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Exploring Low-Waste Patternmaking Techniques for Sustainable Solutions in Fashion Industry

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ABSTRACT In the realm of sustainable fashion, designers are actively exploring innovative strategies to reshape their design processes. This study aims to unveil foundational sustainability principles integrated into sustainable fashion praxis using design thinking methodologies. The focus is on practical low-waste patternmaking as a testing ground to assess these principles feasibility. The research methodology employs a qualitative framework grounded in pragmatism, allowing for a deep engagement in an exploratory data collection process led by a researcher-practitioner in the field of fashion design. While the primary focus is on the core fashion design process, the goal is to align sustainability strategies with key stages in conventional design and production. By aligning the fundamental fashion design process with responsible consumption and production, the study advocates for the adoption of innovative methods that deviates from traditional practices. The studys findings presented comparative insights between conventional approaches and modern sustainable practices. Further exploration of digital advancements in pattern design can streamline sustainability implementation. In conclusion, this challenging yet rewarding study emphasized practical problem-solving strategies in a fashion that is distinct from technical and creative knowledge applications.

INDEX TERMS clothing construction, design thinking, low-waste pattern, sustainable fashion, sustainability integration

I. INTRODUCTION

The recent growing trend towards increased fashion has embraced eco-friendly fibres and sustainable textile solutions, which necessitates a broader consideration of sustainable practices within the fashion design process [1]. While efforts have focused on sustainability concepts like waste reduction, upcycling, and fibre recycling, theres an opportunity to rethink about the clothing construction methods [2]. Traditionally, sustainability has often been an afterthought in fashion design, with little examination of its

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integration into the core design process [3]. This study seeks to address this gap by exploring the application of a first principal design approach rooted in sustainability theory within the fashion design and production process, focusing on the research and analysis and synthesis phases [1].

Fashion design and production follow a systematic sequence of activities and phases that is common across various sectors of the industry [4]. This process comprises five distinct phases: research and analysis, synthesis, selection, manufacturing, and distribution [5]. Each phase involves specific tasks assigned to different individuals or departments, with the designers influence varying according to the companys size [6]. Generally, designers are most actively engaged in the research and analysis, and synthesis phases, offering an opportunity for sustainable interventions [1].

The conventional fashion design process contributes significantly to the industrys wasteful nature, particularly in the cutting phase, where only 85% of the textile is utilized, leaving 15% as waste [7]. This inefficiency arises from the inherent characteristics of pattern pieces, which typically follow a design sketched beforehand [8]. The shape of these pieces is predetermined by the design, leading to fabric waste during the cutting process [9]. Zero-Waste Design (ZWD) addresses this issue by ensuring no fabric is wasted through interlocking patterns, creatively using leftover textile for embellishments or bias binding [10].

To combat this waste, designers need to reorient their thinking processes, particularly in the research analysis, and synthesis phases, where they are most engaged [1]. This study advocates for the adoption of a first principle design approach rooted in sustainability theories, drawing from concepts like designing from first principles, acquiring knowledge in design, and design reasoning and abduction [11]–[13]. Zero-waste pattern-making is employed as a method to evaluate this approach [1].

Sustainable opportunities lie in reevaluating the design process itself, exploring alternative design and production methods, and challenging conventional practices [14]. The fashion design process, encompassing the research and analysis, synthesis, selection, manufacturing, and distribution phases, is often characterized by a standard set of activities [5]. The designer typically functions as a concept developer within the research and analysis phase, defining the brief, while their involvement decreases in the synthesis

phase, with pattern cutters and sample machinists taking a more prominent role [5].

However, this study underscores the importance of designers considering sustainability from the outset, aligning sustainable strategies with intervention points within the design and production process [2]. Sustainable first principles can guide this process, emphasizing the need to establish design requirements, such as desired functions, as a starting point for design concepts [3]. These principles should be crafted to determine where sustainable strategies can be seamlessly incorporated across the environment, society, and the economy at the start of the design process [2].

The concept of parallel lines of thought, as suggested by Lawson, can be applied during the initial design and synthesis phase when sustainable strategies should already be considered [4]. Timo Rissanens work highlighted the segregation of the patternmaking and design process within the first two phases of the design and production process, offering an intervention point for change [2]. Zero-waste pattern making, as developed by Rissanen, emphasizes considering fabric waste during the initial design and synthesis phase, encouraging designers to develop the design and pattern concurrently [5].

In summary, fashions shift towards sustainability demands a holistic revaluation of the design process. Designers must proactively incorporate sustainable strategies from the outset, particularly in the research and analysis, and synthesis phases. By adopting a first principal design approach and embracing zero-waste pattern-making, the fashion industry can reduce its wasteful practices and align more closely with the sustainable principles. This shift involves a fundamental change in mindset, fostering a culture of creativity, mindfulness, and sustainability throughout the entire design and production process.

A. AIMS AND OBJECTIVES

The objectives of the current study are as follows:

- Synthesize a set of first principles, underpinned by a sustainable theory into a new fashion design approach that aligns with sustainable fashion design praxis.

- To investigate and explore various design thinking approaches to motivate the adoption of a first principal approach within sustainable fashion design praxis.
- Trial and evaluate this proposed first s principal approach through the process of zero-waste pattern-making, using thought around data gathering and reflection cycles.

II. RESEARCH DESIGN AND METHODOLOGY

The purpose of this study was to synthesize a first principle approach that is underpinned by sustainability theory. The first principal approach would be positioned within sustainable fashion design praxis, through design thinking, with zero-waste pattern-making acting as a trailing and evaluation method for the approach applied within the scope of the study. The design thinking approaches and theories presented solutions to re-evaluate the current fashion design and production process and promote the integration of sustainable strategies.

