# DEVELOPMENT AND TESTING OF A SUSTAINABLE MATERIAL SELECTION MODEL: EMBEDDING SECONDARY MATERIALS INTO THE APPAREL PRODUCT DEVELOPMENT PROCESS

by

Aline Siqueira

A thesis submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Master of Science in Fashion and Apparel Studies.

Summer 2021

**DEVELOPMENT AND TESTING OF A SUSTAINABLE MATERIAL SELECTION MODEL: EMBEDDING SECONDARY MATERIALS INTO THE APPAREL PRODUCT DEVELOPMENT PROCESS**

by

Aline Siqueira

Approved: _____
Kelly Cobb, MFA
Professor in charge of thesis on behalf of the Advisory Committee

Approved: _____
Hye-Shin Kim, Ph.D.
Chair of the Department of Fashion and Apparel Studies

Approved: _____
John Pelesko, Ph.D.
Dean of the College of Arts and Sciences

Approved: _____
Louis F. Rossi, Ph.D.
Vice Provost for Graduate and Professional Education and
Dean of the Graduate College

## ACKNOWLEDGMENTS

I would like to thank both the Theater and the Department of Fashion and Apparel Studies for making this thesis possible. The connections I have made and the opportunities I have had in these departments have been integral to my growth as a fashion professional and academic scholar.

First, I would like to express my sincere appreciation and thanks to Professor Kelly Cobb, my advisor. Your endless patience, guidance, and encouragement throughout the writing process were critical to the completion of the research. Without your contribution and mentorship, this study would not have been possible. I am grateful and honored to have been your student over the last two years.

Next, I would like to thank Dr. Huantian Cao and Professor Katya Roelse for serving on my thesis committee. Thank you both for your support and guidance over the last year. Dr. Huantian Cao, I am specifically appreciative of your assistance with the statistical analyses in this study. Professor Katya Roelse, thank you for guiding me with your valuable feedback. And also, for allowing me to run my workshop in your class.

Lastly, I would like to express gratitude to my family and friends. To my mother, thank you for your endless encouragement, love, support, and for always believing that I can conquer the world. Thank you to my friends who have been there

to keep me sane and take my mind off my research from time to time. Finally, I would like to express my deepest gratitude and love to my fiancé Diego. Your love, sacrifice, support, tolerance, and patience truly made this thesis possible.

Thank you all for supporting this study and shaping me into the fashion professional and academic scholar I am today.

## DEDICATION

This thesis is dedicated to Thereza and Ismael Gonçalves.

## TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

## ABSTRACT

The purpose of this research was to offer guidance to product developers through a model that embeds a material selection strategy into the traditional process of product development. Through sensory and visual evaluations, the Sustainable Material Selection Model (SMSM) guides fashion professionals to make more sustainable choices by embedding textile waste (secondary materials) into the product development process. The model includes ten steps that offer a hands-on manipulation approach while working with secondary materials. Students enrolled in two apparel design classes at the University of Delaware used the model during a product development activity in a mixed-method experimental research design. Participants provided reflective responses to evaluate the effectiveness of the model. Results show the SMSM helps product developers to generate ideas, critical thinking, and the ability to find patterns, as well as enhance intuition and creativity. The model helps product developers to produce ideas to solve environmental issues in their work.

# Chapter 1

# INTRODUCTION

## 1.1 Introduction

The textile and apparel industry has been complicit in the current environmental crisis. Since the Industrial Revolution, the industry's negative impact has grown unceasingly, contributing to environmental problems from textile material manufacture to apparel production to the saturation of landfills with material waste (Claudio, 2007). In the prevailing economic model, the majority of apparel brands operate within a linear system in which products are produced and then discarded, usually into landfills, causing environmental problems such as carbon emissions and toxic pollution (Schor, 2005). Consumers' desire for novelty and newness has driven to the current situation of over-consumption and over-production. Consumers have adopted wasteful consumption practices as the throwaway fashion culture encourages consumers to dispose of a garment after a few weeks of purchase (Gwozdz et al., 2017). Which, in turn, increases landfill waste and harmful emissions, as well as depletion and exploitation of natural resources. Research (Ha-Brookshire et al., 2009; Laitala et al., 2015) have shown that discarded garments still have a significant portion of their potential useful life embodied at the time of their disposal.

Addressing sustainability issues in the apparel industry is a matter of critical importance. In a sustainable system, products are recovered at the end of life without disposing at landfill sites. According to Irick et al. (2020), "discarded clothing may be transformed into meaningful, functional, and re-valued products through repurposing which can lead to substantial decreases in the textile waste stream" (p.280). Extending the life of a used garment can reduce the environmental impact significantly in comparison to the purchase of a new product. Woolridge et al. (2006) found that approximately 65kWh energy is saved for every kilogram of cotton replaced by used clothing, and 90 kWh for every kilogram of polyester replaced. Therefore, developing ways in which textile waste is cycled back as source materials for new garments would provide environmental savings (Gwozdz et al., 2017).

Fashion practitioners play an important role in addressing environmental problems caused by the apparel industry. Collectively, apparel designers, sourcing specialists, and buyers are responsible for material selection during the product development process (Brahma and Lofthouse, 2007; Shaw and Koumbis, 2017). Previous study has found that more than 80% of the environmental impact of products is determined during the product design phase (Tischner and Charter, 2001). However, Palomo-Lovinski and Kim (2014) revealed that apparel designers do not necessarily have a clear vision as to how to implement sustainability into their workflow process to create a positive impact. The long-standing rationale is, in most institutions, design has not been taught in the context of its social and ecological impact (Mackenzie, 1997). Many designers assume that their area of responsibility is limited to function

and appearance. In reality, the role of the designer is changing radically. The designer's task is not to simply create products to sell, and also, design in benefits and design out impact.

McDonough (2013) claims that questions of resource scarcity and sustainability are questions of design, and that design is a tool for positive impact. Many of the problems we face as a culture are, at root, design challenges (McDonough and Brandgardt, 2013). The United Nations Sustainable Development goals offer clear motivators for 21st century sustainable design in relation to health and well-being (goal 3), industry and innovation (goal 9), as well as responsible consumption and production (goal 12). Sustainable approaches to design are a planetary imperative.

Scholars who focus on the area of textile and apparel have provided researchers with several types of apparel design and production models and frameworks for educational purposes (LaBat and Sokolowski, 1999; Lamb and Kallal, 1992; Watkins, 1988). However, little attention has been given to the designers' role in environmental sustainability in the apparel design and production models (Gam et al., 2009), nor do they consider tacit knowledge. According to Mareis (2012) "tacit knowledge and design are commonly linked to a perspective either on characteristic design activities, such as sketching or modeling, or on more general activities, such as showing, presenting, mimicking, and trying out" (p.63). Many designers use their tacit knowledge gained through years of practical experience when working to solve a design problem (Rust, 2004).

While technological developments advance towards more sustainable methods of production, new understanding, and strategies for designers to meet consumer and industry expectations is needed regarding environmental practices. Major apparel companies are adding sustainability to their business strategies in order to address post-consumption waste. An example is The North Face Renewed program, which diverts unwanted apparel from landfills by repairing used garments to keep them in circulation. Other apparel companies such as Patagonia, Eileen Fisher, and REI are also examples of apparel companies that are incorporating post-consumption waste into their designs.

Despite the growing necessity of environmental practices in the apparel industry and the number of apparel brands that started working with textile waste, little research has explored methods to guide current and future fashion practitioners toward incorporating textile and material waste (secondary materials) into their designs. Irick et al. (2020) noted, "a formal process for utilizing textile waste (pre or post-consumer) in the design and production process has yet to be established" (p. 281). Therefore, the purpose of this research is to offer guidance to fashion practitioners through a model that embeds a material selection strategy into the traditional process of product development. Specifically, this research will involve the development of a model as well as initial testing to evaluate the effectiveness of the model.

## 1.2 Statement of the Problem

Addressing environmental and social issues caused by the textile and apparel industry is critical, as it is estimated that 70 pounds of garment and textile waste are added to landfills each year for everyone in the United States, and the overproduction of garments is depleting natural resources (Council for Textile Recycling, 2020). The 2017 Ellen Macarthur Foundation report "A new textiles economy: Redesigning fashion's future" offers a vision of a fashion system that is circular, ideally creating no waste by design, while strategically capturing value from recycled content. Goal three of the Ellen MacArthur report findings suggest the radical improvement of recycling by transforming clothing design, collection and reprocessing. Due to the growing amount of textile goods going to landfills every year, it is imperative to consider strategies that apply the use of secondary materials in the design of apparel or other softgood products. Increasing consumer environmental and social awareness brings the consumer's expectation that apparel companies will accept environmental (and social) responsibility. The understanding of how the apparel industry can incorporate textile and material waste into their production is a critical need as well as a tremendous opportunity. More than $500 billions of value is lost every year due to clothing underutilization and the lack of recycling, according to the Ellen MacArthur Foundation. Incorporating waste back into the supply chain as 'raw materials' helps companies reduce waste, reuse valuable resources, and save costs on virgin materials at the same time.

Previous literature suggests that there will be increasing opportunities for green apparel products because of growing consumer environmental concerns. Nevertheless, apparel companies have adopted this trend as a competitive opportunity. One possible reason may be the lack of guidance and procedure for utilizing textile waste in the design and production process. Therefore, developing strategies to guide apparel designers and students to incorporate back to production the many tons of textile waste produced to satisfy the constant demand for new fashion is needed.

## 1.3 Research Objectives

The primary objective of this research study was to develop a sustainable material selection model that embeds the use of textile waste (secondary materials) as one option in the materials selection step of the apparel product development process. The second objective was to evaluate the effectiveness of the model in the apparel development classroom/lab.

## 1.4 Research questions

To achieve the objectives of this study, the following research questions were addressed.

*Model Development*

1. What considerations are required to develop a model that embeds secondary materials into the apparel product development process?

2. How might a process model guide apparel product developers toward more sustainable choices?

*Evaluation of the Model*

3. Can a sustainable material selection model based on sensory and visual evaluations guide future fashion professionals to make more sustainable choices in the product development process?
4. Can a sustainable material selection model based on sensory and visual evaluations help/guide future fashion professionals to embed secondary materials into the apparel product development process?
5. Do the perceptions of the model differ based on discipline or curriculum focus (i.e., merchandising/business, design/creative)?

## 1.5 Definition of Terms

*Secondary materials:* textile and apparel industry waste, which includes pre-consumer and post-consumer waste.

*Model:* a system or thing used as an example to follow or imitate. It is the presentation in schematic form, often in a simplified way, of an existing or future state or situation.

*Material selection:* a step in the process of designing any physical object. In the context of product design, the main goal of material selection is to minimize cost while meeting product performance goals (Dieter, 1997).

## 1.6 Assumptions

1. Future fashion professionals need develop skills to work with pre-consumer and post-consumer waste for their future careers.
2. Apparel design students and practitioners develop product development skills as well as sustainability knowledge in their coursework.
3. A sustainable material selection model will help apparel design students and practitioners make better, more sustainable choices in product development.

## 1.7 Limitations

This study is limited by small sample size. The target participants for this study will be apparel design students at one university. The participants will be recruited by a convenience sampling method. Thus, the sample may not be representative of the entire population, and the results may not be generalizable.

## 1.8 Significance

Currently, apparel companies have started to incorporate pre-consumer and post-consumer waste into their design to divert unwanted apparel from landfills (e.g., Patagonia, 2020; The North Face, 2020; Eileen Fisher, 2020). However, there are no standard guidelines or procedures to operationalize the use of textile and material waste in apparel product development. Therefore, developing guidelines for current and future apparel product developers/designers is of great value.

# Chapter 2

# REVIEW OF LITERATURE

## 2.1 Overview

This section will review the impact of the fashion industry, apparel design and product development processes, sustainable apparel product development processes and strategies, and how these are currently being used in the apparel industry. A contextual review of industry projects will further elaborate on this. This literature review will justify the development of a sustainable material selection model.

## 2.2 The Fashion Industry: An Environmental Concern

In recent years, the textile and apparel industry has been focused on increasing efficiency in production to keep the price of the final product low (Claudio, 2007). Hence, the fashion cycle has become shorter and shorter, and products are designed and produced according to pivotal trends that enable quick profit (Schor, 2005). In 2020, the global fashion industry was worth 1.5 trillion U.S. dollars, and it is projected to grow in value to about 2.25 trillion dollars by 2025 (Shahbandeh, 2021). These numbers reflect the increasing demand for fashion products across the world.

In the prevailing economic model, the majority of apparel brands operate within a linear system in which “resources are extracted, shaped into products, sold, and eventually disposed of in a “grave” of some kind, usually landfill or incinerator” (McDonough and Braungart, 2002, p27). In the linear model of production, products are not designed with the end of life in mind. According to Gwilt and Pal (2017),” once purchased, all garments go through a cycle of wearing, laundering, storing, and

perhaps repair and alteration before final disposal" (p.149). Consumers have little acknowledged of where and how to dispose of unwanted garments (Laitala et al., 2015). The majority ended in landfills, causing environmental problems such as carbon emissions and toxic pollution (Hawley, 2011).

On average, 25 billion pounds of textile waste is generated each year in the United States, and the amount has doubled over the last 20 years (Council for Textile Recycling, 2010). In 2018, over 17 million tons of textile waste was generated, according to the Environmental Protection Agency (EPA) (2020). Americans dispose of approximately 70 pounds of used clothing per person per year, and nationally, it costs cities $45 per ton to dispose of old clothing (Council for Textile Recycling, 2020). Only 14.7% of the total textile waste was diverted from landfills by the recycling industry in 2018 (EPA, 2020). Landfilling is the main form of waste management in the United States, and the environmental fate of textiles in landfills depends on the fiber material. Textile waste is not usually considered an issue in waste management because textile waste often is not regarded as toxic (Weber et al., 2017).

Textile waste is generally categorized as pre-consumer and post-consumer waste. Pre-consumer textile waste consists of manufacturing waste that has not reached the consumer, which typically includes (a) textile swatches (leftover textile samples from production), (b) cut-and-sew textiles (textile scraps generated during garment manufacturing), (c) end-of-rolls (factory surplus waste leftover from garment manufacturing), (d) damaged textiles (unused textiles that have been damaged, for example with color or print defects), and (e) clothing samples (part-finished or

finished clothing samples from the design and production of clothing, which have not been worn by consumers), to cite a few (Hawley, 2006).

Post-consumer waste includes any type of garment or household article made from manufactured textiles, such as clothing, footwear, fashion accessories, towels, bedding, and drapery that have already been purchased and then discarded by consumers (both used and unused) (Hawley, 2006).

Previous research has indicated that around 80% of the environmental impact of today's products is determined in the product design and development phase (Brahma and Lofthouse, 2007; European Commission, 2011). Billions of dollars are lost every year due to clothing underutilization and the lack of recycling, according to the Ellen MacArthur Foundation (2017). Research (Ha-Brookshire et al., 2009; Laitala et al., 2015) has shown that discarded garments still have a significant portion, almost 70%, of their potential useful life embodied at the time of their disposal. With textile waste growing, it is increasingly important for apparel designers and product developers to consider ways to employ strategies to incorporate secondary materials (textile waste) back into the product development process of apparel for the sake of our planet.

## 2.3 Academic Apparel Design Processes (Frameworks + Models)

Armstrong and LeHew (2011) have noted that "frameworks for apparel design and product development have been articulated largely by apparel and textile academicians for educational purposes and are consequently prescriptive rather than

descriptive" (p.36). Many of the apparel product development processes described are heavily influenced by models from other fields and follow similar prescriptive design methods. There are a few apparel design models proposed by scholars to guide designers and students in the development process of apparel, creative thinking, and problem-solver (LaBat and Sokolowski, 1999; Lamb and Kallal, 1992; Watkins, 1988).

