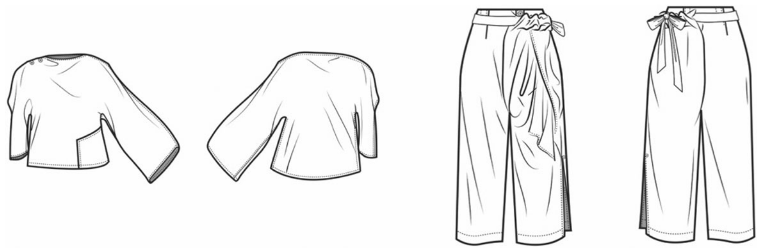


Figure 8
Reconstructing full-length dress to become a top and pants, Zewei, 2021.

To preserve the fabric and enable future transformation, the dress has been created (Figure 6) and visualised on different avatars (Figure 7) can be separated and reconstructed into a top and pants (Figure 8) after a period of wearing, by activating the additional cutting lines embedded during the weaving process. The Mobius Band twist is maintained in the pants, responding to shape and the body's movement around the hips and legs. The fashion pattern design, combined with integrated features such as button-up closures and adjustable straps around the shoulders, waist, and neck, enhances the garment's accessibility and versatility. In conventional garment construction processes, transforming one garment into another form with radical shape change is not possible. In contrast, the Mobius Band zero-waste fashion pattern was designed with minimal cutting lines to reduce the manufacturing sequence and help extend the textile's useful life. The additional cutting zones woven into the fabric act as visual and structural guides for transformation, and serve as a material reminder to the wearer of the garment's potential adaptability. While this method produces no textile waste in the initial weaving or later transformation phases, the act of cutting remains irreversible. Once cuts are made, sewing becomes necessary, reintroducing conventional garment construction techniques which restricts fabric and garment re-use. To fully address pre-consumer textile waste, a compete shift in design thinking and process is required.

Garments, especially those designed for everyday wear, are 3D forms that contain openings or "tunnels" through which different parts of the body pass, requiring specific shaping and spatial arrangement. In conventional construction, cut-and-sew processes

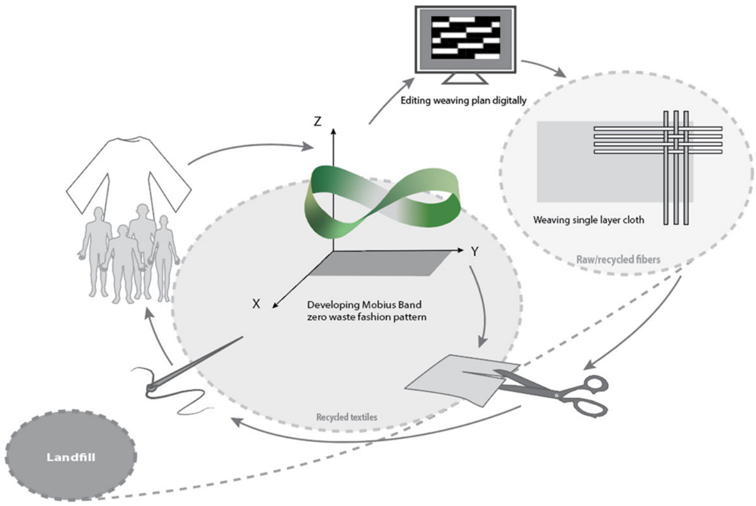


Figure 9
Mobius Band Zero-waste pattern weaving workflow – single layer. This figure presents the design and production workflow of a single-layer woven garment based on the Mobius band zero-waste pattern. It maps out each stage in the process: from initial pattern development, and pattern-to-weave translation, through to digital weaving preparation, weaving on the loom, post-weaving assembly, and the use by the wearer(s). The circular format of the diagram reflects the values of slow fashion, highlighting intentional design, material usage, and integrated systems thinking in both process and outcome. Zewei, 2024.