A. RESEARCH APPROACH

The study followed a pragmatist research paradigm, with a qualitative research approach guiding the study. Qualitative research is employed when the purpose of the research is to construct a meaningful view of a complex and multifaceted problem [6]. The study investigated the complexity of sustainability within fashion design praxis by employing this approach. The study aimed to explore and understand the adoption of a first principal approach within sustainable fashion design praxis through the trailing and evaluating of zero-waste pattern making.

B. RESEARCH DESIGN

The study adopted the transition design approach to contextualize the design into a holistic research design [1]. Transition design is an approach that borrows from various other design approaches. Multiple skill sets are required by transition design, the ability to integrate complex systems, such as the natural and social systems with sensitivity; to consider a solution that looks at short, medium, and long-term solutions; the ability to identify transition in everyday life; and to design for a particular group's needs within a specific context [1]. Transition design considers that we live in transitional times and works on the premise that design is vital for societal

transitioning towards sustainable futures [1]. Within this research design, various methodologies are explored.

III. METHODOLOGY

According to Creswell, "Qualitative research is an approach for exploring and understanding the meaning that individuals or groups ascribe to a social or human problem" [8]. The research process looks at emerging questions and procedures with the researcher interpreting the meaning of the data collected [8]. The study's focus was on synthesizing and evaluating a first principle design approach for the praxis of sustainable fashion design. Design-led research within a qualitative paradigm is defined by process rather than outputs, although it does not form the studys main outcome [9]. This study had a process of development where a prototype was produced. The epistemological value was in exploring, developing, and positioning a first principal approach that would engage zero-waste pattern-making.

A. PRACTICE-LED RESEARCH & PRACTICE-BASED RESEARCH

Within practice-led research, it has become a pressing concern to develop sustainable strategies through design [10]. Irwin states that wicked problems are problems that are "systems problems" that require new problem-solving approaches as they exist within large social systems. Therefore, a design-led approach is required to confront these complex, wicked problems we face in the 21st century [10]. This study used a practice-led research approach or, rather as coined by Irwin, a design-led approach where the research "primarily leads to the new understanding of the design practice itself" [11]. Within practice-based research, new knowledge is gained through both the practice and the outcome of the design process in an artifact [9]. The design outcome artefact must be contextualized through a substantial text component [9]. The process in which the practitioner-researcher generates knowledge is often unique to the practitioner-researchers internal understanding of the process. However, this tacit understanding would need to be externalized to be understood by others [14]. This individualized nature of the practitioner's knowledge is made evident to others through practice-based research [14]. Within this study, the artifacts were created to aid in the reflection process of the study. Therefore, new knowledge creation lies solely in the process, with the prototype aiding in the reflection of the process.

B. DATA COLLECTION METHOD

The first method of data gathering was to document the investigative process of zero-waste pattern-making. Munro states that a suitable manner of data gathering would be to keep a narrative record of the thoughts and actions involved due to the emergent nature of the design process [4]. The study used the think-aloud method during the pattern development process which consists of speaking aloud the thoughts in one's head as one completes a task [5]. Reflection entries were created after each cycle of pattern-making as a process of reflection. The data collection method involved triangulation to ensure credibility within the study

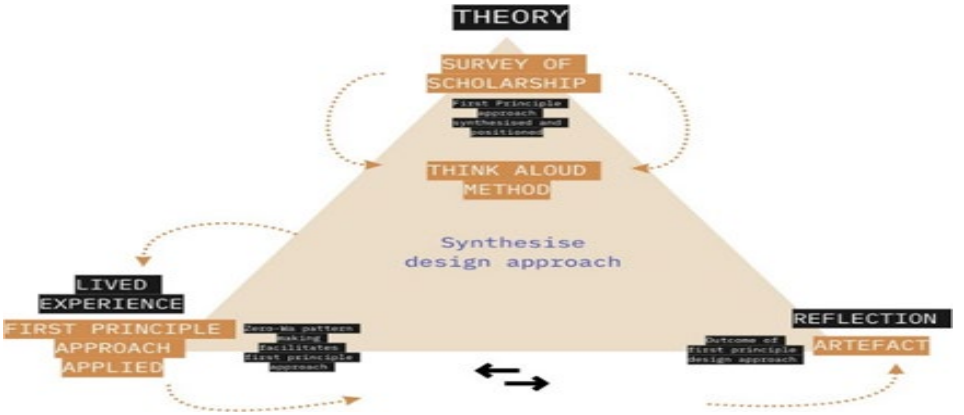

FIGURE 1. Triangulation method deployed in the study (developed by the author).

Triangulation will consist of a focus on theory, lived experience, and reflection to assess the newly synthesized first principle process outputs. The data analysis will be completed through pattern matching which can be helpful on many levels because it aims to externalize both implied mental models and assumptions [15]. According to Sinkovics [15], pattern matching involves comparing the "predicted theoretical pattern" with that of the "observed empirical pattern," which aligns with the aim of the study, synthesizing a first principle approach from a theoretical framework and comparing this with an observed evaluation and trailing of the first principle approach.

Within the triangulation process, the survey of scholarship set out, to investigate sustainability theory to synthesize a first principal approach. This design thinking approach was investigated to position the first

principle approach within sustainable fashion design praxis. The synthesized first principal approach was trailed and evaluated using zero-waste pattern-making as an evaluation method. The artifacts that stemmed from zero-waste pattern-making aided in the reflection process.

C. DATA ANALYSIS

Within the study, the data method was pattern matching to analyze the findings that stemmed from the process of trailing and evaluating the first principal approach through zero-waste pattern-making. Pattern matching aims to externally present findings and assumptions that result from implicit mental modes clearly [15]. This assists the readers in engaging with the body of qualitative work to understand the researchers thought process and why and how they arrived at the findings presented. Most important pattern matching involves a comparison between "predicted theoretical pattern" with "observed empirical pattern" [15]. Therefore, a theory-based pattern is compared to an observed and experienced pattern. This is based on the premise that humans understand the world around them by comparing what they have observed to their internal framework [15].