Watkins (1988) presented a step-by-step design process from the Universal Traveler (Koberg and Bagnall, 1981) as a way to prepare students to become creative problem-solvers. The model included seven steps: (1) acceptance (to get motivated and to find reasons to devote time and effort to a problem), (2) analysis (to conduct exploratory research and find everything about the problem), (3) definition (to decide the most important aspects of the problem: a statement of goals), (4) ideation (to develop as many ways to solve the problem as possible), (5) idea selection (to select the best idea), (6) implementation (to try out the best idea), and (7) evaluation (to analyze what happened when the action was taken) (Watkins, 1988). This design process operates as a cyclical if the evaluation shows that the solution is not a successful one, the whole or part of the process may be repeated (Watkins, 1988). Further, in this model, a designer is continually alternating between divergence or spreading out to look for a wide variety of ideas and convergence or centering on one idea.

Using Watkins' (1988) work as the foundation, Lamb and Kallal (1992) proposed the functional (fit, mobility, comfort, protection, donning, and doffing),

expressive (value, roles, status, and self-esteem), and aesthetic (art elements, design principles, and body-garment relationship) (FEA) model to guide the development of garments that meet consumer needs. Using FEA as design criteria, Lamb and Kallal (1992) developed an apparel design framework that has six steps: problem identification, preliminary ideas, design refinement, prototype development, evaluation, and implementation. The first five steps correspond to Koberg and Bagnall's (1981) steps that problem identification is the incorporation of acceptance, analysis, and definition; preliminary ideas is similar to ideation; design refinement is similar to idea selection; prototype development is similar to implementation; and evaluation is the same (Lamb and Kallal, 1992). The last step, implementation, is the culmination of the design process and may not be reached until the previous steps have been repeated, and a final design is refined (Lamb and Kallal, 1992). Lamb and Kallal's framework can be applied to both fashion design and functional apparel, and they demonstrated the application of the framework in figure skating costume design, cleanroom garment design, and a customized design for a client with spina bifida (Lamb and Kallal, 1992).

In order to provide guidelines for how creative thinking evolves in the textile product design process, LaBat and Sokolowski (1999) developed a three-stage textile product design process. The design process was developed after reviewing design processes for architecture and environmental design, engineering design, industrial product design, and clothing design (including Watkins', 1988 and Lamb and Kallal's, 1992 work). Three common stages among these processes were found: problem

definition and research, creative exploration, and implementation. Figure 2.1 is the detailed textile product design development process. LaBat and Sokolowski (1999) showed the application of the three-stage design process in an industry-university project to redesign an athletic ankle brace.

| I. Problem Definition & Research | II. Creative Exploration | III. Implementation |
|---|---|---|
| A. Initial Problem Definition<br>• Client definition | A. Preliminary Ideas<br>• Expansive, all realm of possibilities | A. Production Refinement<br>• Cost to produce<br>• Time to produce<br>• Methods of production<br>• Sales potential |
| B. Research<br>• User Needs:<br>-Function<br>-Aesthetic<br>-Economic<br>• Market:<br>-Assess current products<br>-Competitive Analysis<br>-Economic conditions | B. Design Refinement<br>• User constraints:<br>-Function<br>-Aesthetic<br>-Economic<br>• Production Constraints<br>-Cost to produce<br>-Time to produce<br>-Methods of production<br>-Sales potential | B. Phase 1: Immediate Production<br>• Changes in product or production that can be accomplished immediately |
| C. Working Problem Definition<br>• Defined by industry client & university designer<br>• Design criteria established | C. Prototype(s) Development<br>• Meshing design criteria and constraints to develop workable ideas<br><br>D. Evaluation of Prototype<br>• Preliminary: by university designer<br>• Final: by university designer and industry client | C. Phase 2: Improvement/Refinement<br>• Further development that may be delayed |

Figure 2.1. Textile product design process stages (LaBat & Sokolowski, 1999).

## 2.4 The Apparel Product Development Processes

Similar to apparel design, apparel product development is a highly iterative and simultaneous process that entails multidisciplinary interaction and collaboration in order to meet the strategic vision and creative design with the use of technology, production processes, and distribution planning to develop products for a target market (Armstrong and LeHew, 2011). The majority of apparel product development processes presented in the literature demonstrate a straightforward sequence from

research (market, trends, materials) and line development to considerations for sourcing, distribution, and retailing (ibid.).

Han et al. (2017) have examined a variety of design models articulated and outlined in the literature in order to summarize and create a standard design and production process model (figure 2.2). The authors developed the model based on processes outlined by McKelvey and Munslow (2003, 3); Jenkyn Jones (2005, 128); Burke (2008); Matharu (2010, 88), and Armstrong and LeHew (2011, 37). In each of the design models examined by Han et al. (2017), the process usually started with a brief, which outlines the design task or problem, then followed by research of the market and of the creative aspects of the range to be produced. The design process is where the problems are solved, and potential solutions generated. Then the process is followed by the making of sample products, which form the basis for promotion and marketing, before the products are manufactured and distributed to retailers, ready for consumers (Han et al., 2017).

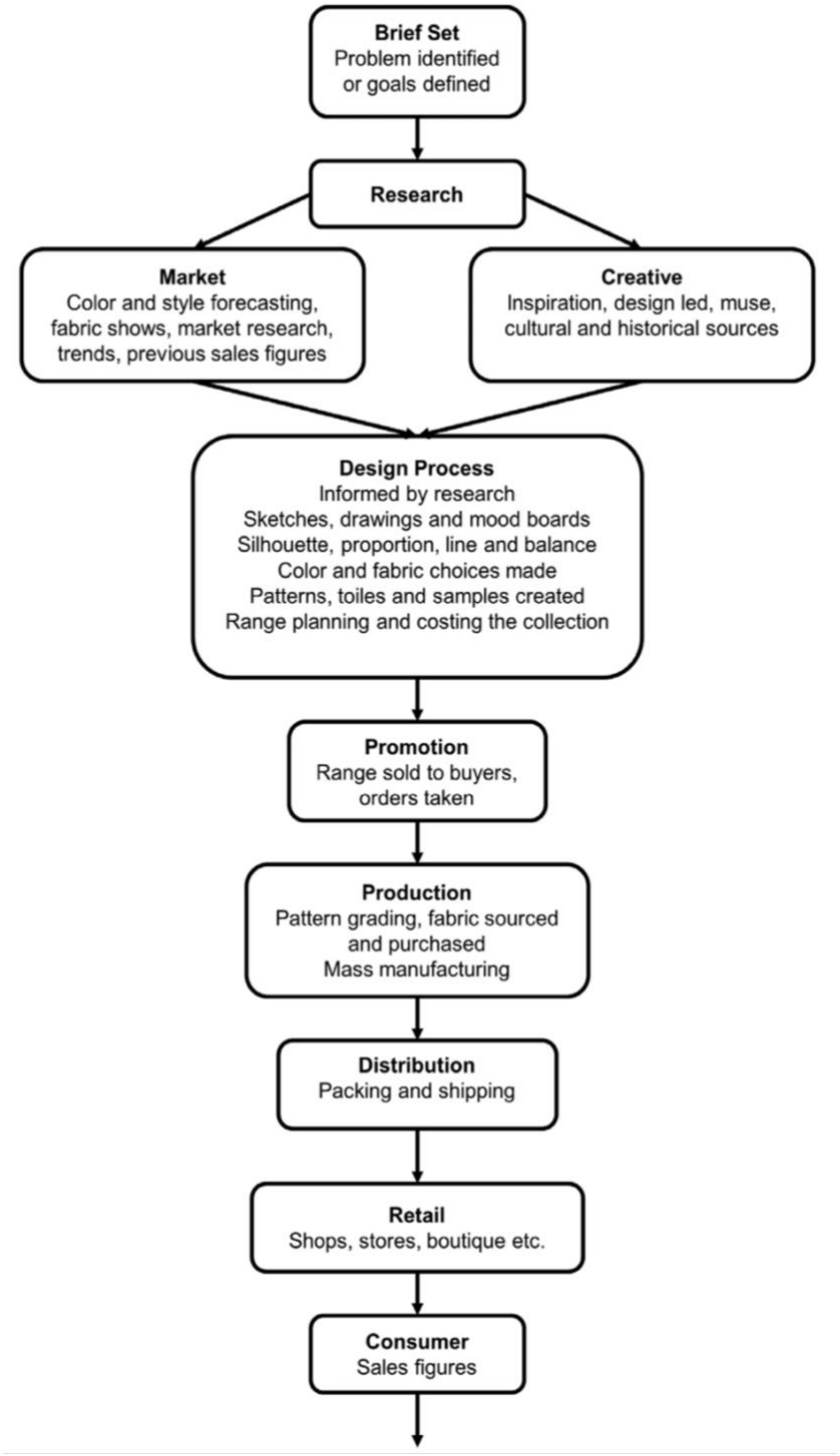



Figure 2.2. Standard design and production process model (Han et al., 2017).

### 2.4.1 Material Selection (within product development process)

The research and design process phase are where designers or product developers select the materials that go into the products. In the fashion industry collectively, apparel designers, sourcing specialists, and buyers are responsible for material selection during the product development process (Brahma and Lofthouse, 2007; Shaw and Koumbis, 2017). Material selection is the focus of this study due to its critical aspect of the design process of an apparel product. Ljungberg (2007) has noted, "material determines the use of our natural resources as well as the amount of energy used for the production and the use of the product" (p.470). Further, it can significantly impact the cost of a product's life cycle (Armstrong and LeHew, 2011). As a general rule, designers and product developers should aim for four goals in material selection (Graedel and Allenby 1995: 240):

- Choose abundant, non-toxic, non-regulated materials if possible. If toxic materials are required for the manufacturing process, try to generate them on-site rather than by having them made elsewhere and shipped.
- If possible, choose natural materials rather than synthetic materials.
- Design for minimum use of materials in products, processes and service.
- Try to get most of the needed materials through recycling streams rather than through raw material extraction.

#### 2.4.1.1 Wearable Product Materials Research Model

Material selection is an important aspect of the design process of an apparel product (Ljungberg, 2007). However, materials selection is usually overlooked in the general apparel design processes, and they are not recognized as a central role in the success of the design (Bye and Griffin's, 2015). Therefore, Bye and Griffin's (2015) developed a model to provide guidelines for material selection for designers to use in conjunction with the product development process.

The Wearable Product Materials Research (WPMR) model developed by Bye and Griffin (2015) supports material experimentation through a systematic visual, tactile, and sensory evaluation of the material selection process, which encourages the designer to think about the application of the material and the user simultaneously. It was developed to complement existing design processes and practices and to guide designers during the material selection phase. The model can be used in the classroom setting and the industry.

The model (figure 2.3) has five steps, and the initial phase begins with the selection of materials according to the design requirements and user needs. Once potential materials are selected, the first step in the model asks designers, "does the material bend and allow movement?". That is a relevant aspect of any material intended to be used in wearable products because the product needs to be worn on the human body, a surface that moves, bends, and changes shape. If the material cannot bend or allow for movement, the designer is asked if these elements can be manipulated through the design, pattern, joining or seaming method, material

manipulation, or cutting. If the designer says no to a step, then the designer should select another material to move through the process. The second step is to determine if the material can hold adequate shape and structure based on the design needs. For the third step, the designer is asked if the material can be joined (sewn, welded, etc.) to self or other components using available manufacturing methods. The fourth step addresses the necessity for humans to be able to dress and undress the designed product by asking if the material can sustain closures such as zippers, hook and loop tape, buttons, etc. The fifty and last step is for the designer to determine if the material addresses user expectations and perceptual qualities needed for product success. Bye and Griffin (2015) demonstrated the application of the WPMR model by applying in the development process of two functional apparel products – a nursing bra and a commercial cooling vest.

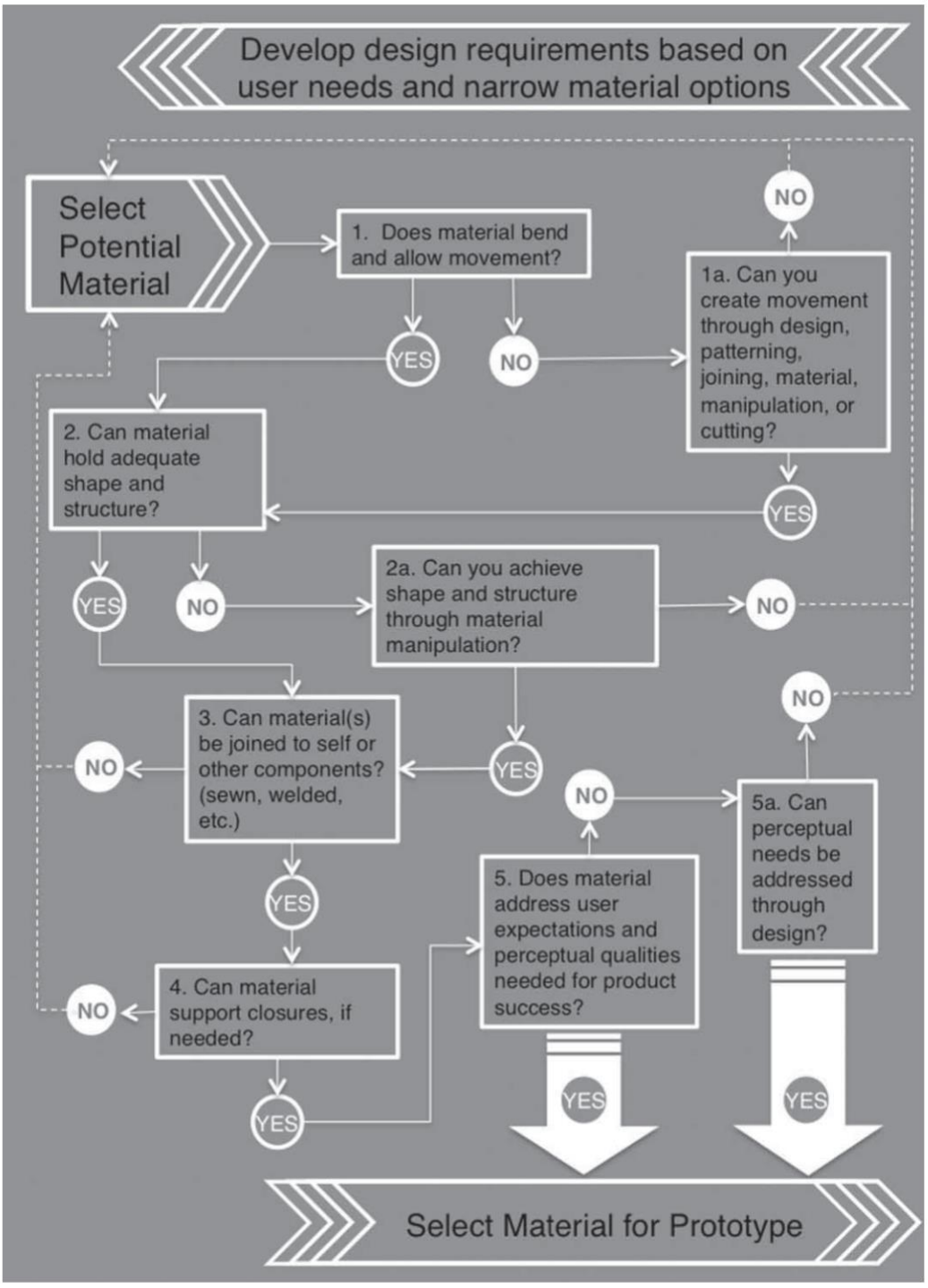



Figure 2.3. WPMR model (Bye and Griffin, 2015).