allow fashion designers and pattern makers to translate these complex 3D forms into flat 2D layouts. This involves reorienting the individual components onto a rectangular flat surface for woven cloth and then assembling them through seams to create the necessary openings. In contrast, this study aims to explore how whole-garment weaving can integrate the Mobius Band pattern into weaving practices to enable the shaping of fully fashioned garment directly on the loom. This approach emerges from an effort to bridge the technical and conceptual divide between textiles and fashion design and production as shown in Figure 9. While the Mobius Band's unique structure helps to reduce the reliance on cut-and-sew practices, it also reveals the need for a more "fundamental" shift: one that fully integrates pattern making and weaving to eliminate cutting altogether. Therefore, the next phase of this study focused on further experimentation with the Mobius Band's potential to produce 3D form directly through weaving, offering a zero-waste process and outcome from the origin of production.

From Shapes to Spaces - Table Loom Weaving

During the weaving process, warp sections are raised or lowered to create a gap, known as the shed, through which the weft yarn flows (Clarke 2011). Weft, in general, refers to the yarn that moves from one selvedge to another within a layer in a horizontal direction across

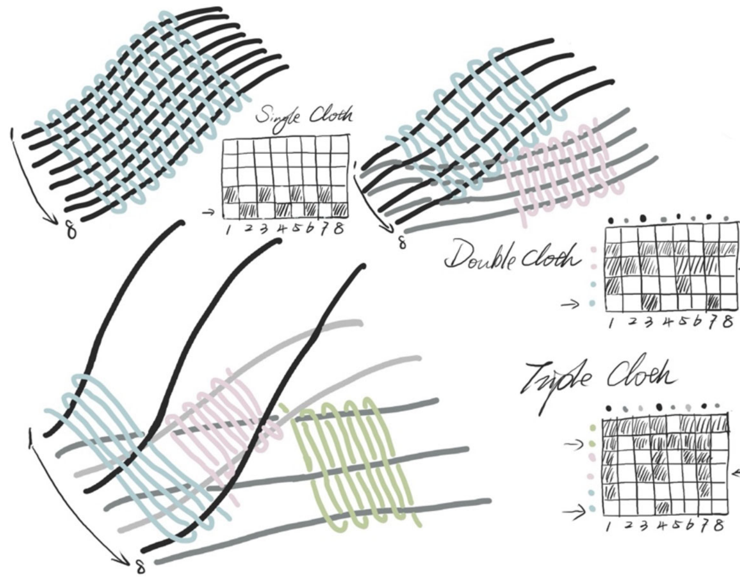


Figure 10
Lifting plans: single, double and triple cloths with weaving pattern, Zewei.

the warp width. This paper addresses the weft's motion from one to several layers, where it becomes a continuous thread that moves between cloth sections or layers to create whole-garment woven apparel. Weaving with the 8 shaft loom using a specific threading plan allows the creation of double and triple cloths that share the same warp length (Shenton 2014). In conventional double cloth weaving, as outlined by Shenton (2014), the standard approach involves weaving one pick at a time, alternating between the top and bottom layers. This approach maintains a clear separation between layers, prevents unintended interlacing and ensures even construction of the cloth. Based on the warp lifting plan and weft motion sequence, these layered cloths can come together at the edge to form a tubular shape (parallel to the warp) or completely separate, enabling weaving of the garment's individual components. When utilising more shuttles, a gap can be created that is parallel to the warp yarns.

Figure 10 illustrates the progression from single to multiple-layered weaving structures. To support this exploratory process, a two-pick sequence per layer was employed, involving a pick in one direction followed by a reverse pick back to the starting side. This was done first for the top layer, then repeated for the bottom layer, resulting in a pick-forward and pick-back for each layer before switching (Figure 10). This 2:2 sequence allowed for clearer separation and more control of each layer, especially during investigations into forming 3D elements such as pleats and tubes. Although this sequence may be considered unconventional in textile design, where a one pick per layer method is generally recommended for building cohesive cloth, it

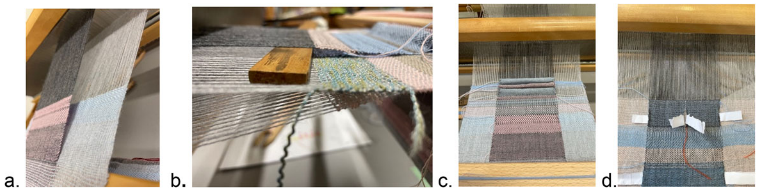


Figure 11
Double cloth techniques - weaving experimentations, Zewei, 2023.

provided a valuable foundation for this study to further explore the weaving techniques towards whole-garment construction further.