Pattern matching involves linking a predicted pattern based on theory to a pattern observed, as theories propose predictions but do not equal patterns. According to Sinkovics, the focus is on two realms, the theoretical and observational. Three broad categories exist: pattern matching, full pattern matching, flexible pattern matching, and partial pattern matching. The data analysis employed within the study was within flexible pattern matching. Flexible pattern matching is employed in exploratory research design [15]. This manner of pattern matching provides more flexible techniques when aligning the theoretical realm with the observed realm. Within this category of pattern matching, the focus is on patterns that emerge from the data collection. These patterns are positioned in exploration and theory building.

The data analysis approach of flexible pattern matching employed within the study was used to address the aim of the study. The theoretical realm was informed by sustainable theory and design thinking approaches presented. This theoretical framework proposed the concepts and ideas that informed the first principle approach within the sustainable fashion praxis. The methodologies and application informed the observational realm within the pattern matching of the data collection methods. A case study was not employed, but the practice-led approach involved participant observation.

The data analysis involves the categorization of themes that emerged from the data that could be compared to the proposed theoretical framework.

IV. FINDINGS AND DISCUSSION

Each of the investigative cycles aligns with the following discussion outline, aimed at establishing the development of applying the first principle approach and outlining the cognitive thinking that pertains to each cycle. The following section discusses each cycle before summarizing the conclusion findings from the pattern design and development process.

Within each cyclical iteration of the practitioner-researcher, a set of design boundaries assisted in the pattern development process. These boundaries become the parameters in which the pattern development unfolded. Following the established design boundaries, the approach to the design process and the challenges and cognitive problem-solving that emerged from the reflection process are presented.

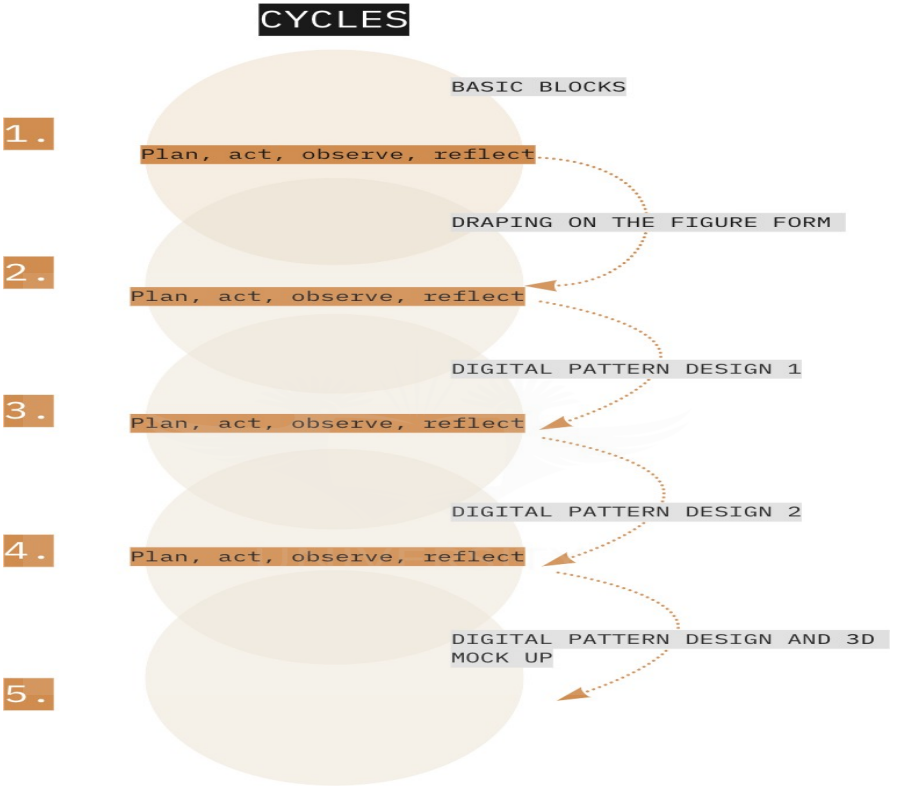

FIGURE 2. Cyclical process applied (developed by the author)

The first attempt at developing zero-waste patterns was the approach familiarly, using elements from traditional pattern making, the foundation block. The process of zero-waste pattern development was a new and unfamiliar process for me as a practitioner-researcher, and therefore, the elements of traditional pattern development were incorporated to assist in the first cyclical iteration. Referring to Figure 2, this section refers to Cycle 1: basic blocks.

A. DESIGN BOUNDARIES

The first approach to the pattern-making process design and development process was to work with half-scale pattern blocks. I selected the bodice block to start with to indicate the key landmarks, such as the neck, waist, and bust point that would assist in the pattern development process [16]. The pattern blocks were the only component taken from the traditional pattern process. No blueprint was developed to guide the design, such as a technical drawing or stylized sketch. The blocks boundary that of a bodice was the only guiding element [16].

The fabric width was another factor that influenced the process, as the zero-waste pattern needs to be developed with the result of zero fabric wastage. During the design process, the full-scale fabric was adjusted to half-scale measurements to suit the half-scale pattern blocks selected as a starting point [16].

Within traditional pattern making, a working pattern is created containing all the necessary manipulations to achieve the desired design outcome, after which finished patterns are traced to include the seam allowance and separate the individual pattern parts. These finished pattern pieces are then transferred to fabric, cut out, and the garment is constructed. During the zero-waste pattern-making process, the garment design results in a "jigsaw puzzle," whereby the pattern pieces fit into one another, resulting in zero fabric waste. Therefore, this approach requires that the seam allowance be accounted for during the initial pattern development when mapping out the design of the working pattern. This is evident in my investigation findings, as adding the seam allowance after development resulted in the blocks "expanding" and hence not fitting together seamlessly [16].