#### 2.4.1.2 Design for Disassembly

Many textiles nowadays are cocktails of different fiber materials blended together. Forst (2020) described blends as “the combination of two or more different components, fibers, yarn or fabric elements, in the same yarn or cloth to create a variety of technical or aesthetic effects” (p.175). There are many reasons for combining fibers such as to compensate for weak performance in one of the parts of the blend and improve the overall performance of the output, aesthetic effects, to improve the efficiency of processing, to reduce costs in the production, and so on (Forst, 2020). However, finding a way to separate blended fiber materials so that they can be recycled according to their own system is a challenge (Ellen MacArthur Foundation, 2017). Therefore, researchers are exploring design for disassembly strategies to apply to the development of textiles.

The design for disassembly method is defined “as the creation of materials or products that can be easily and economically taken apart at the end of their useful life allowing for re-use in appropriate cycles” (Forst, 2020, p.176). Hence, a fundamental element for enabling disassembly for textiles re-use and recycling is the consideration and development of impermanent joining methods and connections. As an example, the company Climatex developed a blended textile with an innovative weaving technique which allows the fibers to be separated and fully recycled (Climatex, n.d.). Further, Forst (2020) explored solutions from a design and making-led perspective through experimentation in a studio in sampling textiles for disassembly. The author tested a variety of unique techniques (dovetail, minimalist, and laser cut) for

assembling textiles components at the yarn and fabric scale. Forst (2020) research findings lead to original recyclable textiles that combine not only resources for optimal performance but also aesthetics. Forst (2020) findings can serve as guidelines for the creation of textiles for disassembly.

## 2.5 Sustainable Apparel Product Development Strategies

The apparel product development is associated with natural resource depletion, contribution to overflowing landfills, and often relies on the exploitation of human labor (Hawley, 2011). In order to address these issues, sustainable design strategies have been largely discussed by academia and practitioners. According to Gwilt (2015), "fashion designing for sustainability involves engaging in strategies and approaches that can help reduce or avoid the social, environmental, economic and cultural impacts associated with the production and consumption of fashion clothing" (p.62). In the following section, a few sustainable design strategies will be discussed.

### 2.5.1 Sustainable Apparel Design and Production Model (C2CAD)

To provide practical guidance for apparel designers and manufactures to develop sustainable apparel product, Gam et al. (2009) incorporated cradle to cradle model (McDonough and Braungart, 2002) into existing apparel design and production models (LaBat and Sokolowski, 1999; May-Plumlee and Little, 1998) to develop a sustainable apparel design and production model C2CAD (cradle to cradle apparel design). The C2CAD model (figure 2.4) has four steps: problem definition and

research, sample making (including “material selection and testing” and “cost and design evaluation” parts), solution development and collaboration, and production (Gam et al., 2009). The significant concept of the C2CAD model is that sustainable features are considered to make decisions during the design process. Designers and manufacturers select fabrics and materials based on their inherent human and environmental health and safety. This model addresses the three sustainability pillars (people, profit, and planet) during the clothing design process. The C2CAD model was applied in the design of children’s knitwear (Gam et al., 2009) in a knitwear manufacturer in Kyunggi, Korea, and men’s jacket (Gam et al., 2011).

In the sample making of the C2CAD model, designers assess materials based on their feasibility as biological or technical nutrients (Gam et al., 2009). The biological nutrient is a material that can be composted, returning nutrients to the earth (McDonough and Braungart, 2002). On the other side, the technical nutrient is an artificial material that can be recycled into a new product of the same quality level as the original (ibid.). Consequently, in the C2CAD model, the chosen materials need to be recyclable at the end of its life. Therefore, this model does not acknowledge pre and post-production textile waste, such as deadstock fabric and upcycled materials, to the process of developing sustainable apparel design. Due to the growing amount of textile goods going to landfills every year, it is necessary to consider incorporating these materials in the design process of sustainable apparel. Incorporating waste back into the supply chain as ‘raw materials’ helps companies reduce waste, reuse valuable resources, and save costs on virgin materials at the same time.

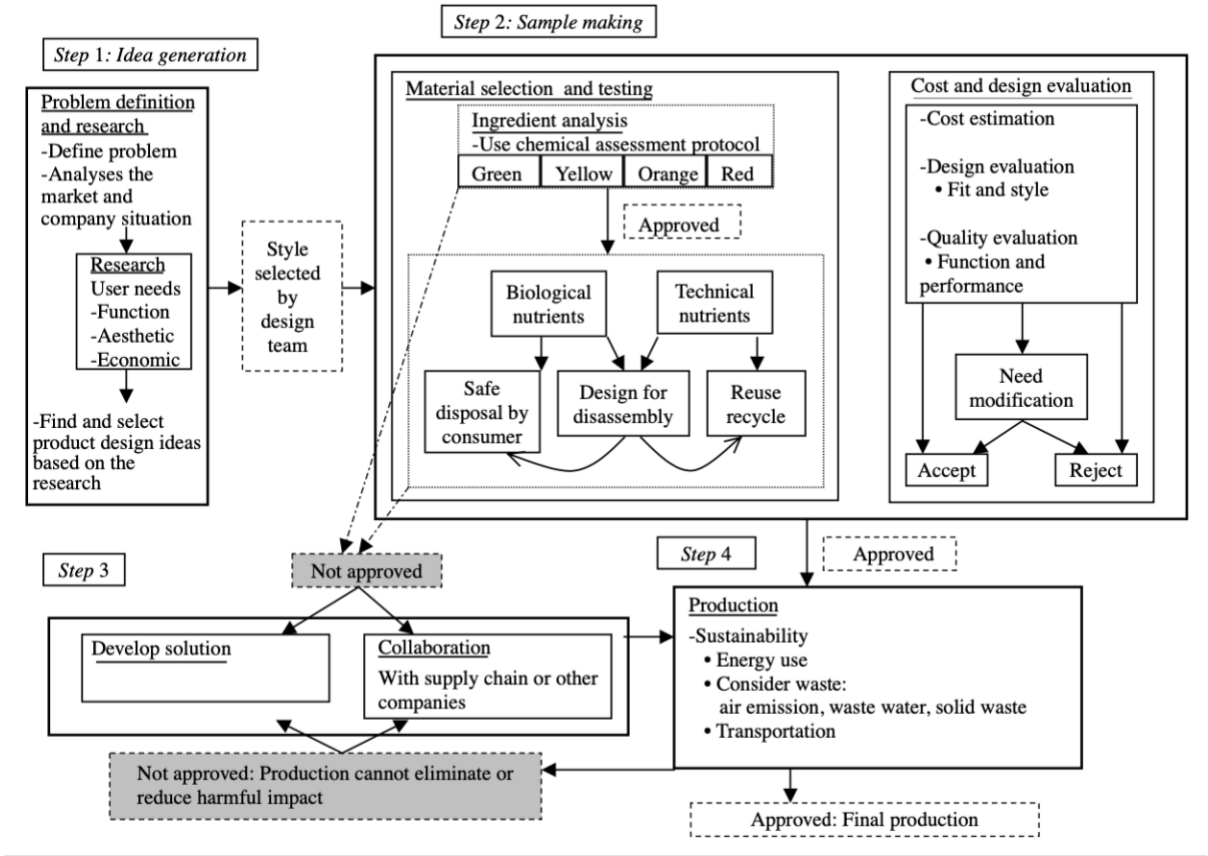



Figure 2.4. Cradle to cradle apparel design (C2CAD) model (Gam et al., 2009).

### 2.5.2 The TEN

In order to guide textile and fashion designers regarding sustainable design strategies, the Textile Environmental Design (TED) created a toolbox called The Ten. The toolbox helps designers to navigate the complexity of sustainability issues and offers approaches to design products in a sustainable manner (TED, n.d.). The set of design strategies includes ten approaches. The first five tactics focus on material,

process, and technological solutions, and from six to ten, the approach is more conceptual, encouraging radical innovation (figure 2.5).

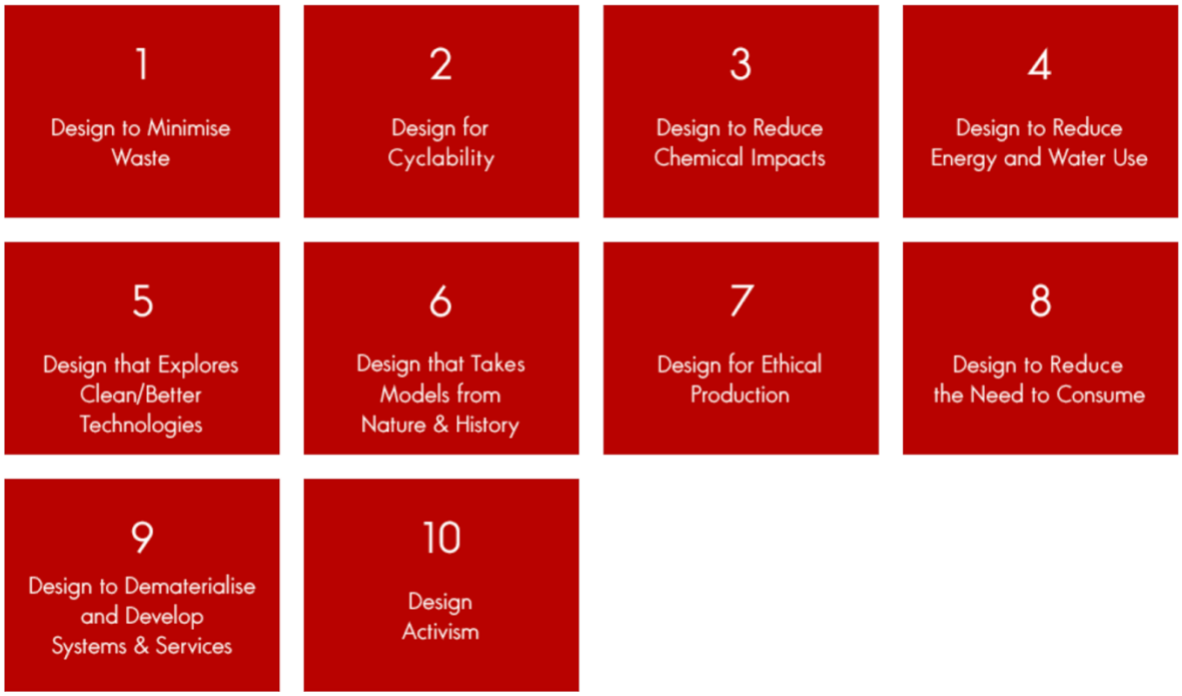



Figure 2.5. 'The TEN', buttons from the TED website

### 2.5.3 Upcycle and Reconstruction

Upcycling is an activity of creating newness or better quality from used or waste materials while adding value (Sung, 2015). In the fashion industry, upcycling means prolonging the life of waste textiles through creativity. Wilson (2016) defined upcycling as a "practice of refashioning something useless into something useful" (p.395). This sustainable design technique utilizes textile waste to create products with a higher retail value than traditionally recycled goods. There are many approaches to

upcycling, for example, using existing waste fabrics to make garments or turning the fabric back into fiber. This reuse and repurposing of existing materials allow a designer to divert textile matter away from incineration or landfill. Thus, prolonging the life cycle of the original textile and reducing further unnecessary textile production, which in turn decreases the demands on natural resources.

Similar to upcycling, reconstruction is a sustainable design strategy of making new garments from waste formed of previously worn clothing or preformed finished clothing products. This process involves first deconstructing garments and then reconstructing the waste materials into new designs. There are a variety of ways to use and apply this sustainable design technique. After deconstructing a garment, the fabric can be cut using pattern blocks, can be draped, and through ripping and shredding a completely new fabric can be created.

### 2.5.4 Modular Design Strategy

As a transformable design approach, modular fashion refers to clothing items that have detachable pieces, allowing the aesthetics and functionality of the items to be converted into multiple styles and functions to meet consumers' needs and tastes over time (Koo et al., 2014). According to Niinimäki and Hassi (2011), "this design concept offers the possibility to upgrade the product or to personalize the product through modifications, e.g., some pieces of the clothing can be changed, or the consumer can select the details according to his/her favorite colors or materials" (p.1880). Its ability to be taken apart and reassembled allows consumers to replace

only damaged parts of a garment rather than purchasing an entirely new garment. Modular clothing may also require less washing since users may opt to clean only the parts of the garment that are easily dirtied (Fletcher, 2008). Modular clothing aligns with a few different aspects of environmentally ethical fashion design. For one, a garment made in a manner that can change appearances easily may encourage consumers to buy fewer clothing items (Cao et al., 2014) due to its versatility. In addition, enabling consumers to change the design of a garment, it may cause them to feel more emotionally attached to the garment, delaying disposal (Cao et al., 2014; Koo et al. 2014), and finally expand the garment life cycle, as consumers repeatedly transform them, reducing consumer needs for new garments (Koo et al. 2014; Rahman and Gong 2016).

### 2.5.5 Zero-waste

Zero-waste design is a sustainable way of manufacturing products by eliminating waste at the design stage. Thus, the concept of zero-waste in apparel design strives to eliminate any wasted textile fabric from the production of clothing by developing products that utilize 100% of a length of fabric so that no scraps hit the 'cutting-room floor' (Carrico and Kim, 2014). There are several ways of making a zero-waste garment, such as through pattern cutting, draping, and through fully fashioned knitting. Regardless of the approach, the aim should be no textile wastage at the end of the design stage. Zero-waste fashion is not a new concept - early examples

of zero-waste or near zero-waste garments include the Japanese kimonos and Indian saris.

## 2.6 Context: Current Industry Based Sustainable Product Development Strategies

In recent years, fashion brands around the world have increasingly been incorporating sustainable practices into the product development process by engaging in repurposing used clothing from take-back programs. Also, they have been involving the consumer to restyle and repair their used garments. In this section, some of these programs will be discussed in detail.

### 2.6.1 G-Star C2C

G-Star RAW is an example of a company that has been developing solutions to minimize the impact of denim production on the environment. Their mission is to create the denim classics of tomorrow through continuous innovation and design, respect for people, the planet, and work transparently (Galijasevic, 2020). G-Star RAW took their denim iconic styles that have been selling well and applied circular principles to these designs. While working collaboratively with fifteen partners, the company has developed a 100% recyclable denim fabric. The fabric is produced with 100% recyclable cotton, a clean indigo dyeing process, 100% renewable energy, and eco-friendly sustainable washing techniques. The water used in production is recycled, leading to zero water waste. Also, the stretch fiber used in the new fabric is called Roica, which is considered a healthy material (Galijasevic, 2020). This new innovative

product received the world's first Cradle to Cradle gold certified for a stretch denim fabric in October 2019 (Galijasevic, 2020). According to Sofie Schop (2020) - G-Star RAW's Sustainability Director, "Cradle to Cradle certification is the most rigorous because it looks at the design from five different perspectives — the material health, water stewardship, social fairness, material utilization, and reuse of renewable energies" (para.6). With G-Star RAW achievement, there is no doubt, the brand is leading the way and pushing the industry to move towards a sustainable approach. According to Adriana Galijasevic (2020), going to the certification process has enabled them to build a design toolbox to share throughout the industry. Working collaboratively, they can inspire and encourage other companies to apply sustainable practices in their development process. Furthermore, the brand's sustainability goal by the end of 2020 is to have 100% sustainable cotton and 90% sustainable material.

### 2.6.2 Eileen Fisher: Waste No More

The Fashion brand Eileen Fisher is known in part for being a pioneer of sustainability in the clothing industry. Since 1984, the company has been designing garments for longevity, along with a conscious effort to protect social and environmental rights by creating a buy-back program that has collected more than one million garments in just ten years to upcycle them into eco-preferred products (Eileen Fisher, n.d.). The pieces still in perfect condition are given a good-as-new cleaning and resold through their Renew program. The clothes that aren't in shape to be resold are used in their Waste No More campaign. The Waste No More team transforms the

clothing into one-of-a-kind artworks, pillows, and wall hangings using a custom felting method. The idea behind the creation of these new materials is developing new technology that decreases the environmental impact overall, like a unique needle-punch felting technique that no longer requires water or dying, making it better for the planet. In addition, recycling wasted materials and turning them into something instead of disposing them into landfills. The brand wants to bring more awareness to the importance of being more conscious of the massive environmental impact that the fashion industry continues to have on the planet.