A 4-shaft loom allows the creation of double cloth (Shenton 2014), while an 8-shaft loom enabled the creation of triple and even quadruple cloths using a shared warp length (Figure 11a and b). By adjusting the weft motion and lifting plan, a rectangular patch pocket can be produced on the loom with a supplementary warp setup (Shenton 2014). This configuration allows different cloth layers to be woven in one warp set, which allows the designer to create tunnels or pleats that go against the warp direction (Figure 11c). Compared to the fixed warp set up, the weft offers greater flexibility: it can change directions, vary yarn type, and cross different warp sections based on the design decision. When weaving double or multi-layered cloth with the intention of forming voids, without relying on post-weaving cutting, the sequence of weft insertion and warp lifting must be carefully designed to avoid interlacing between layers at the cloth edges. As demonstrated in Figure 11d, the pink weft yarn was used to weave the bottom layer. Two blue weft shuttles, inserted manually from opposite sides and halted at the centre without interlocking, create a gap in the middle. This manual weft manipulation was necessary due to the constraints of the threading plan, which limited control via shaft lifting alone. Once the top layer was woven to rejoin the bottom layer, the result was two distinct tubular forms embedded within a single woven structure. This technical exploration of forming voids and tubes within the weave led to the next phase of this study, which investigates how weft motion trajectory can be harnessed to seamlessly form 3D woven structures.

Reflections

Zero waste pattern cutting methods can be employed like jigsaw puzzles or geometric shapes to avoid textile waste generated from cut-and-sew, and to calculate the individual cloths' size, which are rectangular shapes. Alternatively, by applying principles from zero waste fashion pattern cutting, a group of 3D components can be arranged within a wider warp width on the loom. Cutting will still be applied to separate the pieces. However, the rigid set up of the loom, warp and lifting plan predetermines the width of the cloth for a number of metres, which limits the size of individual and grouped 3D form cloth/components. More holistic and simultaneous methods are needed to integrate textile and fashion knowledges to provide a solution for pre-consumer textile waste issues. Thus, this study aims to create spaces between various separated cloths, without cutting lines, to form a completed 3D garment when weaving. The intention is to explore if Mobius Band pattern design thinking can serve to help mitigate the restrictions created by the rigid set up of the loom and ensure flexibility to organise the individual garment components within the predetermined space.

From Lines to Spaces - the Continuous Weft Motion Trajectory Experiment

The capability to weave separate layers allows garment shapes to be composed or folded to a flat form, allowing for weaving within the predetermined loom setup. However, without cut-and-sew, these forms remain 2D compound structures. The transformation into a 3D garment still depends on post-weaving manipulation, which can lead to textile waste. This challenge has been identified through the practical investigations presented earlier in this study, highlighting the need for more integrated 3D weaving methods. Additionally, garments come in various types, shapes and measurements, and existing innovative fully-fashioned weaving methods using a jacquard loom often relying on folding or composing individual components and features (such as pleats, darts, trims or fastenings) of a 3D garment. This has impeded industry and individual adoption of fully-fashioned weaving techniques, and has significantly limited potential for developing a standard procedure to use within future revisions. Thus, the goal of this study is to provide a method that will facilitate further advancements from the 3D block by offering a repeatable design and production process.

Within this study an intentional focus was the behaviours of individual yarns, or "lines," when pursuing the formation of a seamless 3D woven whole-garment on a loom and to form a 3D garment from 1D lines (yarn). The weft motion trajectory experiment (Figure 12a) began by manipulating a continuous weft yarn within a single cloth to add functional design elements. Specifically, loops were woven at the edge of the cloth to form button loops, part of the fastening system that allows garment openings for dressing and can be secured with

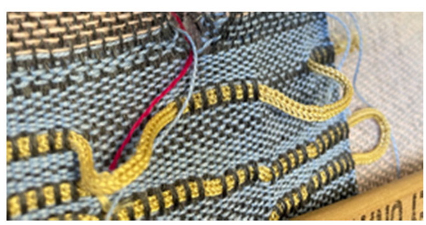
a.  b. 