B. APPROACH TO THE DESIGN PROCESS

The initial approach in design started with the fabric boundary being translated into the width of the pattern paper to ensure that the pieces would

interlock as necessary. The pattern process involved some aspects of traditional pattern making, tracing the blocks, and starting the pattern manipulation from a set of identifiable landmarks, such as the neck, shoulder, and waist [16]. The pattern developed through problem-solving the design, as the design outcome was determined during the pattern development process. The initial placement of the blocks on the pattern paper needed to be considered and could not be placed randomly to ensure that the pattern development space was utilized optimally. The process indicated that the front and back design would need to be developed simultaneously to consider all the pattern development space utilized for the design [16].

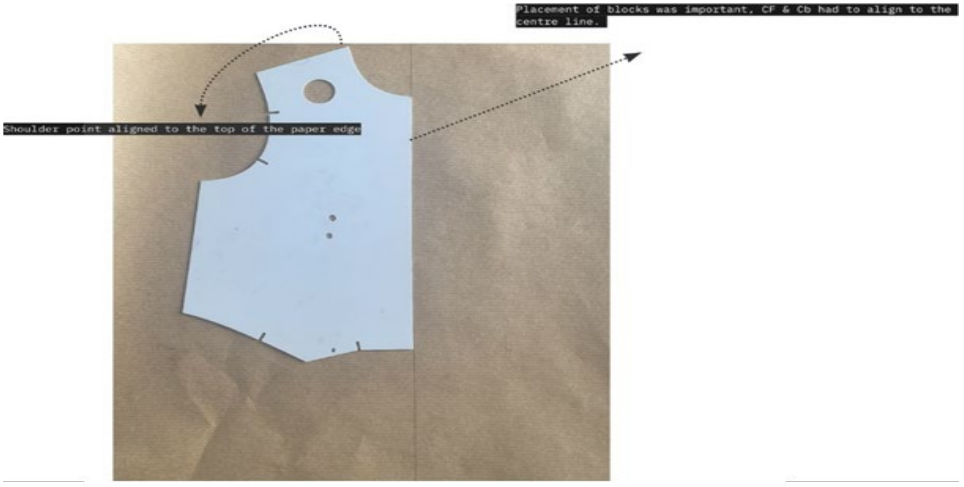

FIGURE 3. Cycle 1 Pattern development process, laying down the basic block (developed by the author)

The paper boundary was divided into two to give equal spacing to both the front and back design, focusing on creating a garment item that would use adjustable working details to create fit, details, such as gathers and drawstrings [16]. The thought process behind this decision was to allow for flexible details that would be able to adjust the garment as needed. This allowed for basic geometric pattern shapes to be developed, which eased the development of the zero-waste pattern and allowed the pieces to interlock with one another more comfortably [16].

The front and back bodice emerged as a basic geometric design with the curved armhole being eliminated, and instead, the side seam extended to the shoulder. The newly developed armhole was included as an opening on the extended side seam. The neckline was developed into a V-shape, with facings developed out of the excess space resulting from the change of the neckline [16]. This resulted in shapes that were not traditional facing shapes and widths. Other aspects of the pattern, where "left-over" space was present, were developed into drawstring casings and ties, thus again indicating a preference for more adjustable working details. Continual consideration had to be given to the measurement of the pattern sections to ensure that the pattern pieces fit together visually on the paper boundary and during the construction process.

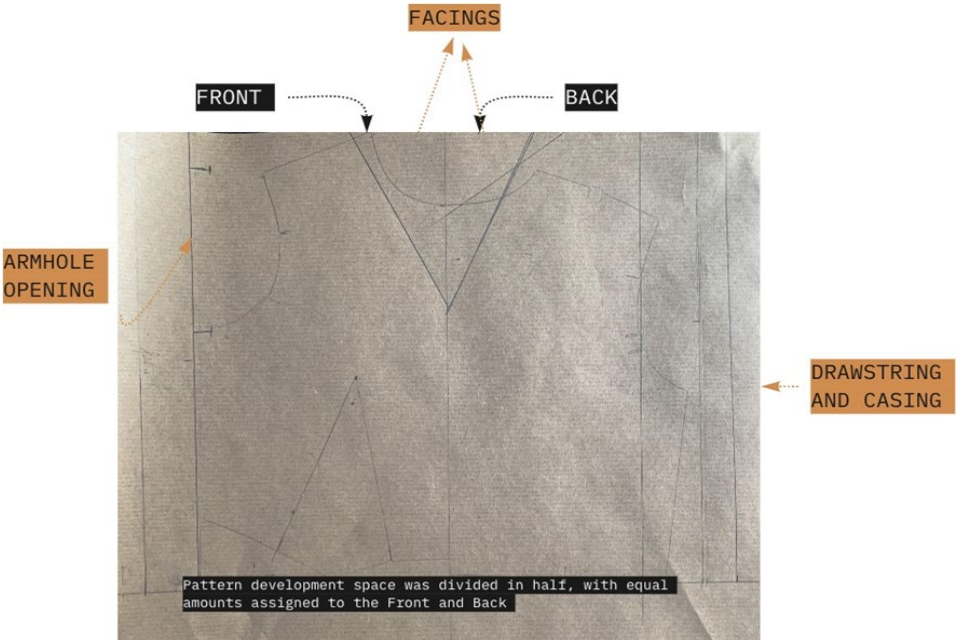

FIGURE 4. Cycle 1 Pattern development process, final pattern (developed by author)

The initial approach to the design, which still incorporated the foundational steps of traditional pattern making, using pattern paper and a basic block set, proved to be limited to the exploration taking place in the design process [17]. The biggest challenge was to adapt to thinking differently about creating a design and pattern that did not align with the processes of the conventional fashion design process. The design was developed more

organically, and both pattern and design were developed in tandem with one another. The cognitive thinking process during the problem-solving process, creating both pattern and design simultaneously, was perhaps not as successful as using a set block boundary limited the exploration of a design [17].