### 2.6.3 Patagonia: Worn Wear

As the secondhand market becomes a bigger part of the retail industry, in 2017, the outdoor retailer Patagonia launched Worn Wear online, a resale business in which Patagonia buys customers' products in decent condition back in exchange for store credit. These products are then repaired, buffed up, and resold on the site. For years, Patagonia has been hosting Worn Wear pop-up events, where customers were invited to bring their used clothing items for repair or exchange. Due to the program's success, Patagonia launched the permanent online version of Worn Wear. So far, Worn Wear has sold more than 100,000 repurposed Patagonia items (Patagonia n.d.). The Worn Wear website also includes detailed product care guides for all fabrics carried in stores. Hence, Patagonia's Worn Wear program aims to reduce environmental impacts by encouraging people to change their relationship to stuff, through repair and reuse of what they already have, and by celebrating quality and durability.

### 2.6.4 Nudie Jeans: Repair for Life

In order to engage consumers in sustainable practice and provide them ways to prolong the lifetime of their clothing, Nudie Jeans offers a free repair service on all its denim. Thus, every pair of Nudie Jeans comes with a promise of free repair for life. Consumers can bring their pairs of worn-out Nudie Jeans to a repair shop, which is well-equipped with high profile repair stations (Nudie Jeans, n.d.). And even if customers live far from a Nudie Repair Shop, they can still get help to mend their jeans by ordering a free repair kit online and watch their videos to show how jeans can be repaired. This approach contributes in many ways to prolong the lifetime of the jeans. Not only does it recognize that denim can be repaired, but it also actually celebrates the act of repairing - thus adding emotional value to the new chapter in their lifecycle. In addition, Nudie Jeans products are made with 100% organic cotton denim, social responsibility, and transparent production. They also resell their second-hand products and recycle worn-out products.

### 2.6.5 The North Face Renewed

Much like the Patagonia Worn Wear program, in 2018, the outdoor brand The North Face launched a design program called Renewed. The North Face Renewed features a collection of clothing refurbished to Like-New condition. The program aims to divert unwanted apparel from landfills by repairing used garments to keep them in circulation. The renewed process has eight steps and six quality controls. The steps are as follow (The North Face, n.d.):

- *Step 1: Pre-sort.* Designers identify the type of the product and select for renewal based on its condition. Everything that can't be renewed is upcycled through the REMADE collection, donated or recycled.
- *Step 2: Sort.* With a more critical eye, technicians inspect garments to identify issues and prepare them to be refurbished. Practitioners identify if the repair can be done without being visually perceptive. The goal is to repair the garment in a way that consumers will not be able to differentiate refurbished apparel from the new condition.
- *Step 3: Identify.* Sort techs match products to their original data. If a style has been recalled or has known quality issues, it will be removed from production. New bar codes are added to track renewal and impact data.
- *Step 4: Clean.* Garments are cleaned to factory grade standards either using the Tersus CO2 cleaning system or high-capacity commercial washing machines.
- *Step 5: Inspect.* Repair technicians identify the processes that need to take place to restore garments to LIKE-NEW condition. Repairs are assigned based on time, complexity and capacity.
- *Step 6: Repair.* Garments are repaired based on standards provided by The North Face quality control team. Highly trained sew technicians ensure that all aspects of the repair meet or exceeds The North Face requirements.
- *Step 7: Finishing.* Finishers polish garments up removing any signs of lint, loose threads, or wrinkles.

- *Step 8: Quality assurance.* Quality assurance certifies that every garment meets or exceeds The North Face standards and there are no signs of exterior visible repairs, defects or imperfections.

With the Renewed program, The North Face is shifting from a traditional, linear model to a circular model where people share, resell, repair, and recycle clothing to keep them out of landfills and in the value chain. In order to train and educate their designers on the principles of circular design, the brand has created The North Face Design Residency. In the program, practitioners learn purposeful solutions that consider the complete lifecycle of garments. Designers apply these concepts while working on the repair and redesign to make future products more repairable, reusable, or recyclable. The of the designers that practiced in the program, Rebecca Homen (2020), reflected on the challenges to work with secondary materials because there is no protocols nor guidance to follow. Also, the challenge of creating design standards while creatively repairing damaged products. One outcome of the program is the creation of new standards to up-cycle and repair products. Moreover, design-led repair tech-packs allow the planning team to standardize processes and forecast future production.

## 2.7 Summary

Literature related to academic apparel product development processes, sustainable apparel product development processes, and how these are currently being

used in the apparel industry was reviewed in this chapter. This overview of the literature has provided the background for conducting this research.

Although the existing academic apparel product development models are helpful tools to guide students and designers to develop functional and sustainable apparel according to user needs, common apparel design processes often overlook the central role of materials to a successful design. Finding guidance for material selection is required because material plays an important role in the apparel design process. Existing sustainable apparel product development models do not acknowledge pre and post-consumer textile waste, such as deadstock fabric and upcycled materials, to the process of developing sustainable apparel products. Due to the growing amount of textile goods going to landfills every year, it is necessary to consider incorporating these materials into the design process of apparel. Incorporating waste back into the supply chain as 'raw materials' helps companies reduce waste, reuse valuable resources, and save costs on virgin materials at the same time. Therefore, apparel product developers must have methods to assist them with secondary use materials in the product development/design process.

# Chapter 3

# MODEL DEVELOPMENT

## 3.1 Overview

Collectively, apparel designers, sourcing specialists, and buyers are responsible for material selection during the product development process (Brahma and Lofthouse, 2007; Shaw and Koumbis, 2017). Despite the growing necessity of environmental practices in the apparel industry, usually, apparel design and fashion merchandising students are not taught to incorporate secondary materials into the product development process. Most apparel design and fashion merchandising students are trained to think in a linear way in which products are designed, produced, and eventually disposed of with virgin materials chosen largely by aesthetics and personal taste.

In the industry, there is a lack of protocols to assist fashion practitioners to incorporate secondary materials into the product development process. Likewise, academic models of product development do not consider secondary materials, nor do they consider tacit knowledge. Bye and Griffin (2015) noted the importance of a hands-on manipulation approach while working with material because it encourages experimentation, which can lead to innovation. The author stated that "working directly with materials can help individuals make new original connections by enhancing their intuition, critical thinking, and ability to find patterns" (p.150). Consequently, fashion practitioners could use their tacit knowledge gained through

their experience to solve environmental issues in their work. Hence, a model is needed that maps out the questions to ask when adopting a secondary material for product development. The main research questions for this study were: **(1) can a sustainable material selection model based on sensory and visual evaluations guide future fashion professionals to make more sustainable choices in the product development process? (2) Can a sustainable material selection model based on sensory and visual evaluations guide future fashion professionals to embed secondary materials into the apparel product development process?**

## 3.2 Model Development

The purpose of this research was to offer guidance to product developers through a model that embeds a material selection strategy into the traditional process of product development. Specifically, this research involved the development of a model as well as initial testing within a design process to evaluate the effectiveness of the model. To achieve this, the researcher followed a three-phase design approach that involved (1) generate criteria, (2) model development, and (3) test/evaluate the model in the design classroom.

### *Phase 1: Generate criteria*

The objective of phase one was to generate criteria to determine constructs for developing a sustainable material selection model. Through exploratory practice-led materials research, the researcher gained better understanding of potential criteria

including evaluative and design approaches. In addition to exploratory design exercises, (see appendix F) the researcher conducted literature review and contextual market review to determine constructs for the development of the new model. In this phase, the author aimed to address the following questions:

1. What considerations are required to develop a model that embeds secondary materials into the apparel product development process?
2. How might a process model guide apparel product developers toward more sustainable choices?

***Phase 2: Sustainable material selection model development***

During phase two, the Sustainable Material Selection Model (SMSM) was developed based on criteria generated from phase 1. The criteria included the importance of developing a holistic model that had a combination of information, guidance, and education, along with well-considered content, proper presentation, and easy access (Lofthouse, 2006). Product developers are motivated by visual-based content and prefer information presented, with maximum graphics use and minimal text (ibid.). Hence, criteria such as design/user-friendly, interactive, visual/sense forward were adopted for the model development. Moreover, the content provided in tools for sustainable fashion design needs to be presented in an appropriate language for product developers, thus, avoiding technical/scientific jargon (Kozlowski et al., 2019). In this sense, the language selected for the SMSM consists of existing simple 'nuggets' of information appropriated for fashion product developers, along with

visual demonstrations. Such as demonstrations of the importance of fiber content, structure, properties, condition, design details, and surface elements. Finally, the model access was another important criterion. A web-based format was chosen due to its practical, ease, and timing saving access (Lofthouse, 2006). This approach also allows for the content to be derived in a highly visual and interactive way, making it very appropriate to the product developers' way of working (ibid.).

The SMSM consists of ten steps including (1) identification of fiber content; (2) identification of fabric structure; (3) fabric stretch; (4) grain; (5) surface finishing; (6) identification of fabric condition; (7) identification of trims and findings; (8) identification of trims and findings conditions; (9) identification of design details; (10) identification of decorative stitches (see figure 3.1).

**Step 1 - identification of fiber content**. Fibers are spun into yarns, which are used to manufacture fabrics, which are in turn used to manufacture products such as apparel, curtains, bedding, and so on. Therefore, all textile artifacts contain fibers that can be natural or synthetic (man-made) (Fashionary, 2020). Fiber identification is important because different fiber types have distinct characteristics. A particular fiber or even fiber blend could impact the material's overall performance qualities such as drape, insulation, and wash care. Thus, it is an essential first step in predicting the behavior of a textile artifact in various designs and environments. Moreover, knowing the identity of the fiber helps the product developer plan appropriate designs for the future product, conservation treatment(s), and/or storage methods.

**Step 2 - identification of fabric structure.** There are three types of fabric structures woven, knit, and non-woven (Fashionary, 2020). Woven fabrics are made by interlacing two or more sets of yarn. Knit fabrics are made by inter-looping yarns and stretch in both directions. Non-woven refers to fabrics that are neither woven or knitted. They are fabrics formed through methods that entangle and bond fibers mechanically, thermally, or chemically. Each fabric structure has different distinct characteristics and behavior, all of which affect their end-use. Therefore, identification of the fabric structure is important because it can indicate which item the product developer could create. Also, it can guide the selection of fabrics that will behave as needed for a particular design.

**Step 3 - fabric stretch.** By identifying the stretch direction and stretch percentage of textile, the product developer can determine the appropriate use of the material according to its given characteristic and behavior.

**Step 4 – fabric grain.** Grain is the direction of the yarns in a fabric. The grain is very important when constructing garments because it determines and affects the drape of the garment greatly (Fashionary, 2020).

**Step 5 – surface finishing.** A finishing process is an additional chemical or mechanical treatment applied to change a fabric's appearance or properties (Fashionary, 2020). A finishing process is often used to change the aesthetic or function of a fabric, including printing and dyeing.

**Step 6 – identification of fabric condition.** The fabric condition can determine its use. As an example, in case of the presence of defects or damage in a

textile, the product developer could find creative solutions and appropriate design use for the material.

**Step 7 – identification of trims and findings.** Analysis of all components in a garment besides the actual fashion fabric. Thus, it could be trims, labels, threads, elastics, underlying fabrics, zippers, buttons, closures, and so on.

**Step 8 – identification of trims and findings conditions.** A similar idea from step 6, The trims and findings conditions condition can determine the material used.

**Step 9 – identification of design details.** Garment details or component parts: elements of garment silhouettes that provide aesthetic interest or provide functionality. Examples include collars, cuffs, pockets. (Keiser and Garner, 2012, p. 229)

**Step 10 – identification of decorative stitches.** Decorative effects: Embellishments that are added to the fabric of a garment, such as smocking, quilting, tucking, and embroidery (Keiser and Garner, 2012, p. 524)

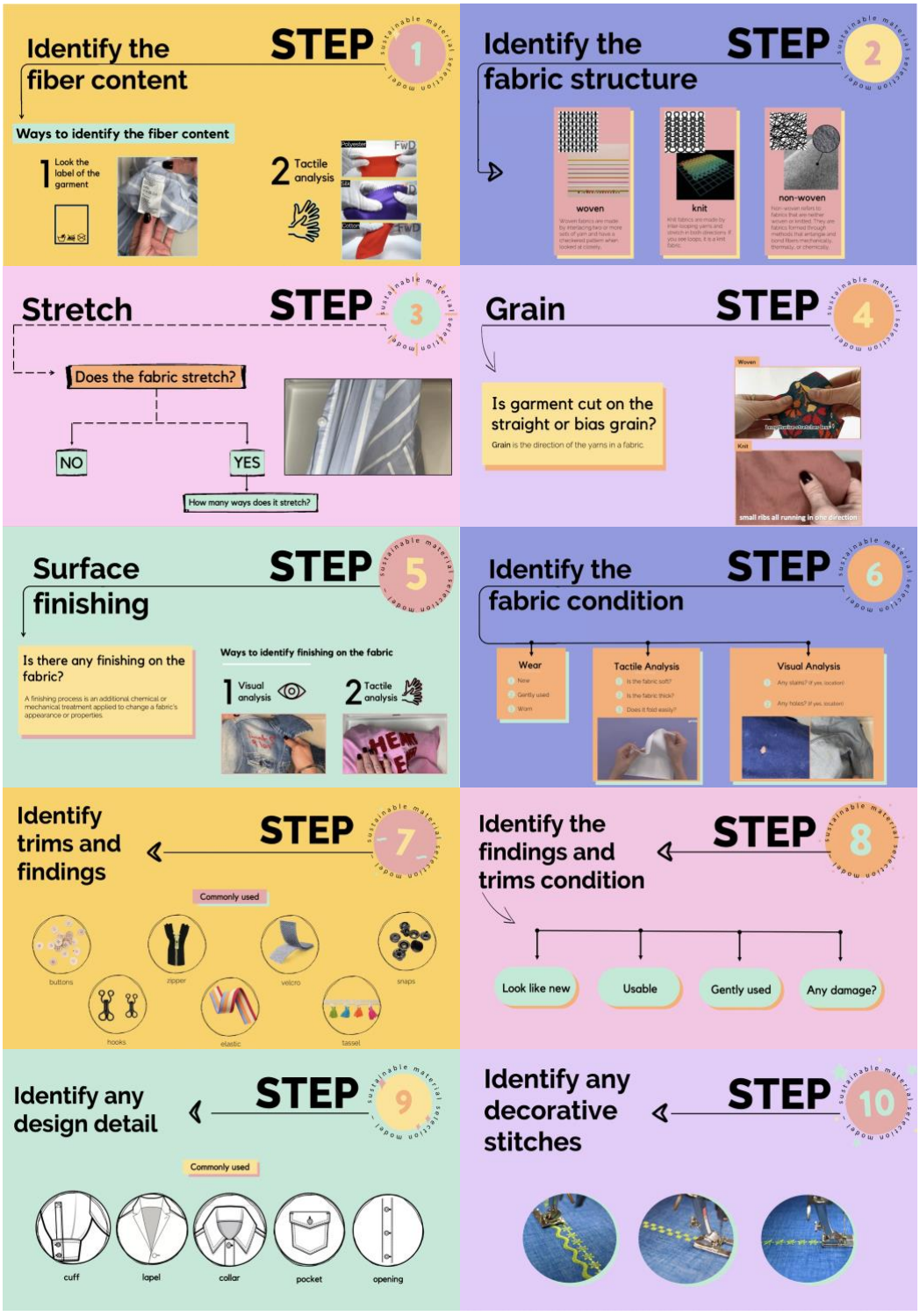



Figure 3.1. Sustainable Material Selection Model

***Phase 3: Test and evaluation of the model***

The objective of phase three was to apply the SMSM to a design process and then evaluate the effectiveness of the model. Further details of this phase are discussed in the evaluation methodology section. In this phase, the author aimed to address the following questions:

3. Can a sustainable material selection model based on sensory and visual evaluations guide future fashion professionals to make more sustainable choices in the product development process?