Figure 12
Weft motion trajectory and 3D seamless form experimentations, Zewei, 2023.

Figure 13
A sleeve form: experimentation with variations in lifting and weft motion trajectory. This figure documents the conceptual progression of 3D shaping achieved through coordinated weft motion and warp lifting sequences. It integrates several techniques explored earlier in this study, such as double cloth, pleats, tubular weaving, and intentional gaps, into a single seamless woven sleeve toile. Together, these elements demonstrate how complex garment features can be formed directly on the loom, Zewei, 2023.

buttons. Although, in early-stage experimentation the weft yarn motion trajectory still moved within a single cloth, this continuous yarn can create loops vertically or horizontally, alongside or against the warp yarns (Figure 12b). This indicates the potential to use the weft yarn's motion trajectory to create 3D form on the loom.

The flexibility of the weft motion was further utilised and developed among multiple layers to successfully form pleats seamlessly on the loom; this practice can be considered a pathway to shape a garment as it often contains spaces (Figure 13). The separated tunnels can be formed with additional weft yarns to allow structures like sleeves or legs. By altering the direction of individual weft shuttles and with the indication of the reverse point, a gap can be created without cutting. When weaving a garment, the sleeve component can be created directly by utilising the elements mentioned above. This requires careful consideration of the warp lifting plan and sequencing, as well as recognition of fundamental fashion pattern making knowledge. The continuous weft motion trajectory demonstrates potential to form sectional 3D forms/garments on the loom without cut-and-sew involvement.

Reflections

In this study, a yarn can be considered as one-dimension, a cloth as two-dimensions, and a garment as three-dimensions. The transformations among 2D-3D are always the essential focus for existing innovative methods, however, this Mobius band design research envisions connecting dimensions seamlessly. Aiming to weave a seamless 3D whole-garment means the weft motion trajectory must be continual until it covers the body and crosses the entire garment. Mobius Band's non-orientable surface and single edge features (Figure 14) symbolise an infinite, uninterrupted path. This quality suggests the potential for continuous transformation and flexibility in garment form, challenging conventional notions of fixed orientation and structure in both fashion pattern making and loom weaving.

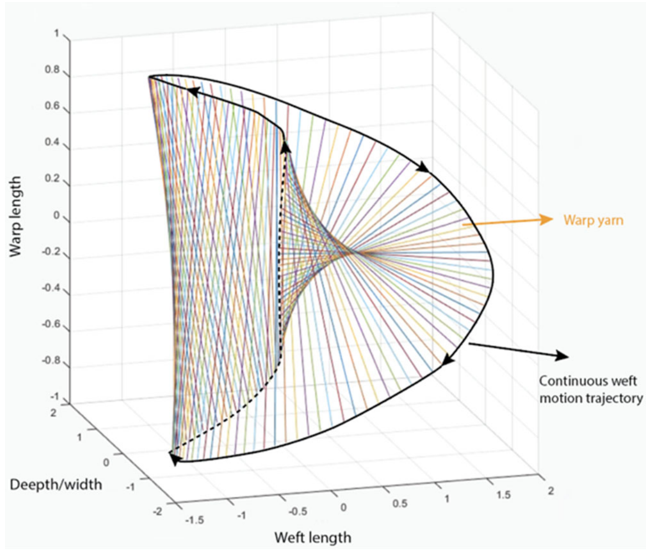


Figure 14
The mobius Band design thinking in relation to 3D weaving, matlab, (the colourful lines indicate the warp yarns in a form of mobius Band, and the black lines indicated the continues weft motion trajectory when forming a 3D structure), Zewei, 2024.