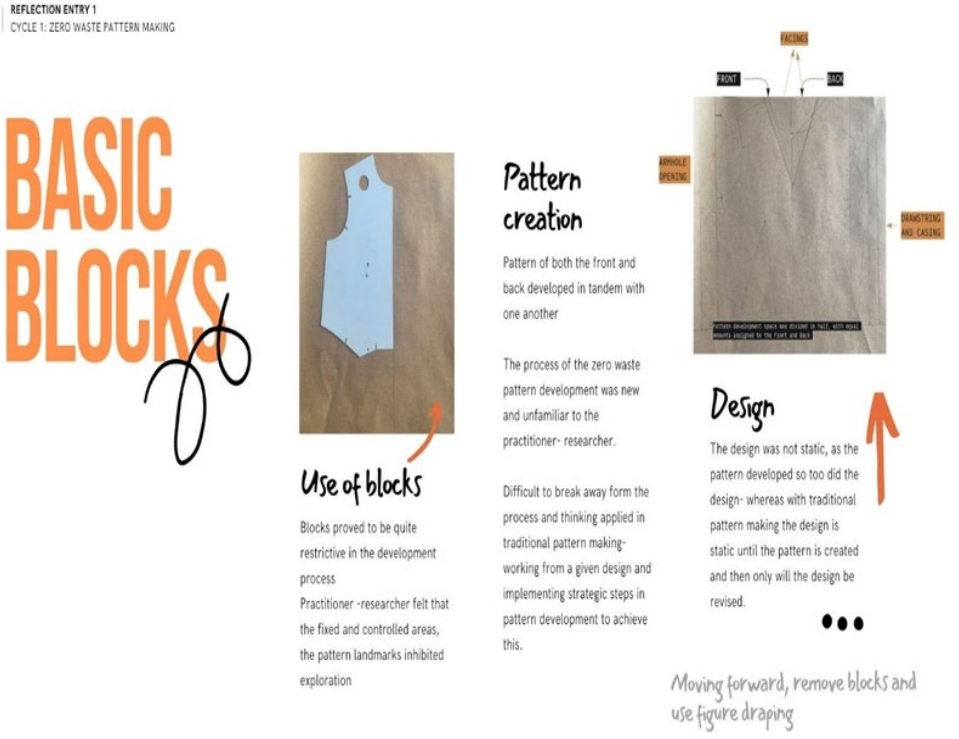

FIGURE 5. Reflection Entry 1: Basic Block Approach within Zero-waste pattern development

The pre-set landmarks on the pattern and the initial start to the process stunted the exploration as I struggled to break away from conventional pattern-making thinking and doing. The zero-waste pattern development was initially difficult as I explored a safe design within the new space of developing both design and pattern concurrently. Without a provided blueprint, such as a sketch, the initial problem-solving process felt foreign, and it was challenging to adjust to thinking about design and pattern techniques simultaneously [17].

During the process, it became apparent that one of the main aspects that differ from the conventional design and pattern-making process was that the design is not static. During the cognitive problem-solving process, the design aspects continually changed and developed. Unlike traditional pattern making, where the outcome of the garment is determined before the pattern process, during the practical application within the study, the design evolved into a fluid process as cognitive problem-solving occurred. The final design outcome was determined by achieving a zero-waste pattern that prescribes to the first principles determined for the study of responsible consumption and production [17].

C. ZERO-WASTE PATTERN DEVELOPMENT: DIGITAL PATTERN DEVELOPMENT

The last iteration in the zero-waste pattern development process was conducted within the digital space [18]. However, the pattern was developed in the digital space within this iteration, evaluated on the figure form, and then adjusted within the digital space again. From the previous cycle, the value of the process came to light, especially with more complex shapes and patterns being developed as zero-waste [18].

D. DESIGN BOUNDARIES

During the previous cycle, the only design boundary identified was that of the fabric width; this has been a consistent design boundary in which the zero-waste patterns have been developed [19]. The width plays an important role, as fabric rolls come in the standard sizes of 150cm and 115cm. This is a variable that the designer cannot change. However, the designer can determine the meterage they would like to use. The design space within this iteration was extended to work with a larger pattern development space, as the previous cycle indicated the design would need to consider this aspect of the development process [19].

E. APPROACH TO THE DESIGN PROCESS

The initial approach to the design process excluded the use of the guides that divided the pattern development space in half, assigning equal parts to develop the front and back design [20]. None of the landmark measurements, as used in Cycles 1,2, and 3, were included, and the design process would start with placing style lines or shapes to initiate the design process. Exploring organic shapes was still a design element that the researchers wanted to explore [20]. However, the previous cycles indicated

that the geometric shapes were the most successful in achieving an interlocking system of pattern pieces that would result in a zero-waste pattern.

An opening for the garment was plotted on the pattern development space, with the conscious intention of placing it on the edge of the development space to explore designing without the pattern development space being divided and the centre point being determined. Curved style lines were placed to initiate the design process [20].

