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Redesign in the textile industry: Proposal of a methodology for the insertion of circular thinking in product development processes

Thomas Germano Battesini Teixeira [a], Janine Fleith de Medeiros [a,b], Camila Kolling [b], José Luis Duarte Ribeiro [b], Donato Morea [c,*]

[a] Department of Business Management, Universidade de Passo Fundo, Passo Fundo, RS, Brazil
[b] Industrial Engineering Department, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brazil
[c] Department of Mechanical, Chemical and Materials Engineering, University of Cagliari, Via Marengo, 2, 09123, Cagliari, Italy

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ABSTRACT

Despite the growing attention toward negative environmental impacts generated by the textile industry, companies face challenges in achieving sustainable and circular economy (CE) transition. The literature has so far lacked a systematic effort to analyze how textile companies can insert CE elements in their new product development process (NPD), especially regarding the proposition of methodologies that can better assist the companies in this regard. This study aims to identify good green innovation and CE practices in NPD adopted by textile companies and propose a methodology from Design Thinking (DT) to insert circular thinking in NPD. To that end, we conducted the research in two steps: (i) narrative bibliographic review and (ii) field research. The bibliographic review was conducted in the "Web of Science", "Scopus", and "Scielo" databases. The field research was executed with four textile companies. Our results show that companies tend to consider socio-environmental aspects at different stages of the development of new products. However, there is opportunities for improvement, especially through the use of ideas from DT. The proposed methodology is composed of two main cycles: the design cycle (DT stages) and the consumption cycle (subsequent stages). It encompasses the five main stages of the DT and the three macro phases of NPD of the textile industry. The ideas coming from the DT, especially creativity, focus on the user and stakeholder integration, assist in the development of innovative and circular solutions. The methodology presents how companies can work on reuse, recycling, and manufacturing issues, so that CE occurs. In the end, we evaluated, together with experts, the applicability of the proposed use of ideas of DT in practical cases. The research advances the discussions on NPD in the textile sector, especially on its potential to contribute to the transition to CE. It explores how DT assists in inserting circular thinking into the NPD and presents alternatives for companies to develop circular products and insert green innovations in their NPD.

1. Introduction

Innovating and doing business without considering environmental and social aspects is no longer attractive to many companies (Behnam and Cagliano, 2017). Investing in green and ethical practices, in addition to being an essential factor for sustainable development, also provides a competitive advantage (Gao et al., 2019; Lončar et al., 2019). Particularly considering the new product development process (NPD), studies indicate that green products are key to business success and performance in terms of environmental sustainability (Dangelico, 2017).

Recognized as a driver for the new growth paradigm (Dangelico, 2016), centered on a circular economy (CE) (Sauvé et al., 2016), the environmentally sustainable development of products has been the focus of numerous studies, which has made the literature on the subject evolve significantly (de Medeiros et al., 2022). However, some sectors tend to present difficulties in their processes to be reorganized from the sustainability perspective (Joyce and Paquin, 2016), especially from the perspective of the CE (Sassanelli et al., 2020).

Focusing specifically on the textile industry, studies indicate that companies face complex challenges in transitioning to CE (Abdelmeguid et al., 2022; Hugo et al., 2021). Despite the existence of circular initiatives in the textile industry's production chain, changes toward CE are still delayed (Hugo et al., 2021). The environmental unsustainability caused by the textile industry occurs not only due to the high waste of

* Corresponding author.
E-mail address: donato.morea@unica.it (D. Morea).

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raw materials but also because, in almost all stages of the life cycle of a textile product, there are negative effects on the environment (whether short-term or long-term) (Vehmas et al., 2018).

The textile production process generates high energy and water consumption, toxic chemical pollution (especially to water), soil degradation, and greenhouse gas emissions, producing a high carbon footprint (Niinimäki et al., 2020; Niinimäki and Hassi, 2011). Furthermore, only 27% of the clothes produced are recycled or reused (Moorhouse, 2020). In such a way, large amounts of products end up as garbage in landfills, incinerated, or abandoned in remote places (Gupta et al., 2022). Despite technological advances in recent decades, little has been done regarding the use and disposal of fashion products (Freudenreich and Schaltegger, 2020; Todeschini et al., 2020).