The Full Length Sleeve Coat Block

A full-length sleeve coat was developed to test the possibility of weaving a whole-garment with continuous weft motion trajectory among layers, by adjusting the lifting sequences to utilise the shed to create spaces for garment wearing. With embodied knowledge of fashion pattern making, the researcher aimed to develop a coat pattern that involved zero textile waste and could serve as a block for further design adaption (the block usually permits new designs with minimal need for pattern adjustments and alterations). Innovative zero-waste pattern cutting methods have limited adoption by industry, possibly due to their inconsistent processes and opportunistic results that are difficult to replicate in production. The coat block in this study was developed with the intention to allow designers and pattern makers to read and utilise it, as the pattern shapes are still similar to basic pattern blocks, for example the sleeve and pleat shape (Figure 15).

Toiling in Parallel Thinking

The block in conventional fashion production is the basic form often created for the specific garment style (drafted to a specific set of body measurements and body shapes). The threading plan in textile production determines the width, length and potential weaving pattern for a cloth. Often each threading plan may only allow one size of cloth to be woven across the entire warp length and it is rarely changed in industry as it is considered time-consuming. Thus, the coat block was developed by considering both textile and fashion

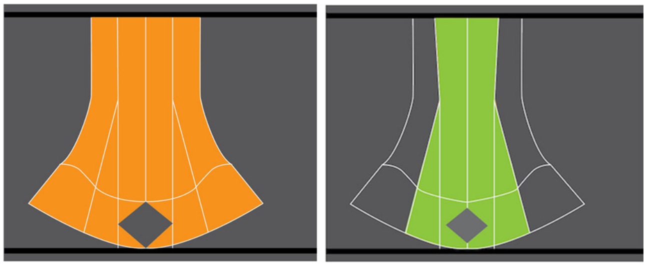


Figure 15
Adobe Illustrator Drawings of initial sleeve block for a coat, part of the development process. (grey layer- garment base; orange layer- full sleeve pattern, can refer to cut one single in pattern making; green layer-transformed version, two overlapped layers, can refer to cut one pair in pattern making), Zewei, 2023.

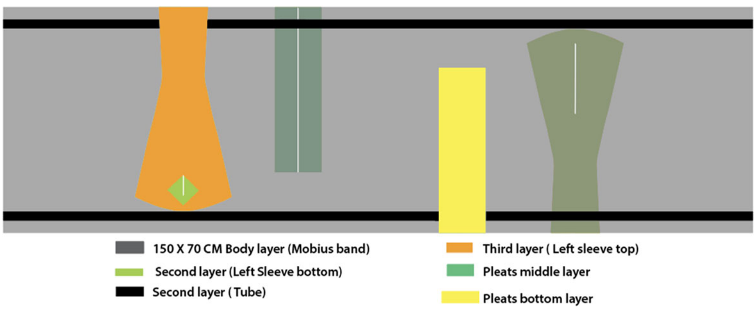


Figure 16
Initial development of the Mobius Band coat block in Adobe Illustrator. This figure shows the drafted fashion pattern, Zewei, 2023.

aspects to allow designers to develop 3D whole-garment woven apparel without cut-and-sew. The aim is to produce no waste but also to pursue an alternative way to create apparel.

The size of the coat block was developed by considering the pre-determined TC2 warp set up (off-white mercerised cotton warp, the width 75 cm, the reed is 120/10, 2 ends per dent, 24 ends per cm, 3 × 2/20Nm twisted in Z twist) to minimise the textile waste in testing the method. Therefore, a half-scale coat was developed to consider the cloth width, garment circumference, the direction of the sleeve tunnels to parallel the warp and the zero-waste fashion pattern lay out (Figure 16). When weaving, yarns were interlaced with the continuous weft motion trajectory to connect individual shapes seamlessly and to test the possibility of creating a 3D whole-garment directly within the loom space. If the coat block is operating correctly, this TC2 loom's full warp width will enable a cloth width of 150 cm, allowing for the creation of a full-size coat and further variations as needed.