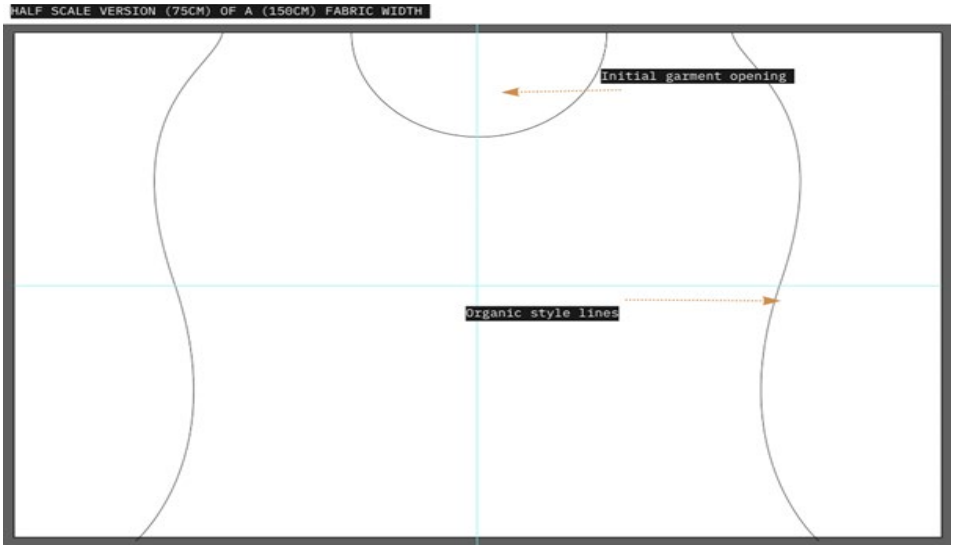

FIGURE 6. Pattern development process digital design, initial garment opening and organic style lines (developed by the author)

Once the shape was identified, it came to light that this process would not succeed due to the nature of the pattern process, where the front and back design would need to be developed concurrently. The opening of the garment was moved to the centre of the page; the intention was not to develop a symmetrical design but to consciously be aware that the assigned pattern space would need to accommodate the front and back of the garment design [20].

The first shape developed was a circular shape that would function as the garment opening; it was moved to align with the centre of the pattern development space [20]. Aligning to the previous cycles, the thinking and doing activities in developing zero-waste patterns happened simultaneously,

and the design development depends on a series of creative problem-solving steps. Once a design and pattern development approach were identified in one area, it could directly influence another area. The design evolved with the inclusion of organic lines, which were removed, once the practitioner-researcher realized that the current process was not conducive to developing the garment holistically. The design process was re-started with the circular shapes and continued through development, directed by the designer's inherent knowledge base [20]. As the design and pattern development process progressed, the placement of lines determined what the shape and/or style line could potentially be developed into as a garment component. The shapes on the pattern development area started emerging as pockets, facings, or pleats, for example. A pocket was developed that incorporated a fold- back, similar to the Cycle 3s pocket design. This, in turn, spurred the development of binding as the pocket edge would need to be refined. Within the previous cycles, the focus was on developing the pattern, and the trims and finishes were not necessarily considered, but the main pattern pieces needed to construct the garment [20].

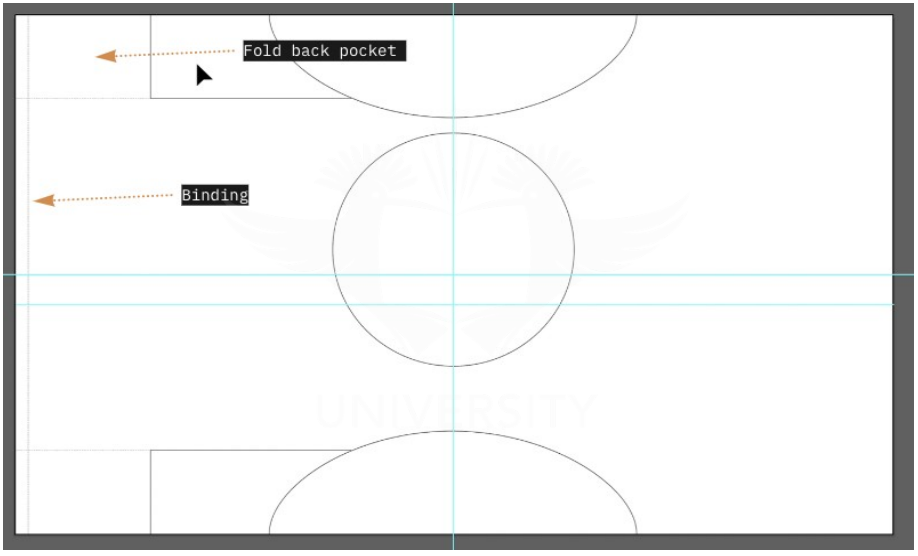

FIGURE 7. Pattern development process digital design 3, possible pocket design and binding (developed by the author)

Including pocket binding as part of the pattern development area resulted in the length of the initial area being shortened. Within the design boundaries,

the one boundary that cannot be adjusted is the fabric width, but the designer can determine the length. This decision impacted the pattern, as the adjustment in the development area affected the style lines and shape placement already designed. This resulted in all shapes having to be adjusted in terms of placing each in the pattern development space [20]. A pleat was included on the back of the design as a design feature. From here, the rounded garment opening was adjusted into a more complex shape which resulted in developing a fold back collar element on the opening. This design decision indicated that the garment would either be a dress or a top. Assigning the garment category was not intentional but like the pattern pieces individually emerging as pockets or facings. Holistically they emerge as apparel items [20].