This scenario and the rapid global expansion of this industry have increasingly demanded that viable alternatives toward the sustainability of product development processes be proposed and disseminated (Colasante and Adamo, 2021; Nagano, 2022). Therefore, there is a need for the textile industry to innovate its business models (Boons and Lüdeke-Freund, 2013; Todeschini et al., 2017). However, to date, responses to the textile industry's large-scale negative environmental and social impacts have been reactive and focused on fragmented strategies, lacking a cohesive perspective (Kozlowski et al., 2012).

To this end, studies suggest that it is necessary to comprehend and analyze "how" different organizations in the sector have adapted to meet the sustainability assumptions correctly (Sandvik and Stubbs, 2019; Tebaldi et al., 2018; Todeschini et al., 2020). In addition, previous studies emphasize the need to adopt emerging methodologies that can better assist innovation practices for developing environmentally sustainable products (Ahmed et al., 2019, de Medeiros et al., 2018a,b) and closed cycles (Moesch, 2019). Fung et al. (2021) reiterate the need for future research that explores how CE elements affect the sustainable product development process in the textile industry.

In this context, innovation methods deriving from design can help guide the way toward circular and environmentally sustainable projects. Among the different existing methods, studies have shown that Design Thinking (DT) provides a useful framework to guide the development of green products (Faludi et al., 2020; Redante et al., 2019) and circular solutions (Andrews, 2015; Andrews et al., 2021; Brown et al., 2021), assisting in solving urgent sustainability problems (Greco et al., 2021; Shapira et al., 2017).

DT can be understood as a systematization of design mechanisms applied to innovation (Mahmoud et al., 2016; Seidel and Fixson, 2013). It is characterized by a creative, iterative, and human-centered approach (Brown, 2008; Shapira et al., 2017). In particular, DT is beneficial in stimulating the creative process required to develop viable and sustainable business models, helping to align different stakeholder interests (Geissdoerfer et al., 2016). Finally, DT can be an essential tool to help companies that aim at circular innovation and the transition of their businesses to sustainable models (Guldmann et al., 2019).

Given the above, the present study explores the following research question (RQ): *How can we establish a methodology from Design Thinking (DT) to insert the practice of circular thinking in developing products in the Textile Industry?* To this end, we: (i) identified good practices of green innovations and related to the circular economy in NPD of brands that operate in the textile sector; (ii) systematized, based on the precepts of the DT and the knowledge generated by the field study, a methodology that can be used in the Textile Industry NPD aiming at the circularity of natural resources; and (iii) evaluated, together with experts, the applicability of the proposed methodology for use in practical cases.

To that end, a qualitative exploratory research was carried out. Initially, we conducted a narrative bibliographic review about green innovations, circular economy, and design methodologies for the product development process, including DT. Then, we conducted multiple case studies through interviews with managers of four textile companies. Finally, an evaluation of the proposed methodology by experts was performed.

Our study responds to the calls of Fung et al. (2021) and Abdelmeguid et al. (2022) for the need for research on sustainable NPD and CE in the textile industry. It also advances the propositions Elf et al. (2022) and Hugo et al. (2021). They suggested the relevance of conducting research on CE in the textile industry in other cultural contexts, especially in developing countries. In addition, we justify the validity of our research since exploratory studies with a qualitative approach are relevant in the field of green innovation to understand better the transition process aimed at the success of activities developed by organizations and their ecosystems (de Medeiros et al., 2022). Thus, our study contributes to the literature for the sustainable transition and the development of circular businesses in the textile industry through DT. The methodology proposed provides guidance and better clarifies the procedures necessary for implementing a sustainable NPD in the textile sector.

The remainder of the paper is structured as follows. After this introduction, Section 2 describes the methodology adopted, explaining the criteria used to develop the narrative bibliographic review, the information about the multiple case studies, conducting the interviews, and the steps for data analysis. It also explains how we validated the methodology based on a survey with experts. Section 3 presents the results and analysis of the narrative review, while Section 4 presents the analysis of the multiple case studies. Section 5 presents the proposed methodology, and Section 6 discusses the validation of the methodology by experts. Finally, Section 7 summarizes conclusions, limitations, directions for future research, and research implications.