Coat Block Development

In the initial development process, paper models and Adobe Illustrator were used when designing the coat block in relation to the

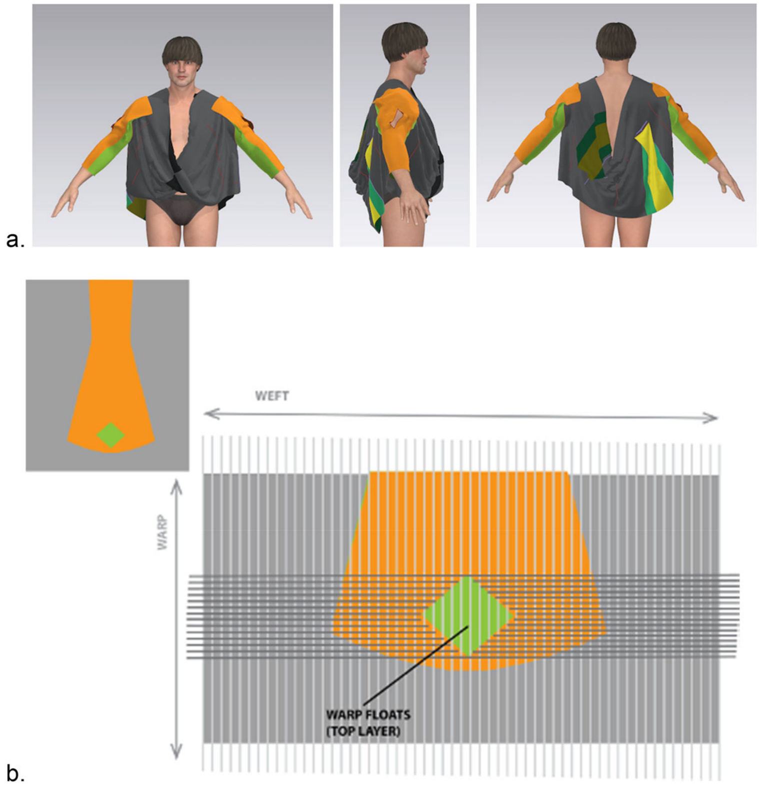


Figure 17
Coat block in CLO3D, a. the front, side and back of the garment. b. details of the rectangular shape section in relation to weaving. Zewei, 2023.

allocated patterns to weave layers accordingly. The feasibility of this method and functionality of the block in both pattern-making and weaving practice was always a key focus. The sleeve section was generated on top of a conventional sleeve block and split into two parts, which were overlapped to align with the edge of the Mobius Band fashion pattern (Figure 17). This ensures that the tunnel is clear when weaving and allows the sleeve to be separated from the body part. Conventionally, the sleeve piece is cut out separately, with the side seam sewn together to form a tubular shape, allowing arm access and movement. It is then attached to the armhole of the torso part to form a garment. In this study, the continuous weft motion trajectory replaces the cut-and-sew method to create a seamless 3D woven garment without textile waste.

The rectangular shape in the initial coat block (Figure 17b) was created not only to increase design complexity but also also to explore the functional impact on the weft motion trajectory during the whole-garment weaving process. Two shuttles can be used to start from opposite sides and reverse at the edge of the rectangular shape, creating warp floats within the shape - offering potential zones

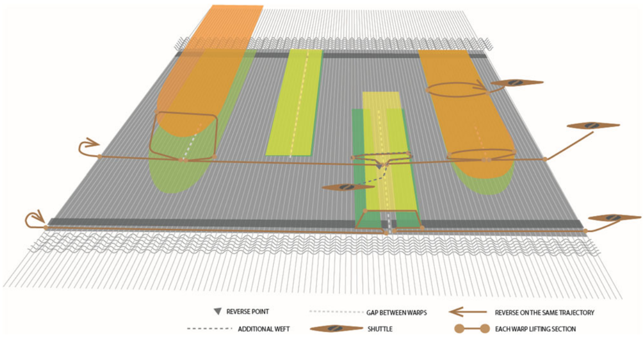


Figure 18

The weft motion trajectory mapping within the Mobius Band pattern. This figure illustrates how the weft motion trajectory is mapped and adjusted in response to the shaping of the different garment section. Depending on the desired form, the trajectory is manipulated to either close or open an area within the cloth, enabling spatial transitions essential to the Mobius band whole-garment construction. Zewei, 2023.

a. b. c. d.