4. Can a sustainable material selection model based on sensory and visual evaluations guide future fashion professionals to embed secondary materials into the apparel product development process?

5. Do the perceptions of the model differ based on discipline or curriculum focus (i.e., merchandising/business, design/creative)?

# Chapter 4

# EVALUATION METHODOLOGY

This research involved the development of a model as well as initial testing within a design process to evaluate the effectiveness of the model. In order to evaluate the effectiveness of the SMSM, the model was applied to a design process in an apparel development lab setting. This section will cover the methodology used to evaluate the effectiveness of the SMSM.

## 4.1 Design

The method of inquiry for this study follows mixed-method experimental research design consisting of questionnaire and pre-post testing. Two online questionnaires were used to obtain knowledge about the participants and collect responses to specific questions directed at their attitudes, beliefs, behaviors, or perceptions (Wrench et al., 2019). A mixed-methods design is characterized by the combination of at least one qualitative and one quantitative research component (Johnson et al., 2007). Therefore, both questionnaires (pretest and posttest) developed for this study consisted of open- and close-ended questions. The mixed-method questions were implemented to gain a depth understanding of participants' perspectives on the use of the newly developed model. According to Nataliya et al., 2006, “when used in combination, quantitative and qualitative methods complement each other and allow for a more robust analysis, taking advantage of the strengths of each" (p.3). Specifically, surveying with open-ended questions can offer the researcher

valuable, deep, unconstrained participant responses to general questions, allowing participants the possibility to express their perspective using their terms and expressions (Wrench et al., 2019).

To capture valuable insight from student participants, a pre-post test method was selected as it "is mostly implemented by social scientists to evaluate the effectiveness of educational programs, the restructuring of social groups and organizations, or the implementation of behavioral interventions" (Allen, 2017, p.2). The pre-post test consisted of similar questions asked before and after the model activity. Both questionnaires were designed to gather participants' general knowledge about secondary materials, criteria to select materials and perceptions about the use of the SMSM.

## 4.2 Procedure

The Internal Review Board (IRB) accepted the parameters of this study with exemption. The Human Subjects Protocol, Informed Consent to Participate in Research, and IRB Approval forms can be found in Appendices C-F and with the IRB Net reference number 1704018-1. Upon approval from the University of Delaware IRB approval, the researcher developed a product development activity to be applied in two undergraduate courses. The activity had two phases, and it was expected to take 1 hour of the class time. Phase one participants were asked to explore, manipulate, and evaluate the secondary materials they had. They used the SMSM to

guide this exploratory phase. In phase two, participants were asked to use the information they collected in phase one to create a new fashion item with the secondary materials they had just analyzed. Participants were asked to sketch their designs. The activity was completed via the online learning platform Canvas, which allows students to access course materials, grades, assignments, and quizzes through their own account. A quiz was created by embedding the videos, images, and gifs into the question boxes.

Prior to the product development activity, all the participants were asked to answer a pretest questionnaire, where participants' (a) knowledge about secondary materials, (b) previous experience with upcycling and repurposing, (c) criteria to select materials, and (d) demographic information were assessed.

A posttest survey was conducted after participants had completed the product development activity. On the posttest survey, participants provided reflective responses to evaluate the effectiveness of the SMSM in the product development process. The survey consisted of questions concerning: (a) knowledge about secondary materials, (b) criteria to select materials, (c) perceptions about the SMSM, and (d) demographic information. Both pretest and posttest questionnaires were administered through Qualtrics.

### 4.3 Participants

The population of interest for this study were current and/or future fashion professionals involved in the product development process. Participants were recruited

through convenience sampling. The researcher contacted two professors who teach undergraduate fashion courses at the University of Delaware. With the professors' assistance, the researcher sent the invitation to participate in the study to the students via email. Classes included Advanced Apparel Product Development and Management (APDM) and Research and Discovery (RD). APDM covers all phases of apparel product development for a targeted market from conceptualization through execution of sample garments for mass production, and RD covers research methods and discovery in carrying out projects generating new knowledge and solutions to problem-solving.

The email sent to the students briefly explained what the research study was about, what will make them eligible to participate, how interested participants could participate in the study, and the Informed Consent Form with the IRB approval. The Informed Consent Form briefed the participants about the study procedure and other information such as risk/ discomforts and benefits of participation, and assurance of anonymity. Additionally, the Informed Consent Form provided the contact information of the University's Institutional Review Board for questions about the study and participant rights.

***Pretest.*** Participants were 24 females who were of traditional college age (18-24) enrolled in two apparel design classes at the University of Delaware. Classes included Advanced APDM (n = 8) and RD (n = 16). The majority of the participants were academic juniors (46%, n=11), while 42% (n=10) were senior, 4% (n=1)

sophomore, and 8% (n=2) other. The academic associations of the students were as follows: 54% (n=13) were Design major; 46% (n=11) Merchandising major.

***Posttest.*** Participants were 25 females who were of traditional college age (18-24) enrolled in two apparel design classes at the University of Delaware. Classes included Advanced APDM (n = 10) and RD (n = 15). The majority of the participants were academic seniors (48%, n=12), while 44% (n=11) were junior, and 8% (n=2) other. The academic associations of the students were as follows: 60% (n=15) were Design major; 40% (n=10) Merchandising major.

## 4.4 Materials and Instruments

The SMSM was used during phase one of the product development activity to guide participants to evaluate the secondary materials used in the activity. A design worksheet (see appendix A) was developed to guide participants during the whole product development activity. The secondary materials used in this study included participants' unwanted or unusable personal clothing. The activity was completed via the online learning platform Canvas in a quiz format (see appendix B).

To measure participant's perceptions of the SMSM, items from Davis et al. (1992) perceived usefulness and ease of use scale were used. All the selected items were adapted to fit the context of this study (table 4.1). The questions were measured on a 5-point Likert scale (1 being "Strongly agree" to 5 being "Strongly disagree").

Table 4.1.Items adapted from Davis et al. (1992).

| Construct | Items |
|---|---|

| | |
|---|---|
| Perceived usefulness | It would be difficult to develop a fashion product which embeds secondary material without the sustainable material selection model.<br>Using the sustainable material selection model improved my design performance.<br>The sustainable material selection model addressed my design-related needs.<br>Using the sustainable material selection model saved me time. Using the sustainable material selection model made it easier to do my design process.<br>Overall, I find the sustainable material selection model useful. |
| Perceived ease to use | I found it easy to follow the material selection model.<br>I found it cumbersome to use the material selection model. *<br>My interaction with the material selection model was easy for me to understand<br>The material selection model provided helpful guidance to work with secondary materials.<br>The use of the material selection model was confusing. *<br>Interacting with the material selection model required a lot of my mental effort. *<br>Overall, I found the material selection model easy to use. |

*Reversed coded items

### 4.5 Data Analysis

The quantitative part of the data was analyzed in SPSS using descriptive statistics. A one-sample t-test was run to determine whether the mean of participants' perceptions of usefulness and ease of use of the model was significantly greater or less than 3. The independent sample t-tests were used to compare the mean between design and merchandising students' major on their perceptions of the model.

Thematic analysis approach was used to analyze participants' reflective responses. Braun and Clarke (2006) define Thematic analysis as "a method for

identifying, analyzing and reporting patterns within qualitative data" (p. 79). This method of data analysis has been described as a useful method for researchers because it facilitates the organization of data while capturing valuable information (Braun & Clarke, 2006). The thematic analysis allows the researcher to interpret responses to determine common perspectives among participants (ibid.). The qualitative coding software NVivo 11.0 was used for identification and categorization of themes, categories, subcategories, and frequencies. Initial categories were identified by visual overview of reflections and then subcategories were identified, reviewed, and edited to reflect content. Coding was performed by the author of this study and verified by the faculty advisor.

# Chapter 5

# RESULTS

This chapter contains the quantitative and qualitative results of the study. This section will disclose and overview the significant themes related to the research questions as identified from the questionnaires (pretest and posttest).

## 5.1 Validation/Evaluation of the SMSM: *Quantitative analysis*

After using the model in the product development process, participants were asked to evaluate the SMSM. Participants' perceptions of usefulness and ease of use of the SMSM were used to evaluate the effectiveness of the model. A one-sample t-test was run to determine whether the mean of participants' perceptions of usefulness and ease of use of the model was significantly greater or less than 3. Overall, the means were statistically significantly lower than 3. The means and p-values are reported in Table 5.1. and Table 5.2.

Table 5.1. Statistical results of participants' evaluation of the model (H0: All population Mean = 3).

| Items – *perceived usefulness* | N | M | SD | p-values of t-tests |
|---|---|---|---|---|
| It would be difficult to develop a fashion product which embeds secondary material without the sustainable material selection model. | 25 | 2.80 | 1.08 | .364 |
| Using the sustainable material selection model improved my design performance. | 25 | 2.08 | .572 | .000 |

| | | | | |
|---|---|---|---|---|
| The sustainable material selection model addressed my design-related needs. | 25 | 1.96 | .611 | .000 |
| Using the sustainable material selection model saved me time. | 25 | 2.32 | .802 | .000 |
| Using the sustainable material selection model made it easier to do my design process. | 25 | 1.96 | .735 | .000 |
| Overall, I find the sustainable material selection model useful. | 25 | 1.60 | .645 | .000 |

Note: 5-point Likert scale: 1 being “Strongly agree” to 5 being “Strongly disagree”.

Table 5.2.Statistical results of participants’ evaluation of the model (H0: *All population* Mean = *3*).

| Items – *perceived ease of use* | N | M | SD | p-values of t-tests |
|---|---|---|---|---|
| I found it easy to follow the material selection model. | 25 | 1.12 | .332 | .000 |
| I found it cumbersome to use the material selection model. * | 25 | 3.88 | 1.23 | .002 |
| My interaction with the material selection model was easy for me to understand. | 25 | 1.36 | .490 | .000 |
| The material selection model provided helpful guidance to work with secondary materials. | 25 | 1.56 | .651 | .000 |
| The use of the material selection model was confusing. * | 25 | 4.24 | .970 | .000 |
| Interacting with the material selection model required a lot of my mental effort. * | 25 | 1.60 | .645 | .000 |
| Overall, I found the material selection model easy to use. | 25 | 1.32 | .476 | .000 |

Note: 5-point Likert scale: 1 being “Strongly agree” to 5 being “Strongly disagree”.

*Reversed coded items

The independent sample t-tests were used to compare the mean between design and merchandising students' major on their perceptions of the model. Perceiving the SMSM useful did not differ significantly between Design major (M = 1.60, SD =.74) and Merchanting majors (M = 1.60, SD =.52) in an independent samples t-test, t(22.890) = .000, p = 1.00.

Perceiving the SMSM ease to use did not differ significantly between Design major (M = 1.33, SD =.49) and Merchanting majors (M = 1.30, SD =.48) in an independent samples t-test, t(19.584) = .168, p = .87.

Belief that the SMSM provided helpful guidance to work with secondary materials to use did not differ significantly between Design major (M = 1.67, SD =.72) and Merchanting majors (M = 1.40, SD =.52) in an independent samples t-test, t(22.833) = 1.075, p = .29

Belief that the SMSM improves the design performance did not differ significantly between Design major (M = 2.27, SD =59) and Merchanting majors (M = 1.80, SD =.42) in an independent samples t-test, t(22.851) = 2.297, p = .03

## 5.2 Validation/Evaluation of the SMSM: *Qualitative analysis*

A summary of the themes found in participants' reflective responses is presented in Table 5.3, Table 5.4, Table 5.5, Table 5.56, and Table 5.7.

***Behavior/attitude change***

On the pretest questionnaire, participants were asked to indicate the reasons to have chosen the materials for their past three designs. The themes and frequencies found in participants' responses are outlined in Table 5.3. Outlined frequencies reflect direct statements made by participants.

Table 5.3.Summary of Student Responses Pretest: Think about your past three designs. How or why did you select the fabric(s) or material (s) for those designs?

| Theme: *Main ideas (reasons for material selection)* | Frequency |
|---|---|
| Aesthetic | 2 |
| Color | 4 |
| Design Concept | 3 |
| Fabric Characteristic | 8 |
| Fabric Composition | 3 |
| Secondary Fabric | 4 |
| Texture | 4 |

In order to identify behavior/attitude change towards material selection, on the posttest questionnaire, participants were asked to indicate future considerations or criteria they will use to select materials. The themes and frequencies found in participants' responses are outlined in Table 5.4. Outlined frequencies reflect direct statements made by participants.

Table 5.4.Summary of Student Responses Posttest: Moving forward for future designs, what considerations or criteria will you use to choose fabric and material?

| Theme: *Main ideas (reasons for material selection)* | Frequency |
|---|---|
| Durability | 2 |
| Material Characteristic | 5 |
| Quality | 2 |
| Secondary Materials | 9 |
| Sustainability | 14 |
| Texture | 1 |

Results suggest the use of the SMSM impacted participants' decision-making. On the pretest, participants reported texture, color, aesthetic, and comfort as criteria used to select fabric and materials to create fashion products. After the use of the SMSM, participants expressed that they would consider using secondary materials to develop future designs and sustainability principles.

***Model evaluation/validation***

90% of the participants believe that the SMSM provided helpful guidance to the development of the fashion product. The reasons were identified, and it is arranged by themes and frequencies outlined in Table 5.5. Outlined frequencies reflect direct statements made by participants.

Table 5.5.Summary of Student Responses Posttest: Did the sustainable material selection model provide helpful guidance to the development of the fashion product? Why or why not?

| Theme: *Main ideas (reasons for helpful guidance)* | Frequency |
|---|---|
| Clear instructions | 3 |
| Helpful to consider details | 7 |
| Helpful to generate ideas | 7 |
| Helpful to material identification | 9 |
| Helpful to sustainability awareness | 3 |

90% of the participants indicated that the SMSM was easy to follow and understand. The reasons were identified, and it is arranged by themes and frequencies outlined in Table 5.6. Outlined frequencies reflect direct statements made by participants.

Table 5.6. Summary of Student Responses Posttest: Was the sustainable material selection model easy to follow and understand? Why or why not?

| Theme: *Main ideas (reasons for being easy to follow and understand)* | Frequency |
|---|---|
| Clear directions | 6 |
| Concise model | 2 |
| Good examples | 1 |
| Helpful to the design process | 5 |
| Length | 2 |
| Simple to follow | 4 |
| Steps-by-step format | 3 |
| Straightforward directions | 4 |
| Video format | 5 |

Participants' reflective responses indicated that 88% of the participants consider using the SMSM in the future for developing an apparel product that embeds secondary material. The reasons for considering using the model were identified, and it is arranged by themes and frequencies outlined in Table 5.7. Outlined frequencies reflect direct statements made by participants.

Table 5.7. Summary of Student Responses Posttest: Would you consider using the sustainable material selection model in the future for developing an apparel product that embeds secondary material? Why or why not?

| Theme: *Main ideas (reasons for considering using the model)* | Frequency |
|---|---|
| Facilitate the design process | 6 |
| Helpful to material evaluation and identification | 5 |
| Length | 2 |
| Sustainability reasons and values | 7 |
| Useful | 2 |

# Chapter 6

# DISCUSSION & CONCLUSION

The results gathered through the two questionnaires offered insights into the five research questions proposed in this study. This chapter discusses and analyses the results of the study relevant to individual research questions, as well as cross-case analysis.