2. Method

Based on the general objective of the study, we conducted an exploratory study with a qualitative approach. Initially, we carried out a bibliographic research on the topics of interest (subsection section 2.1.). Afterward, we conducted a field research with organizations in the textile sector (subsection section 2.2.). Finally, we proceed with a validation of the proposed methodology with experts (subsection section 2.3.). The three steps are complementary and help answer the study's research question.

2.1. Narrative bibliographic review

We chose the narrative method to develop the bibliographic research. In narrative reviews, the criteria for analysis and literature search are not systematic or explore all sources of information (Schrank et al., 2012). Cordeiro et al. (2007) state that in this type of review, the theme is broader and without restrictions for its construction. Thus, the choice of studies, as well as their interpretation, depends on the subjectivity of the authors. In addition, according to Elias and Mansouri (2020), narrative reviews allow the identification of previously discussed themes and establish possible relationships with new perspectives. Observing the focus of the study, the themes investigated in the development of the review were: green innovations and circular economy (subsection section 3.1.) and design methodologies for the product development process (subsection 3.2.).

In this way, we searched for studies in the Scopus, Web of Science, and Scielo databases. Scopus is the largest database of abstracts and citations in the peer-reviewed literature and has more than 80 million items and 1.8 billion references cited (Elsevier, 2023). Web of Science contains more than 171 million records and 1.9 billion cited references (Clarivate, 2023). Scielo also has many documents and references (Scielo, 2023) and is an important source of information (Meneghini, 2013). The following keywords were used: "design thinking", "fashion", "circular economy", and "sustainable". The search was performed using the same keywords in both databases, without the restriction of time interval and filtering by the presence of keywords in the title and/or abstract and/or keywords of the article. After reading the abstracts, the works that presented relevant contributions following the objectives of

the article were selected and read.

2.2. Field research: Multiple case study

As for field research, we chose to research organizations in the textile sector that operate in southern Brazil, producing garments and clothes. According to the Brazilian Textile and Apparel Industry Association (ABIT), Brazil is the largest complete Textile Chain in the West, with revenues reaching R$161 billion in 2020. In addition, the country is a world reference in fashion design and exported US$ 1.06 billion in 2021 (ABIT, 2022). The production chain of the textile sector works with several links, ranging from the production and processing of fabrics to the manufacture of finished products intended for consumption. The primary raw materials of the production chain are natural, synthetic, or artificial fibers (Caldeira et al., 2017).

To understand in detail how companies in this sector can develop sustainable solutions that can be circular, we opted for in-depth multiple case studies (Voss et al., 2002; Yin, 2009). We selected four organizations for data collection, observing as criteria the value proposition communicated on social networks, the process or closed chain practices described in posts, and, finally, the comments and engagement of consumers. In this way, the selected companies have a value proposition related to sustainable aspects. According to Malhotra (2019), the cases selected in a qualitative study should allow the detailed investigation of contemporary phenomena in the real environment without clearly defining the boundary between the phenomenon and the context. Studies with this sample are valid when there is a broader set of variables of interest and theoretical propositions that make it possible to guide the collection and analysis of the resulting observations. Table 1 presents the description of each case and the interviewees. The selected companies produce everyday clothing, accessories, and shoes.

An interview protocol was used to collect information from the selected cases (Supplementary Material). The research protocols tend to guide researchers during the collection process, facilitating the achievement of objectives but also allowing new insights to be contemplated (Malhotra, 2019). The main studies that served as a basis for the elaboration of the instrument are presented in Table 2. Three experts validated the protocol: a designer, a doctor whose thesis addressed the use of productive methodologies; a researcher linked to the Postgraduate course in Administration, PhD in organizational communication; and a production engineer, PhD whose thesis focused on the use of DT for sustainable practices in the furniture industry.

Table 1
Interviewee and companies' description (source: authors' elaborations).