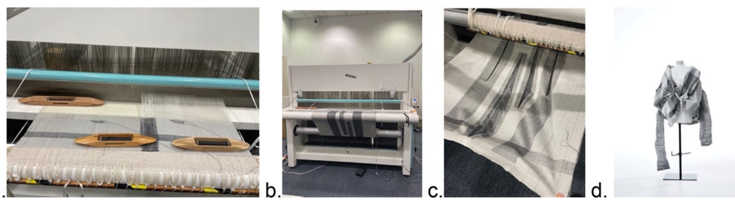


Figure 19

3D whole-garment woven coat on TC2 loom. a. Photograph capturing the weaving process: a section of warp is being lifted with two shuttles used for weaving the sleeve and one shuttle for the main body of the garment. b. The mobius Band whole-garment is shown complete on the loom. c. Upon release of warp tension from the loom, the 3D form emerges directly, revealing the spatial structure of the garment. d. The half-scale coat sample with sleeve variations to meet wearer's preference and Zewei, 2023.

of flexibility, breathability, or articulation in the garment (e.g. for movement around joints or ventilation). While this may potentially create interesting textile features, this study prioritised testing and developing a Mobius Band seamless 3D whole-garment coat block to allow further adoption. Additionally, current pattern-making software like CLO3D limits visually showing this feature as it developed to serve the conventional apparel production model to design 2D fashion patterns and fabrics. As a result, it does not fully support or visualise continuous weaving concepts, particularly those involving embedded textured features in weaving. Further technology development may be needed to fill this gap to allow digital textile and fashion integrated practice.

When utilising the Mobius Band seamless 3D whole-garment weaving method, the specific warp yarn must be assigned to a particular layer to aid the formation of the tunnel segment and allow the

Figure 20
Full scale coat- Mobius Band seamless 3D whole-garment coat. a. The front and side views of the coat in the form of the Mobius Band. b. Alternative ways of wearing the same coat, including inside-out and upside-down orentations. Photo credit: Tianyi Wang.

continuous weft yarn to move between layers seamlessly (Figure 18). For instance, in the sleeve part, one-third of the warp yarn is contained in each of the three layers: the body, sleeve bottom, and sleeve top (Figure 18). A change in shape could result in the warp yarn being used incorrectly between layers, which could induce warp interlacing and lead to problems including tunnel closure and unsuccessful 3D form creation.

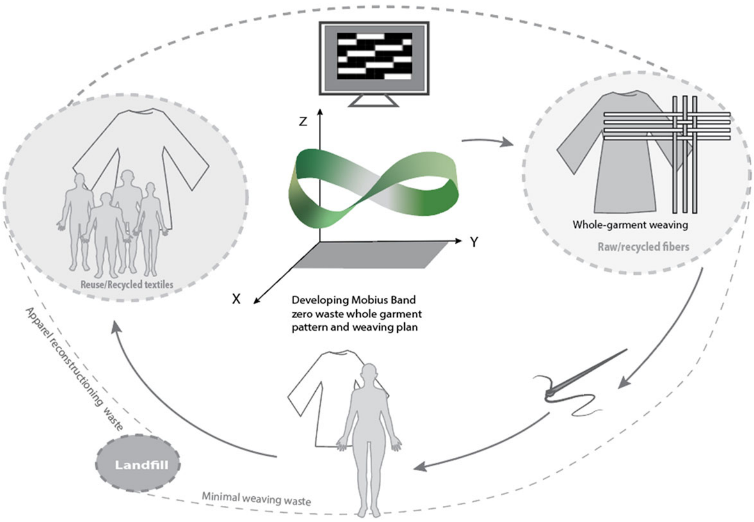


Figure 21
Mobius Band Whole-garment weaving workflow- (envisioning a future in which customised, whole-garment woven apparel may be reused or reconstructed to create new apparel after a certain amount of use), Zewei, 2024.