## 6.1 Discussion

The purpose of this study was to offer guidance to product developers through a model that embeds a material selection strategy into the traditional process of product development. Additionally, this study sought to validate the newly developed model as an effective and valuable tool to be used during the product development process.

Participants agreed the model was easy to use and useful when working with secondary materials. The common reasons found were that the model was "*simple to navigate*", the instructions were "*fairly straightforward*", "*clear and concise*". Participants also mentioned that "*there were good examples of the different concept*" and "*each step was not too long*". In a fast-paced industry, learning and using a tool can be time-consuming and become a barrier to implement sustainability into the design process (Kozlowski et al., 2019). The feedback from participants shows the model was simple to follow and provided clear, concise, and straightforward instructions with practical examples. Thus, the results suggest the use of the model

would not take much time in the design process and could be carried out on a regular basis.

Previous research suggests that sustainable tools should “be presented in a highly visual and interactive way, making it very relevant to the designers’ way of working” (Lofthouse, 2006, p.1388). This study is consistent with this finding. Participants liked the video and step-by-step format chosen to deliver the content. Several participants mentioned that the videos facilitate the use of the model. Participants used phrases including “*the model was easy to follow because of the video clips given for each step*” and “*it was primarily easy to follow and understand with the help of the videos*”. Furthermore, participants also thought “*the step-by-step process made it easy*”.

The general reaction of the participants was that the model provided helpful guidance to the development of the fashion product because it helps with material and details identification. Participants used phrases including “*it helped me understand the material that I was working with better and pointed me in a direction of what type of products that I could potentially design*” and “*it helped me realize the small design components that go into making a garment and whether that can manipulate its secondary use*".

Furthermore, the findings suggest that the SMSM can stimulate and enhance the user's creativity. Participants' reflection responses express that the model “*provided a structure for creating and developing ideas*” and “*helped me to better understand how to utilize material that is already there to create something new*”.

The feedback from the participants also indicated that the model had educational value in sustainability awareness. Due to the combination of information and guidance, participants stated that the model "*provides insight to the most effective material to use in design to reduce any negative impact to the environment*" and "*it made me aware of the importance to upcycle.*". A summary of additional student quotes about the reasons the model was helpful to the product development process can be found in Table 6.1.

Table 6.1. Summary of Student Responses: Did the sustainable material selection model provide helpful guidance to the development of the fashion product? Why or why not?

| Themes: Helpful to… | Participant responses |
|---|---|
| Consider details | "Yes, the model stepped me through all details I should consider when trying to make a new design out of existing materials." |
| | "The model made me look into details of the garment that I might not have considered which strengthened the overall process." |
| Generate ideas | "It gave me some new ideas on how to use the fabric when designing my new garments." |
| | "It helped me understand the fabric which gave me an idea of what it could be repurposed for". |
| | "I think it did because it helps give inspiration for designers to think outside the box on how materials could be implemented". |
| Material identification | "It helped me understand the material that I was working with better and pointed me in a direction of what type of products that I could potentially design". |

| | |
|---|---|
| | "Yes, because we analyzed the structure of the fabric, the fiber content, etc. This helps the designer know what the original product is made of which helps in designing a future product from the secondary material." |
| Sustainability awareness | "I now know how beneficial it is to upcycle." |

Moreover, 88% of the participants consider using the SMSM in the future for developing an apparel product that embeds secondary material. The common reasons were that the model facilitates the design process, helps participants to efficiently evaluate the material, and incorporates sustainable practices into the design. Participants used phrases including "*it [the model] keeps you organized and on track, so you do not miss any crucial steps in the process*" and "*I think it is a good start at brainstorming what components your garment or secondary materials consist of. It makes you aware of all the things or components of a material that should be considered*".

In alignment with previous literature, participants reflect on the importance of sustainable practices in the apparel industry. One participant stated, "*unfortunately, sustainability can get neglected when designing garments. It is important to continue to find sustainable ways to create designs. The model is an important reference to take notice of throughout the design process*." Another participant mentioned, "*the model made me aware of how beneficial secondary materials are to fashion*". According to the findings in this study, the apparel industry still lacks sustainable practices. One main reason could be that fashion students are not usually trained to work with

secondary materials (Palomo-Lovinski and Kim, 2014). Research suggests the greatest opportunity for secondary materials is to repurpose them into new products (Hawley, 2011). However, education and understanding are scarce of sustainability in fashion and tangible ways to enact change in creating clothing (Kozlowski et al., 2019). Therefore, the SMSM could serve as an educational tool to be used to train fashion students to work with reclaimed textiles.

Additionally, the results of this study suggested that the use of the SMSM can impact participants' decision-making. On the pretest, participants reported texture, color, aesthetic, and comfort as criteria used to select fabric and materials to create fashion products. After the use of the SMSM, participants expressed that they would consider using secondary materials to develop future designs and sustainability principles. Students used phrases including "*I would like to use secondary fabric because I feel like there is so much of it so I would like to consider using it in future designs*" and "*I will make sure to consider what materials I already have to include in any designs or new upcycle projects*".

Finally, the results show that perceptions of the usefulness of the SMSM did not differ significantly between participants with no design background and extensive design background. This finding suggests that the model could be a beneficial and valuable tool to be used by designers, sourcing specialists, and buyers, which usually are fashion professionals involved and responsible for material selection during the product development process (Brahma and Lofthouse, 2007; Shaw and Koumbis, 2017).

## 6.2 Limitations and Future Research

This study is limited by the small number of participants and lack of a control group. The participants consist of a convenience sample of apparel design students at one university, therefore limiting the sample size and preventing random sampling.

Further, the sample size is small. Due to the small sample size and sampling limitations, the generalizability of the results to other universities must be taken with caution.

This study only provides a preliminary evaluation of the validity of the SMSM, and future studies with a greater number of participants need to be conducted.

The SMSM is a newly developed model with great potential to guide product developers to embed secondary materials into the product development process. Future application of the model is necessary to further validate the model in a corporation setting to understand its usefulness, as well as explore the benefit of the model to the product development process. Additionally, further work could include an investigation into how the SMSM model could be useful in industries beyond fashion.

## 6.3 Conclusions and Implications

This study successfully developed a model that offers guidance to fashion practitioners to embed textile waste as a sustainable material selection strategy into the traditional product development process. The SMSM is a highly beneficial and valuable tool that serves as a critical need in the apparel industry to guide apparel

design students and practitioners to embed secondary materials into the product development process. This study builds off previous research, filling a gap in sustainable strategies in product development by offering a tool to help apparel designers to make better, more sustainable choices in the product development process.

Through sensory and visual evaluations, the model guides product developers to make more sustainable choices within the materials selection phase of the apparel product development process. The model offers a hands-on manipulation approach while working with materials. “Working directly with materials can help individuals make new original connections by enhancing their intuition, critical thinking, and ability to find patterns” (Bye and Griffin, 2015, p.150). The model helps product developers to generate ideas to solve environmental issues in their work.

The results of this study show the SMSM could serve beyond as a potential source of inspiration and creativity. The model is a functional tool that provides product developers information and guidance they need to get started to embed sustainability early in the design process. This combination of information, guidance, and education helps product developers to build up their tacit eco-design knowledge, and/or support idea generation at the beginning of a sustainable project.

The apparel industry is fast-paced. Therefore, product developers need a tool that takes up little time and can be referred to as and when required (Kozlowski et al., 2019). In this context, the SMSM was developed targeting how product developers work on a day-to-day basis. The feedback from participants shows the model was

simple to follow and provided clear, concise, and straightforward instructions with practical examples. In this sense, the model would not take much time in the design process and could be carried out on a regular basis.

Additionally, feedback from participants suggested the importance of a visually based and easy access content delivery. Several participants reported how the videos facilitate the use of the model. Product developers are motivated by visual-based content and prefer information presented, with maximum graphics use and minimal text (Lofthouse, 2006). Therefore, the visual and interactive approach of the model is highly beneficial in facilitating the use of the model.

A model that incorporates sustainable strategies into product development is beneficial beyond apparel, offering opportunities for many industries including automotive and home goods. Moreover, the SMSM could also serve as an educational tool to be used in both industrial and an academic setting.

## REFERENCES


Allen, M. (2017). *The sage encyclopedia of communication research methods* (Vols. 1-4). Thousand Oaks, CA: SAGE Publications, Inc. doi:10.4135/9781483381411

Armstrong, C. M., & LeHew, M. L. A. (2011). Sustainable apparel product development: in search of a new dominant social paradigm for the field using sustainable approaches. *Fashion Practice*, *3*(1), 29–62. https://doi.org/10.2752/175693811X12925927157018

Bhamra, T., & Lofthouse, V. (2007). *Design for sustainability: a practical approach* (Ser. Design for social responsibility series). Gower.

Burke, S. (2008). *Fashion Entrepreneur: Starting Your Own Fashion Business*. Dorset: Ringwood.

Bye, E., & Griffin, L. (2015). Testing a model for wearable product materials research. *International Journal of Fashion Design, Technology and Education*, *8*(2), 139–150. https://doi.org/10.1080/17543266.2015.1018959

Cao, H., Chang, R., Kallal, J., Manalo, G., McCord, J., Shaw, J., & Starner, H. (2014). Adaptable apparel: a sustainable design solution for excess apparel consumption problem. *Journal of Fashion Marketing and Management*, *18*(1), 52–69. https://doi.org/10.1108/JFMM-08-2012-0046

Carrico, M., & Kim, V. (2014). Expanding zero-waste design practices: a discussion paper. *International Journal of Fashion Design, Technology and Education*, *7*(1), 58– 64. https://doi.org/10.1080/17543266.2013.837967

Chapman, J. (2009). Design for (Emotional) Durability. *Design Issues*, *25*(4), 29–35. https://doi-org.udel.idm.oclc.org/10.1162/desi.2009.25.4.29

Claudio, L. (2007). Waste couture: environmental impact of the clothing industry. Environmental Health Perspectives, 115(9), 454. http://www.jstor.org/stable/4626880

Climatex (n.d.). *Textile Lock.* https://www.climatex.com/en/sustainability/textile-lock/

Council for Textile Recycling, (2020). *Issue.* https://www.weardonaterecycle.org

Dieter, G., E. (1997). Overview of the materials selection process. ASM International, 4, 243–254. https://doi.org/10.31399/asm.hb.v20.a0002450

Eileen Fisher (n.d.). *Waste no more.* https://www.wastenomore.com

Ellen MacArthur Foundation (2017). *A new textiles economy: Redesigning fashion's future.* http://www.ellenmacarthurfoundation.org/publications

Environmental Protection Agency (2020). *Facts and Figures about Materials, Waste and Recycling.* https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/textiles-material-specific-data

European Commission (2011). *Ecodesign your future.* https://ec.europa.eu/growth/policies/sustainable-business/ecodesign/files/brochure_ecodesign_en.pdf

Fashionary. (2020). *Textilepedia: the complete fabric guide*. Fashionary International

Fletcher, K., 2008. Sustainable Fashion and Textiles: Design Journeys. Earthscan, London.

Forst, L. (2020). Disassembly discussed: creative textile sampling as a driver for innovation in the circular economy. *Journal of Textile Design Research and Practice, 8*(2), 172– 192. https://doi.org/10.1080/20511787.2019.1667156

Galijasevic, A. (2020). *Episode 188 - G-star raw on circularity + their 100% recyclable denim icons.* https://consciouschatter.com/podcast/2020/2/25/s04-episode-188-g-star-raw-cradle-the-cradle-gold-certified-recyclable-denim

Gam, H. J. (2007). *Development and implementation of a sustainable apparel design and production model* (dissertation).

Gam, H. J., Cao, H., Farr, C., & Heine, L. (2009). C2CAD: a sustainable apparel design and production model. *International Journal of Clothing Science and Technology, 21*(4), 166–179. https://doi.org/10.1108/09556220910959954

Graedel, T., & Allenby B. (1995). Industrial ecology. Englewood Cliffs (NJ): Prentice Hall.

Gwilt, A. (2015). *Fashion design for living*. Routledge, Taylor & Francis Group.

Gwilt, A., & Pal, R. (2017). Conditional garment design for longevity. In PLATE: Product Lifetimes And The Environment (Vol. 9, pp. 149–153). https://doi.org/10.3233/978-1-61499-820-4-149

Gwozdz, W., Kristian, S. N., & Müller, T. (2017). An environmental perspective on clothing consumption: consumer segments and their behavioral patterns. (2017). *Sustainability, 9*(5), 762–762. https://doi.org/10.3390/su9050762

Ha-Brookshire, J. E., & Hodges, N. N. (2009). Socially responsible consumer behavior?: exploring used clothing donation behavior. *Clothing and Textiles*

*Research Journal*, *27*(3), 179–196. https://doi.org/10.1177/0887302X08327199

Hakkio, S., & Laaksonen, P. (1998). Relationships in marketing channels: examining communication abilities through cognitive structures. *Psychology & Marketing*, *15*(3), 215–240. https://doi.org/10.1002/(SICI)1520-6793(199805)15:3<215::AID-MAR2>3.0.CO;2-D

Han, S., Tyler, D., & Apeagyei, P. (2015). Upcycling as a Design Strategy for Product Lifetime Optimisation and Societal Change. *PLATE (Product Lifetimes And The Environment) Conference.*

Han, S. L. C., Chan, P. Y. L., Venkatraman, P., Apeagyei, P., Cassidy, T., & Tyler, D. J. (2017). Standard vs. upcycled fashion design and production. *Fashion Practice*, *9*(1), 69–94. https://doi.org/10.1080/17569370.2016.1227146

Hawley, J. M., (2006). Digging for Diamonds: A Conceptual Framework for Understanding Reclaimed Textile Products. *Clothing and Textiles Research Journal, 24(3),* 262-275. https://doi.org/10.1177/0887302X06294626

Hawley, J. M., (2011b). TEXTILE RECYCLING OPTIONS: Exploring What Could Be. In Gwilt, A., & Rissanen, T. (Ed.), *Shaping Sustainable Fashion: Changing the Way We Make and Use Clothes* (1st ed., pp. 143–164). Routledge.

Irick, E., Eike, R. J., Cho, S., & Kim, M. (2020). Repurposing apparel: a guided process for sustainable design education. *International Journal of Fashion*

*Design, Technology and Education*, *13*(3), 280–291. https://doi.org/10.1080/17543266.2020.1788652

Jenkyn Jones, S. (2005). *Fashion Design*. 2nd ed. London: Laurence King.

Johnson, R., Onwuegbuzie, A., & Turner, L. (2007). Toward a definition of mixed methods research. Journal of Mixed Methods Research, 1(2), 112–133. https://doi.org/10.1177/1558689806298224

Keiser, S. J., & Garner, M. B. (2012). *Beyond design: the synergy of apparel product development* (Third). Fairchild.

Koberg, Don and Jim Bagnall. 1972. *Universal Traveler*. Los Altos, CA: William Kaumann.

Koo, H. S., Dunne, L., & Bye, E. (2014). Design functions in transformable garments for sustainability. International Journal of Fashion Design, Technology and Education, 7(1), 10–20. https://doi.org/10.1080/17543266.2013.8452499

Kozlowski, A., Searcy, C., & Bardecki, M. (2016). Innovation for a sustainable fashion industry: a design focused approach toward the development of new business models. *Environmental Footprints and Eco-Design of Products and Processes*, *151-169*, 151–169. https://doi.org/10.1007/978-981-10-0245-8_5

Krippendorf, K. (1980). Content analysis: An introduction to its methodology. Newbury Park, CA: Sage Publications.