Unit	Number of employees	Value proposition	Interviewees' information	
			Position	Code
Company 1	10–50	Combining fashion with art through the culture of sustainability	Creative Director	Interviewee A
Company 2	10–50	Produce comfortable, durable, and timeless clothes from organic knitted cotton, denim, and jacquard produced by family farming	Ecommerce Manager	Interviewee B
Company 3	50–100	Produce vegan and minimalist clothing items that simplify the act of dressing up with quality and fair price	Commercial Director	Interviewee C
Company 4	10–50	Produce adult and children's shoes, backpacks, toiletry bags, and clothing 100% vegan (free from materials of animal origin)	Commercial Director	Interviewee D

Table 2
Questionnaire blocks (source: authors' elaborations).

Block	Authors
New Product Development Process (NPD)	Dissanayake and Sinha (2015); Cooper et al. (2016); Rozenfeld et al. (2012); Kahn (2018); Redante et al. (2019)
Green Innovation and Circular Economy	Webster (2015); Kirchherr et al. (2017); Todeschini et al. (2020); Claxton and Kent (2020); Nobre and Tavares (2021); Patwa et al. (2021)
Design Thinking (DT) applied to NPD	Brown (2008); Liedtka (2015); Geissdoerfer et al. (2016); Todeschini et al. (2017); Redante et al. (2019)

The interviews were conducted in the "Google Meet" platform between May and June 2021 and lasted approximately 60 min. With the interviewees' consent, the interviews were recorded and later transcribed (Miles and Michael Huberman, 1994). In addition, notes were taken during the interviews, and when incomplete information was identified, participants were contacted to provide additional information (Voss et al., 2002).

As for data analysis, we followed the methodology proposed by Bardin (1977). In this sense, we emphasize that although most of the classic analyzes that follow the author's proposition culminate in numerical descriptions of some characteristics of the text corpus, significant attention has been given to the types, qualities, and distinctions present in the collected data (Bauer and Gaskell, 2002). Therefore, performing content analysis meant using a set of communication analysis techniques to obtain (non-quantitative) indicators that would allow us to infer knowledge (Bardin, 1977).

For the codification and categorization of the textual material resulting from the transcripts, we initially conducted a detailed examination of the speeches. The transcripts were read and reread until they became familiar. Afterward, we separated and isolated each significant fraction, which was coded. According to Bauer and Gaskell (2002), a coding framework constitutes a set of questions (codes) with which the coder deals with the materials and through which he obtains answers. After coding, categorization was performed. For that, we use the deductive method (Elo and Kyngäs, 2008). That is, the key concepts (codes) were established with reference to the variables found in the bibliographic research carried out.

Based on the suggestions of Yin (2009) and Voss et al. (2002), we adopted some practices to guarantee the validity and reliability and reduce the bias of the method, such as analysis of the information available on the companies' websites, conducting multiple cases and using a protocol for data collection and analysis.

2.3. Validation of the methodology: Survey with experts

Zachrisson Daae (2014) and de Medeiros et al. (2018)a,b point out that methodological propositions, specifically related to sustainable design, demand additional views for validation. In this sense, the third methodological step of the present study includes an evaluation of the proposed methodology with experts. Three professionals researching sustainability issues and design methodologies were selected to participate in this stage. Table 3 presents the description of the experts interviewed.

As for the number of specialists, authors present that there is no minimum or maximum number stipulated (Silva and Russo, 2019). They generally recommend the use of the saturation sampling technique, in which new interviewees are suspended depending on the researcher's assessment due to repetition or redundancy (Fontanella et al., 2011).

The validation procedure was performed from personal interviews

Table 3
Experts' description (source: authors' elaborations).