Weaving While Assembling the Garment on the TC2 Loom

The half-scale coat developed as part of this study demonstrated the potential of utilising the Mobius Band's continuous weft motion to weave a whole-garment on a loom seamlessly by enabling uninterrupted transitions between different garment components, such as sleeves, main body, and openings, without cut-and-sew processes (Figure 19a). When the cloth is tensioned it appears flattened (Figure 19b) but the weaving process facilitates its transformation from 1D to 2D and 1D to 3D simultaneously; as soon as the cloth is cut off from the loom the 3D form appears (Figure 19c). A minimal stitching line may be needed around the garment's hem to give a neat finish. Alternatively, joining the selvedge together to form a Mobius Band structure (Figure 19d) allows the coat to be worn inside out.

The plain weave structure was used in this study as the main objective to test the possibility of forming a 3D whole-garment on a loom. Further research is required to explore different weave structures that may result in different textures, cloth densities and surfaces. Additionally, the weaving process still allows the wearer to adjust the shape of the finished garment as they prefer, due to the way the weaver beats the weft and throws the shuttles. Figure 20 demonstrates the full-scale garment developed from the earlier half-scale coat, while the fashion pattern and weaving plan stay the same. Scaling the prototype to full size was essential to test the garment's wearability, structural behaviour, and the viability of applying the Mobius Band weaving concept beyond experimental scale. Overall, this study demonstrates the Mobius Band whole-garment woven method's potential to eliminate textile waste in production and its applicability to slow and small-scale industries. Further research is needed to explore the use of various yarn types and weights for complex form generation on the same 3D weaving block, facilitating on-demand design and localised production.

Insights and Conclusions

In this study, a simultaneous design approach is utilised to ensure a more balanced and comprehensive development of the Mobius Band 3D whole-garment weaving method. However, the distinction between textile and fashion knowledges and terminologies are inevitable as these have a long history in design, communication and production. Further integration and redefinition of terminologies is needed to bring these two disciplines together and move towards holistic sustainable design. When envisioning the future of this method, the study considered that the beauty of these hand-woven garments might encourage long-term consumer care. In comparison to contemporary fast fashion production, the value of hand-woven garments becomes especially significant, embodying time, care, and craftsmanship that contrast sharply with the speed and disposability of mass-produced garments. While, it suggests potential for emotional durability and extended use, the primary aim of this study was to test and demonstrate the viability of the method. The coat's seamless construction, spatial adaptability, and integration of zero-waste principles show how pattern-making and weaving can be more deeply aligned. Though further refinement and testing are needed, especially in an industrial context, this study highlights the foundational success of the Mobius Band whole-garment weaving method. Further research could explore the adaptation of this approach across other loom technologies and garment types to expand its applicability and impact.

The Mobius Band design thinking play's a significant role elaborating the rigid thinking that woven apparel must be formed using a 2D-3D or 3D-2D-3D approach. With the combination of conventional and zero-waste pattern making knowledge, fundamental weaving knowledge in combination with a jacquard loom allows woven apparel to be formed from 1D-3D directly. This paper addresses the potential of utilising the weft motion trajectory to weave a 3D whole-garment without the involvement of the conventional cut-and-sew process, therefore eliminating textile waste in production. Figure 21 illustrates the progressive stages of this method, envisioning a future in which a woven garment is designed according to the specific needs of the wearer(customised) and woven locally. With the Mobius band pattern's capacity for transformation, the garment can later be reconstructed into new forms after a period of wear, or its adaptable sizing features can accommodate the needs of different wearer(s), thereby extending the garment's lifecycle.

This study is situated at the intersection of textiles and fashion. The explanations of the experimental process aim to allow fashion designers and pattern makers to understand the weaving process from the fashion perspective, to address the gap in knowledge and allow further adoption and development of 3D weaving blocks/patterns without cut-and-sew. The 3D coat block is also developed for the weaver to utilise for further texture development, such as changing yarn type and colour as well as weave structures for aesthetic and functional needs. Further research is needed to develop different types of blocks for various garment styles and to test their suitability for industrial operations. Creating woven apparel from 1D to 3D challenges conventional design thinking and knowledge. This approach offers an opportunity to develop a zero-waste slow woven apparel production model that can reform the industry with the support of internal technical advancements.

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