LaBat, K. L. & Sokolowski, S. L. (1999). A three-stage design process applied to an industry-university textile product design project. *Clothing and Textiles Research Journal*, *17*(1), 11–20. https://doi:10.1177/0887302X9901700102

Laitala, K., Klepp, I. G., & Boks, C. (2015). Making clothing last: a design approach for reducing the environmental impacts. *International Journal of Design*, *9*(2), 93–107. http://hdl.handle.net/10642/4920

Lamb, J. M., & Kallal, M. J. (1992). A conceptual framework for apparel design. *Clothing and Textiles Research Journal*, *10*(2), 42–47. https://doi:10.1177/0887302X9201000207

Ljungberg, L. Y. (2007). Materials selection and design for development of sustainable products. *Materials & Design*, *28*(2), 466–479. https://doi.org/10.1016/j.matdes.2005.09.006

Lofthouse, V. (2006). Eco-design tools for designers: defining the requirements. *Journal of Cleaner Production*, *14*(15), 1386–1395. https://doi.org/10.1016/j.jclepro.2005.11.013

Mackenzie, D. (1997). *Green design: design for the environment* (2nd ed.). L. King.

Matharu, G. (2010). *What is Fashion Design?* Mies: Rotovision.

May-Plumlee, T., & Little, T. J. (1998). No-interval coherently phased product development model for apparel. *International Journal of Clothing Science and Technology*, *10*(5), 342–364. https://doi.org/10.1108/09556229810239333

Mareis, C. (2012). The epistemology of the unspoken: on the concept of tacit knowledge in contemporary design research. *Design Issues*, *28*(2), 61–71. https://doi.org/10.1162/DESI_a_00143

McDonough, W. and Braungart, M. (2002), Remarking the Way We Make Things: Cradle to Cradle, North Point Press, New York, NY.

McKelvey, K., and Munslow, J., (2003). *Fashion Design: Process, Innovation and Practice*. Oxford: Blackwell Science.

Nataliya, V. I., John, W. C., & Sheldon, L. S. (2006). Using mixed-methods sequential explanatory design: from theory to practice. *Field Methods*, *18*(1), 3–20. https://doi.org/10.1177/1525822X05282260

Niedderer, K. (2007). Mapping the meaning of knowledge in design research. *Design Research Quarterly*, 2 (2) pp. 1-13. http://hdl.handle.net/2436/38736

Niinimäki K., & Hassi, L. (2011). Emerging design strategies in sustainable production and consumption of textiles and clothing. Journal of Cleaner Production, 19(16), 1876–1883. https://doi.org/10.1016/j.jclepro.2011.04.020

Nudie Jeans (n.d.). *Repair for life. https://www.nudiejeans.com/?gclid=CjwKCAiAiML-BRAAEiwAuWVggg694LC601YymXYPLZoAncuJUUub1mVrac6e7cf48gJra5I89W0PmxoCs-UQAvD_BwE*

Palomo-Lovinski, N., & Hahn, K. (2014). Fashion design industry impressions of current sustainable practices. *Fashion Practice*, *6*(1), 87–106. https://doi.org/10.2752/175693814X13916967094911

Patagonia (n.d.). *Worn wear*. https://wornwear.patagonia.com

Rahman, O., & Gong, M. (2016). Sustainable practices and transformable fashion design - Chinese professional and consumer perspectives. *International Journal of Fashion Design, Technology and Education*, *9*(3), 233–247. https://doi.org/10.1080/17543266.2016.1167256

Rust, C. (2004). Tacit Knowledge and Invention in Science. *Design Issues*, Vol. 20, No. 4, pp. 76-85. https://www.jstor.org/stable/1512004

Schor, J. B. (2005). Prices and quantities: unsustainable consumption and the global economy. *Ecological Economics*, *55*(3), 309–320. https://doi.org/10.1016/j.ecolecon.2005.07.030

Shahbandeh, M. (2021, January 22). *Global Apparel Market - Statistics & Facts*. Statista. https://www.statista.com/topics/5091/apparel-market-worldwide/

Sung, K. (2015, April). A review on upcycling: Current body of literature, knowledge gaps and a way forward. Paper presented at the ICEES conference: 17th international conference on environmental and earth sciences, Venice, Italy.

Textile Environmental Design (n.d.). *The Ten.* http://www.tedresearch.net/teds-ten-aims/

Tischner, U., & Charter, M. (2001). Sustainable product design. In *Sustainable Solutions: Developing Products and Services for the Future*; Charter, M., Tischner, U., Eds.; Greenleaf Publishing: Sheffield, UK, 2001; pp. 118–139.

The North Face (n.d.). *The North Face Renewed.* https://www.thenorthfacerenewed.com

Watkins, S. M. (1988). Using the design process to teach functional apparel design. *Clothing and Textile Research Journal*, *7*(1), 10–14. https://doi:10.1177/0887302X8800700103

Weber, S., Lynes, J., & Young, S. B. (2017). Fashion interest as a driver for consumer textile waste management: reuse, recycle or disposal. *International Journal of Consumer Studies*, *41*(2), 207–215. https://doi:10.1111/ijcs.12328

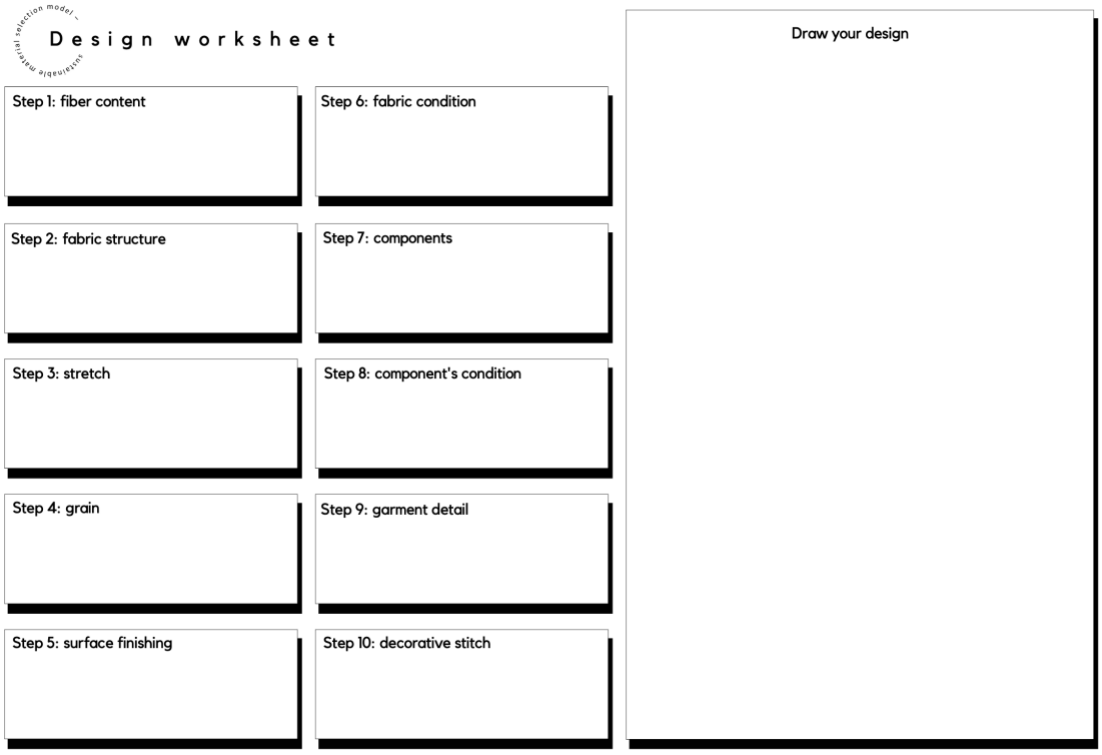
Wilson, M. (2016). When creative consumers go green: understanding consumer upcycling. *Journal of Product and Brand Management*, *25*(4), 394–399. https://doi.org/10.1108/JPBM-09-2015-0972

Woolridge, A. C., Ward, G. D., Phillips, P. S., Collins, M., & Gandy, S. (2006). Life cycle assessment for reuse/recycling of donated waste textiles compared to use of virgin material: an UK energy saving perspective. *Resources, Conservation & Recycling*, *46*(1), 94–103. https://doi.org/10.1016/j.resconrec.2005.06.006

Wrench, J. S., Thomas-Maddox, C., Richmond, V. P., & McCroskey, J. C. (2019). *Quantitative research methods for communication: a hands-on approach* (Fourth). Oxford University Press.

# Appendix A

## DESIGN WORKSHEET



## Appendix B

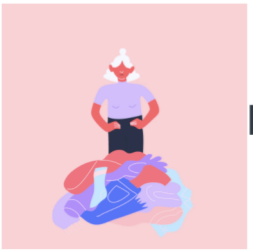
## PRODUCT DEVELOPMENT ACTIVITY

# Sustainable Material Selection Model

This is a preview of the draft version of the quiz

**Due** Feb 24 at 11:59pm **Questions** 12
**Available** Feb 24 at 12am - Feb 24 at 11:59pm 1 day **Time Limit** None

## Instructions



## Product Development Activity

Your task is to develop a fashion item (it could be a garment, accessory, textile, or footwear) using secondary materials.

The secondary material you will use for this activity is the item I asked you to select from your closet.

This design activity will have 3 phases.

- In the first phase, you will explore, manipulate, and evaluate the materials you have.
- In the second phase, you will use the information you collected in phase one to create a new fashion item.
- Phase three, you will answer a few survey questions.

**There is no right or wrong answer!**

**Have fun!**

**Question 1** 0 pts

**Hi - Welcome to phase 1!**

Every design development starts with a research, an exploratory phase. For this activity, it would not be different. You will manipulate, analyze, and evaluate your garment.

You will use the tool to help you with that. The tool is called the **Sustainable Material Selection Model**, which consists of 10 steps.

I am going to introduce to you each step, ask you some questions, and you are going to write down your answer related to each step on the worksheet.

**Now, this is very important!!** There is no right or wrong answer. It is ok if you don't know the answer to a question. Just write it down that you don't know you are not sure.

The goal of this phase is to generate ideas that you will apply to phase 2.

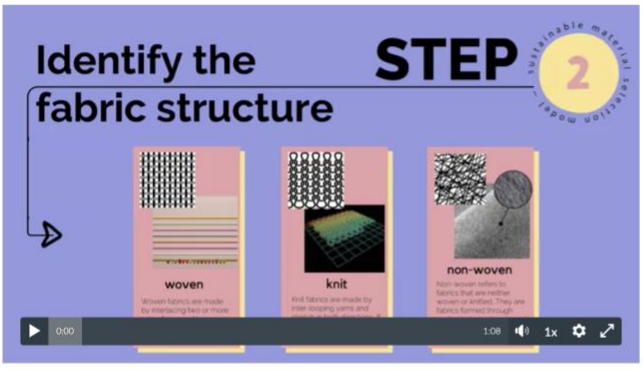
So, get your garment, your paper, and your pencil!

**Let's get started! Press play**


- [ ] Cotton
- [ ] Polyester
- [ ] Rayon
- [ ] Silk
- [ ] Other
- [ ] I don't know (not sure)

Next

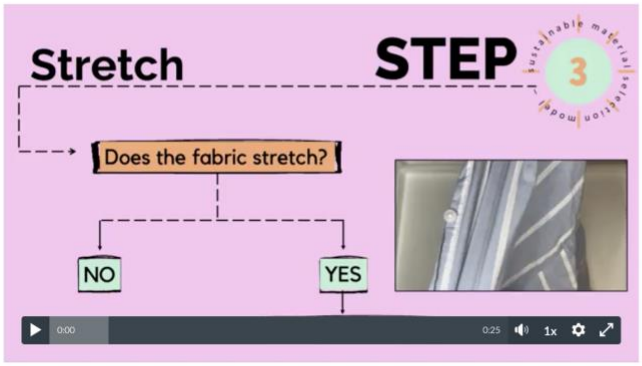
**Question 2** 0 pts




- ○ Woven
- ○ Knit
- ○ Non-woven
- ○ I don't know (not sure)

Previous Next

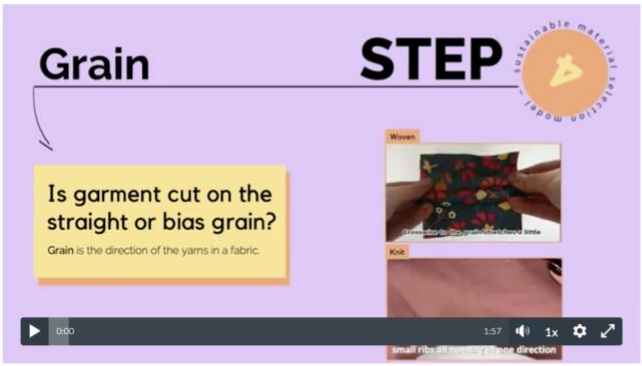
Question 3 0 pts




- No
- Yes (how many ways? Write the answer on worksheet)
- I don't know (not sure)

Previous Next

Question 4 0 pts




- Straight grain
- Bias grain
- Other
- I don't know (not sure)

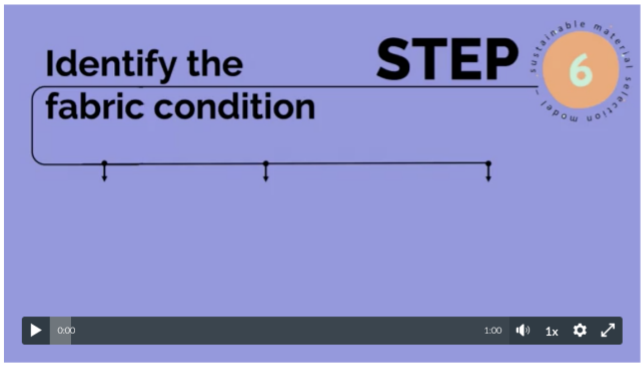
Previous Next

Question 5 0 pts


- [ ] Graphic print
- [ ] Foil print
- [ ] Distressed
- [ ] Puff print
- [ ] Others
- [ ] I don't know (not sure)

Previous Next

Question 6 0 pts



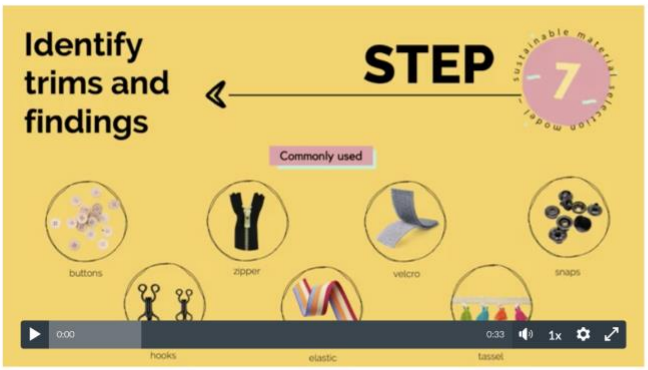

Wear

Tactile analysis

Visual analysis

Previous Next

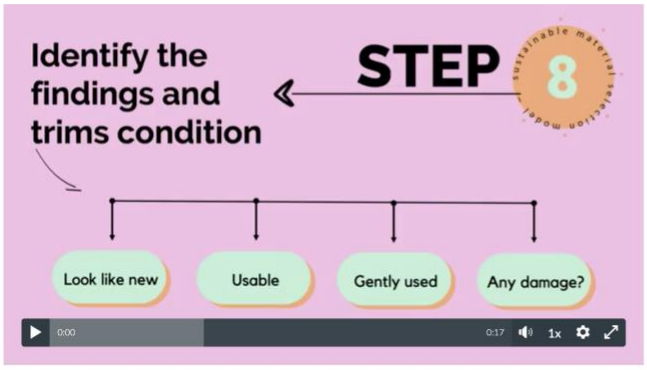
Question 7 0 pts




- [ ] Labels
- [ ] Zipper
- [ ] Button
- [ ] Others
- [ ] I don't know (not sure)
- [ ] No trims or findings

Previous Next

Question 8 0 pts




- ○ Look like new
- ○ Usable
- ○ Gently used
- ○ Any damage?
- ○ Other
- ○ I don't know (not sure)

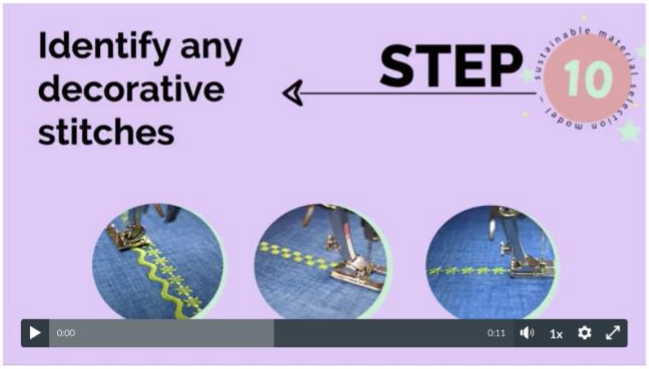
Previous Next

Question 9 0 pts


- Collar
- Cuff
- Pocket
- Opening
- Hood
- Other
- I don't know (not sure)

Previous Next

Question 10 0 pts




- Non, my garment does not have decorative stitches.
- Yes, my garment has decorative stitches.
- I don't know (not sure)

Previous Next

**Question 11** 0 pts

**Hi - Welcome to phase 2 of your design activity!**

Now that you completed the exploratory phase and identify what types of secondary materials you have. You will use this information to create a new fashion item.