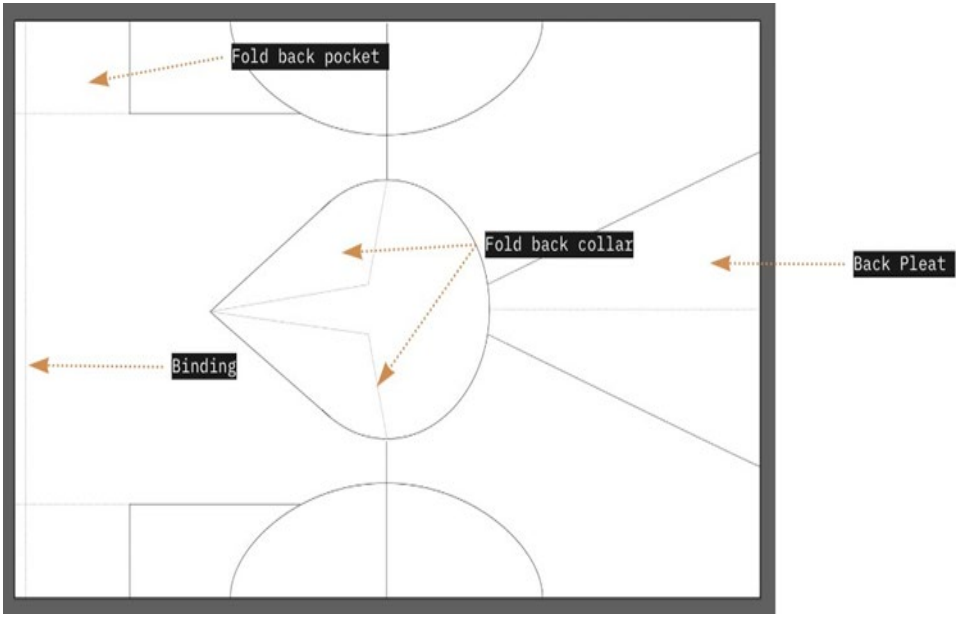

FIGURE 8. Pattern development process digital design, fold back collar design (developed by the author)

A complex shape emerged with the collar development that needed to be assigned as a pattern piece or developed further. To resolve this, a stencil was created and moved around the pattern development space to assist in problem-solving this component. Other aspects of the pattern (shapes) were also traced and used as a stencil to assist in matching up components, very similar to solving a puzzle [20].

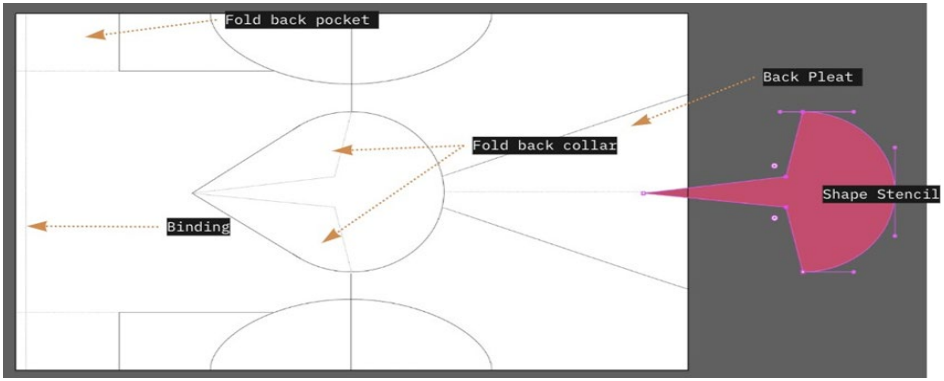

FIGURE 9. Pattern development process digital design 3, shape stencil (developed by the author)

The shape was initially thought to be developed into a hoodie if combined with the other unassigned pattern areas. An attempt was made to resolve this, but through further exploration, the shape would become both a functional pocket and a decorative shape on the front of the garment. The half circle on either side was reshaped to match up with the curve of the shape extracted from the opening. The one-half circle became the facing to the pocket, to create the pocket bag. With one half-circle shape developed into a pocket, the side pockets were removed and replaced with pleats on either side [20].

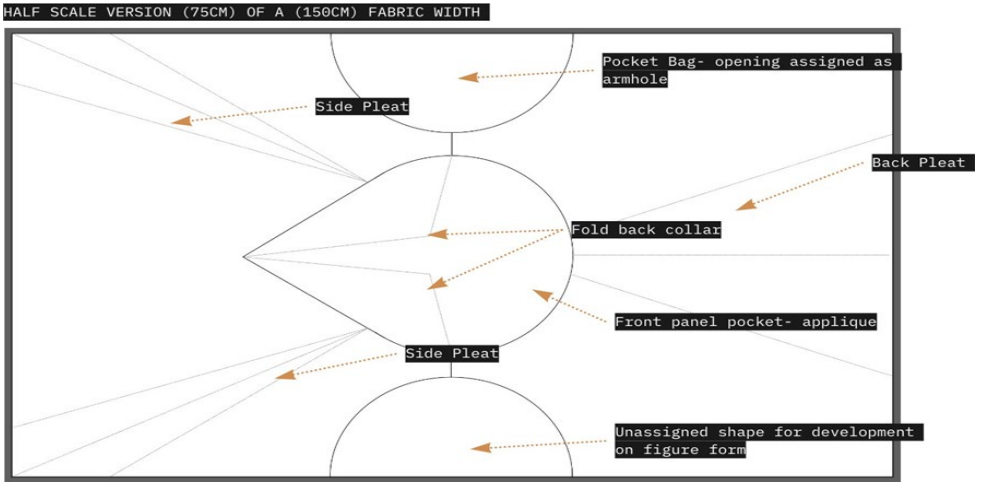

FIGURE 10. Final developed garment pinned on figure form Cycle 5 (developed by the author)

Figure 11. Final developed garment pinned on figure form Cycle 5 (developed by the author)

The one-half circle was not resolved in terms of use and placement on the garment, but then I adopted the reflection findings from Cycle 4 and decided to construct the pattern mock-up on the figure form, assess and evaluate it, and refine the pattern from there. Moving the two-dimensional zero-waste pattern into a three-dimensional space for further adjustments.