In this phase, you will create a new design concept of a fashion product (it could be a garment, accessory, textile, or footwear) using as much as possible of the materials you analyzed in phase 1.

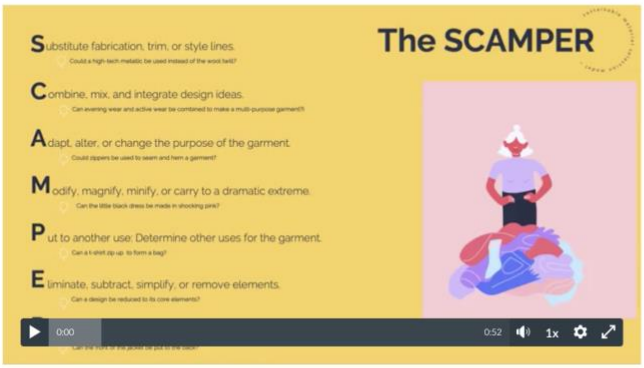
Please, use the part of your worksheet that says, "draw your design" to sketch your product.

Your sketch does not need to be perfect. I will not evaluate your sketch abilities.

The goal of this activity is for you to use your creativity to create something new with secondary materials.

To help you enhance your creativity. I am going to introduce you to the SCAMPER technique.

**Press play!**




**When you finish sketching, please, if it is possible, take a picture of the worksheet and upload it here ↘ I would love to see your design.**
**When you are done, click next to answer a few survey questions.**

Upload Choose a File

◂ Previous Next ▸

**Question 12** 0 pts

**Please, click in the link below to answers a few survey questions.**

https://delaware.ca1.qualtrics.com/jfe/form/SV_cRO3CHo3C6qlAhw


◂ Previous

# Appendix C

## HUMAN SUBJECTS PROTOCOL

HUMAN SUBJECTS PROTOCOL
University of Delaware

Protocol Title: Development of a sustainable material selection model for Apparel Product Creation

Principal Investigator
Name: Aline Gomes Siqueira
Department/Center: Fashion and Apparel Studies
Contact Phone Number: (917) 459-7569
Email Address: siqueira@udel.edu

Advisor (if student PI):
Name: Kelly Cobb
Contact Phone Number: 267-475-2263
Email Address: kcobb@udel.edu

Other Investigators: N/A

Investigator Assurance:

By submitting this protocol, I acknowledge that this project will be conducted in strict accordance with the procedures described. I will not make any modifications to this protocol without prior approval by the IRB. Should any unanticipated problems involving risk to subjects occur during this project, including breaches of guaranteed confidentiality or departures from any procedures specified in approved study documents, I will report such events to the Chair, Institutional Review Board immediately.

1. **Is this project externally funded?** ☐ YES ☒ NO

If so, please list the funding source:

**2. Research Site(s)**

☒ University of Delaware

☐ Other (please list external study sites)

Is UD the study lead? ☒ YES ☐ NO (If no, list the institution that is serving as the study lead)

3. **Project Staff**

Please list all personnel, including students, who will be working with human subjects on this protocol (insert additional rows as needed):

| NAME | ROLE | HS TRAINING COMPLETE? |
|---|---|---|
| Aline Gomes Siqueira | Principal Investigator | Yes |
| Kelly Cobb | Advisor | Yes |
| | | |
| | | |
| | | |
| | | |
| | | |

4. **Special Populations**
Does this project involve any of the following:

Research on Children? No

Research with Prisoners? No

If yes, complete the Prisoners in Research Form and upload to IRBNet as supporting documentation

Research with Pregnant Women? No

Research with any other vulnerable population (e.g. cognitively impaired, economically disadvantaged, etc.)? please describe No

5. **RESEARCH ABSTRACT** Please provide a brief description in LAY language (understandable to an 8th grade student) of the aims of this project.

Textile and material waste is a critical environmental and social issue in the fashion industry. Secondary materials are composed of textile and apparel industry waste, which includes pre-consumer and post-consumer waste. The purpose of this research is to offer guidance to designers and product developers through a model that embeds a material selection strategy into the traditional process of product development. Specifically, this study aims to develop a sustainable material selection model that embeds the use of textile waste (secondary materials) as one option in the materials selection step of the apparel product development process, as well as initial testing to evaluate the effectiveness of the model. The research consists of model development. The model will be tested as part of a product development activity with undergraduate students.

6. **PROCEDURES** Describe all procedures involving human subjects for this protocol. Include copies of all surveys and research measures.

A model will be developed by the researcher and tested by participants. Participants will be undergraduate students majoring in apparel design at the University of Delaware. A non-probability convenience sampling method will be used to recruit participants. This is a voluntary activity that students will receive one point extra credit to participate in. First, a pretest online base questionnaire will be administered. Next, participants will be asked to participate in a product development activity. Participants will be required to use the sustainable material selection model as a tool to guide their design process. After the activity, participants will be asked to complete a posttest online base

questionnaire to evaluate the use of the sustainable material selection model. All tests will be completed during class time.

7. **STUDY POPULATION AND RECRUITMENT**
Describe who and how many subjects will be invited to participate. Include age, gender and other pertinent information.

Participants will be undergraduate students majoring in apparel design at the University of Delaware. These students are male and female, ages 18-23.

Attach all recruitment fliers, letters, or other recruitment materials to be used. If verbal recruitment will be used, please attach a script.

*Hello,*
*My name is Aline Siqueira, and I am a graduate student in Fashion and Apparel Studies, working on my master's thesis. My research involves the development of a sustainable material selection model with the purpose to guide apparel designers in the selection of secondary materials. I am creating a tool that will help people make more sustainable choices in product development.*

*I would like to invite you to participate in this study. This will require approximately one hour of your class time. During the study, you may choose to stop participating at any time. There are no risks involved in this study. There is no compensation for participating in this study, though I would be happy to provide a summary of the results when the study is complete. Your responses will be confidential; data will be analyzed and reported in aggregate form. I will request general information about you to help with my analysis, and it will not be used to identify you. Your decision of whether or not to participate will not prejudice you or your future relations with the University of Delaware. You will be required to use your personal computer to complete the tests.*

*If you consent to participating in this study, please use this link to access the survey. If you have trouble accessing the survey, please contact Aline Siqueira (siqueira@udel.edu) for an electronic copy that can be printed, scanned, and returned by email.*

*If you have any questions or would like to request a copy of the results, please contact Aline Siqueira (siqueira@udel.edu). If you have questions regarding your rights as a participant, you may contact the UD IRB Office at (302) 831-2137 or via email at hsrb-research@udel.edu.*

Approximately 50 completed questionnaires are anticipated.

A copy of the survey that has been designed by the researchers is attached.

Describe what exclusionary criteria, if any will be applied.
None

Describe what (if any) conditions will result in PI termination of subject participation.
None

8. **RISKS AND BENEFITS**
List all potential physical, psychological, social, financial or legal risks to subjects (risks listed here should be included on the consent form).

This research will benefit future designers in making more sustainable choices benefiting people, planet and business.

In your opinion, are risks listed above minimal* or more than minimal? If more than minimal, please justify why risks are reasonable in relation to anticipated direct or future benefits.

No risk/ risks are less than minimal.

*(*Minimal risk means the probability and magnitude of harm or discomfort anticipated in the research are not greater than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests)*

What steps will be taken to minimize risks?
Not applicable.

Describe any potential direct benefits to participants.

Not applicable.

Describe any potential future benefits to this class of participants, others, or society.

Not applicable.

If there is a Data Monitoring Committee (DMC) in place for this project, please describe when and how often it meets.

No.

9. **COMPENSATION**
Will participants be compensated for participation?
No.

If so, please include details.

10. **DATA**
Will subjects be anonymous to the researcher?
Yes

If subjects are identifiable, will their identities be kept confidential? (If yes, please specify how)

How will data be stored and kept secure (specify data storage plans for both paper and electronic files. For guidance see http://www.udel.edu/research/preparing/datastorage.html )

Digital copies of the data will be kept on a password-protected space on the researcher's main laptop that carries the statistical analysis tools. The researcher's laptop is also password protected.

How long will data be stored?
3 years

Will data be destroyed? x YES ☐ NO (if yes, please specify how the data will be destroyed)
The digital data files will be erased.

Will the data be shared with anyone outside of the research team? ☐ YES x NO (if yes, please list the person(s), organization(s) and/or institution(s) and specify plans for secure data transfer)

How will data be analyzed and reported?

Data will be analyzed using descriptive statistics to test research questions. Data will be reported only in aggregate form.

Data will be analyzed to test research hypotheses and questions. Data will be reported only in aggregate form.

11. **CONFIDENTIALITY**
Will participants be audiotaped, photographed or videotaped during this study?
No

How will subject identity be protected?
No subject identification will be linked to the data or completed questionnaires.

Is there a Certificate of Confidentiality in place for this project? (If so, please provide a copy).
No.

12. **CONFLICT OF INTEREST**
(For information on disclosure reporting see: http://www.udel.edu/research/preparing/conflict.html )

Do you have a current conflict of interest disclosure form on file through UD Web forms?
No.

Does this project involve a potential conflict of interest*?
No

* As defined in the University of Delaware's Policies and Procedures ,a potential conflict of interest (COI) occurs when there is a divergence between an individual's private interests and his or her professional obligations, such that an independent observer might reasonably question whether the individual's professional judgment, commitment, actions, or decisions could be influenced by considerations of personal gain, financial or otherwise.

If yes, please describe the nature of the interest:

13. **CONSENT and ASSENT**

__ Consent forms will be used and are attached for review (see Consent Template under Forms and Templates in IRBNet)

____ Additionally, child assent forms will be used and are attached.

X
____ Waiver of Documentation of Consent (attach a consent script/information sheet with the signature block removed).

See script above to be used for modified informed consent.

____ Waiver of Consent (Justify request for waiver)

14. **Other IRB Approval**
Has this protocol been submitted to any other IRBs?
No.

If so, please list along with protocol title, number, and expiration date.

15. **Supporting Documentation**
Please list all additional documents uploaded to IRBNet in support of this application.

Survey
Informed Consent to Participate
Class activity
Material selection model - Sample is included as model are still in development

# Appendix D

# INFORMED CONSENT TO PARTICIPATE RESEARCH

**CONSENT TO PARTICIPATE IN A RESEARCH STUDY**

**Title of Study:** Development of a Sustainable Material Selection Model for Apparel Product Creation

**Principal Investigator(s):** Aline Siqueira and Kelly Cobb.

Important aspects of the study you should know about:

- **Purpose:** The purpose of the study is to offer guidance to designers and product developers through a model that embeds a material selection strategy into the traditional process of product development. Specifically, this study aims to develop a sustainable material selection model that embeds the use of textile waste (secondary materials) as one option in the materials selection step of the apparel product development process, as well as initial testing to evaluate the effectiveness of the model.
- **Procedures**: If you choose to participate, you will be asked to complete an online survey, which includes basic demographic information such as your sex, gender, and major. Also, you will be requested to complete a product development activity, followed by a few survey questions.
- **Duration:** This will take about one hour.
- **Risks**: There are no risks associated with this study.
- **Benefits:** Your participation in this study will benefit future designers in making more sustainable choices benefiting people, planet and business.
- **Costs and Compensation:** There are no costs to you for participating in this study. There is no compensation for participating in this study, though I would be happy to provide a summary of the results when the study is complete.
- **Participation:** Taking part in this study is entirely voluntary. You do not have to participate in this study. If you choose to take part, you have the right to stop at any time. If you decide not to participate or if you decide to stop taking part at a later date, there will be no penalty or loss of benefits to which you are otherwise entitled. Your decision to stop participation, or not to participate, will not influence current or future relationships with the University of Delaware or other colleges and universities.

**Contact Information:** If you have any questions about the purpose, procedures, or any other issues related to this research study you may contact the Principal Investigator, Aline Siqueira at (917) 459-7569 or siqueira@udel.edu. You may contact the Academic Advisor, Kelly Cobb at (302)-831-6132 or

kcobb@udel.edu. If you have questions regarding your rights as a participant, you may contact the UD IRB Office at (302) 831-2137 or via email at hsrb-research@udel.edu.

**CONSENT TO PARTICIPATE IN THE RESEARCH STUDY:**

**I have read and understood the information in this form and I agree to participate in the study. I am 18 years of age or older. I have been given the opportunity to ask any questions I had and those questions have been answered to my satisfaction. I understand that I will be given a copy of this form for my records.**

If you consent to participating in this study, please use this link to access the survey. If you have trouble accessing the survey, please contact Aline Siqueira (siqueira@udel.edu) for an electronic copy that can be printed, scanned, and returned by email.

# Appendix E

# IRB APPROVAL

**Institutional Review Board**
210H Hullihen Hall
Newark, DE 19716
Phone: 302-831-2137
Fax: 302-831-2828

| | |
|---|---|
| DATE: | January 29, 2021 |
| TO: | Aline Siqueira, MS |
| FROM: | University of Delaware IRB |
| STUDY TITLE: | [1704018-1] Development of a sustainable material selection model for apparel product creation |
| SUBMISSION TYPE: | New Project |
| ACTION: | DETERMINATION OF EXEMPT STATUS |
| EFFECTIVE DATE: | January 29, 2021 |
| REVIEW CATEGORY: | Exemption category # *(2)* |

Thank you for your New Project submission to the University of Delaware Institutional Review Board (UD IRB). According to the pertinent regulations, the UD IRB has determined this project is EXEMPT from most federal policy requirements for the protection of human subjects. The privacy of subjects and the confidentiality of participants must be safeguarded as prescribed in the reviewed protocol form.

This exempt determination is valid for the research study as described by the documents in this submission. Proposed revisions to previously approved procedures and documents that may affect this exempt determination must be reviewed and approved by this office prior to initiation. The UD amendment form must be used to request the review of changes that may substantially change the study design or data collected.

Unanticipated problems and serious adverse events involving risk to participants must be reported to this office in a timely fashion according with the UD requirements for reportable events.

A copy of this correspondence will be kept on file by our office. If you have any questions, please contact the UD IRB Office at (302) 831-2137 or via email at hsrb-research@udel.edu. Please include the study title and reference number in all correspondence with this office.

## Appendix F

## EXPLORATORY DESIGN EXERCISE