F. THEORETICAL REALM VS OBSERVATIONAL

The following section will discuss the findings from the data presented through the zero-waste pattern development process. The evaluation process was executed as a reflection activity on each cycle. The following categories were allocated to discuss the findings: design boundaries, the design process, and the problem-solving process. Each category compared the traditional design and production process to the first principle approach.

G. DESIGN BOUNDARIES

Traditional patternmaking often begins with a fashion designers sketch, with little consideration for how pattern pieces will fit together or their shapes. The primary goal is to translate the sketch into a three-dimensional garment. The sketch dictates the pattern development process, with the foundational block chosen based on the design. Analysis of the sketch determines pattern techniques and processes, and fabric usage is only

considered after the design and pattern are completed, resulting in fabric waste.

In contrast, zero-waste pattern development, as explored in this study, prioritizes fabric considerations from the outset. The fabrics width, often standardized, must be established before development begins. This approach, starting with the "pattern development area" in mind, aims to create zero-waste designs. Each pattern piece is carefully crafted to account for shape and interconnectedness within the overall design.

H. DESIGN PROCESS

The analysis of the design determines conventional pattern development. The corresponding foundation block is selected based on the depending on the garment category the design adheres to. Once the foundation block (basic block) has been selected and traced, the appropriate pattern techniques are applied to achieve the sketched design. Once the manipulation of the foundation block is complete, the working pattern has been established. The finished or final patterns are traced from the working pattern, which will be overlayed onto fabric, cut, and the garment will be constructed.

From the trailing and evaluation process of the first principle approach through the zero-waste pattern making, the five cycles presented a clear distinction between conventional pattern development and zero-waste pattern development. The key finding of the trailing and evaluation process applied within the scope of the study was the success of the first principle design. Evident in the design approach, the design outcome of each garment was only realized and resolved at the end of the design and pattern development process. The identified requirement/principle for this study, aligning the core fashion design process to responsible consumption and production, was the guiding factor in selecting the pattern development process. Zero-waste pattern-making creates a design and pattern concurrently and embodies responsible usage of resources within the production process. Identifying and synthesizing the first principal from existing sustainability theory provided a foundation that aligns with an approach that addresses all necessary system needs, economic, social, and environmental. The trailing and evaluation of the first principle approach within the study indicate that facilitating the approach within the design and

production process requires innovative methods and processes that the convention process does not employ.

I. PROBLEM-SOLVING PROCESS

In the conventional design and pattern process, cognitive thinking unfolds linearly, mirroring the design process itself. It begins with the research and analysis phase, where designers translate trend and market insights into a suitable garment design. Creative problem-solving is essential to bridge the gap between these insights and the final design. Once the design is complete, the subsequent phases focus on problem-solving how to transform the design into a pattern.

The second phase involves analysing the design and considering the initial steps of pattern development. This entails decisions about foundational blocks, pattern techniques, and processes. The third phase occurs during pattern development, where designers and pattern makers implement these decisions, addressing any complexities that may arise in the process.

In contrast, within the zero-waste pattern development cycles, problem-solving is an ongoing and cyclical process. It seamlessly transitions between design and pattern development, emphasizing the interconnected nature of thinking and doing. This differs from the conventional approach, where these activities tend to occur in isolation.

J. CONCLUSION

The study proved to be both challenging and rewarding throughout its duration. The process of data collection presented a significant learning curve, particularly in the domain of zero-waste pattern making, which was previously unfamiliar. Initially, the undertaking felt daunting, however, the iterative development of each pattern and the reflective process involved in it ultimately yielded valuable insights. This application of a new problem-solving approach within a fashion context provided a fresh perspective, distinct from the application of technical and creative knowledge. Additionally, the synthesis of the first principal approach was initially overlooked at the outset of the study, which later emerged as a valuable design strategy and a noteworthy learning outcome.

The urgency to develop impactful and sustainable strategies to drive positive change within the fashion industry has become increasingly apparent. This newfound perspective has influenced the researcher's role as

both a fashion educator and a fashion designer, emphasizing the importance of fostering a comprehensive understanding of sustainability and innovative sustainable practices among the students. Delving into the intricacies of the fashion design and production process has underscored the necessity for effective, sustainable interventions.

Lastly, it is crucial to underscore the value of design-led research within fashion praxis. The study emphasized the significance of practical strategies that can concretely influence the design process. The prioritization of moral and ethical values that designers should champion over mere success is a philosophy that should be cultivated among the youth.

K. LIMITATIONS OF THE STUDY

The zero-waste pattern-making process trailed and evaluated the adoption of one first principle within the context of the study, which focused on the core fashion design process (research and analysis phase and the synthesis phase). This provided a limited application of the first principal approach in sustainable fashion practice, although the facilitation process was extensive. The process of zero-waste pattern had to be trailed and evaluated through a cyclical process as presented within the study. This evaluation method focused on one principle presented in the first principal approach within the sustainable fashion design praxis. As the scope of the research identified the core fashion design process as the phases where the designer can implement impactful change, the first principle that could align with these phases was identified for trailing and evaluation.

L. RECOMMENDATIONS

Future research in the first principal design for sustainable fashion should expand the approach beyond the initial research and synthesis phases, exploring its applicability in other stages of the design and production process. Not all identified first principles may be relevant at the outset, but they may find value in later phases. Designers should play a central role in determining which principles align with their specific contexts. Studies should also investigate facilitation methods for adopting the first principal design in various phases, including design for disassembly, innovative construction techniques, supply chain practices, and Fourth Industrial Revolution (4IR) aspects. Furthermore, the integration of digital advancements in pattern design and production should be explored to streamline the implementation of sustainability principles throughout the

entire process. In summary, future research should broaden the scope, examine facilitation strategies, and leverage digital technologies to enhance sustainability in fashion praxis.

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