Expert	Characterization
A	Ph.D. in Design from UFRGS, with a Masters in Marketing from Dublin Business School (Ireland), MBA in Strategic Design from ESPM/Rio and degree in Industrial Design/Visual Programming from UFSM. Experience in the areas of Design, Marketing and Management, working as a teacher, consultant and entrepreneur. He is currently a professor of graphic design at the Federal University of Goiás (UFG).
B	Innovation Manager at the Science and Technology Park of the University of Passo Fundo (UPF). Ph.D. in Design and Technology from the School of Engineering at UFRGS. Consultant in Strategic Design for product and service innovation. Experience in the areas of Design, Ergonomics and Engineering, with an emphasis on innovation and technologies, working mainly on the following topics: User Experience (UX), Design Thinking, Sustainability, Entrepreneurship and Innovation.
C	Ph.D. of the program of Doctorat en Arquitectura, Energia i Medi Ambient - Universitat Politècnica de Catalunya (2018). He was coordinator of the Product Design Course at the University of Passo Fundo (UPF) from 2010 to 2018. He is a Collaborating Professor in the Graduate Program in Civil and Environmental Engineering - PPGEng at UPF since 2019. Experience in the field of Design, working mainly on the following topics: production, creation and management of Design.

and through the analysis of the usability requirements proposed by Lofthouse (2006). According to this author, industrial designers need tools and methodologies that use holistic models capable of combining education, guidance, and information together with the considered content, in addition to an adequate and easily accessible presentation.

3. Narrative review results

3.1. Green innovation and CE in the textile sector

Green innovation, also recognized as eco-innovation, environmentally sustainable innovation, or environmental innovation, consists of developing products and processes that consider mitigating environmental problems (de Medeiros et al., 2022). It involves considering environmental aspects in the production and consumption process (Dangelico, 2016). In the textile industry, it can be analyzed in terms of green product innovation, green technology innovation, green image innovation, green service innovation, and green marketing innovation (Chen et al., 2021). Green innovation is a term related to CE ideas (Prieto-Sandoval et al., 2018).

CE replaces the 'end-of-life' concept, seeking to reduce, reuse, recycle and recover materials in production, distribution, and consumption processes (Kirchherr et al., 2017). The idea is to achieve zero waste and pollution throughout the life cycle of materials, from environment extraction to industrial transformation and end consumers (Nobre and Tavares, 2021). CE involves using renewable energy and eliminating toxic products and waste through the superior design of materials, products, and systems (Ellen MacArthur Foundation, 2013). It seeks to retain the value of products as long as possible (Korhonen et al., 2018) and recover the value of waste (Prieto-Sandoval et al., 2018). Therefore, CE is "an economic system that represents a change of paradigm in the way that human society is interrelated with nature and aims to prevent the depletion of resources, close energy and materials loops, and facilitate sustainable development" (Prieto-Sandoval et al., 2018, p. 610). According to the same author, this concept is implemented at the micro (enterprises and consumers), meso (economic agents integrated in symbiosis), and macro (city, regions, and governments) levels and requires innovations in the way society legislates, produces, and consumes.

Through circular initiatives, companies are drivers of sustainable economies by changing production processes and consumption patterns, satisfying consumer needs in new ways, and through new business models (Geissdoerfer et al., 2017). According to Webster (2015), CE offers opportunities for innovation in the design of products, services, and business models. In recent years, CE has emerged as a solution to the fashion industry's challenges (Brydges, 2021; Colasante and Adamo, 2021; Elf et al., 2022). This industry habitually follows a linear model composed of three main stages: take (raw material collection), make (clothing production), and waste (use and subsequent disposal of clothes) (Brydges, 2021).

Brydges (2021) exemplifies some CE practices in the textile industry, such as using natural fibers, reducing the number of chemicals in the dyeing process, transitioning from seasonal to non-seasonal collections, investing in recycling programs, and education actions for stakeholders. Other CE practices in this industry involve long-life design, repair services, use of recycled materials, reuse of materials, and rental or sharing platforms, among others (Elf et al., 2022).

Many of the CE practices carried out by the sector are related to the 3Rs (reduction, reuse, and recycling). For example, reducing the use of raw materials, reducing the consumption of natural resources and chemical products in the production process, renting or selling used clothes, implementing techniques to reuse natural resources and waste in the manufacture of new products, and recycling synthetic materials and textile waste (Hugo and Nadae, 2021).

Material selection is critical in the textile industry. Environmental impacts, even on more minor scales, still exist through the use of resources such as water and chemicals, which affects the entire supply chain involved. According to Claxton and Kent (2020), consumption waste refers to the use and disposal stages of the product life cycle, which are more challenging to assess, influence, and measure. Usage is characterized by the energy consumption of the consumer's washing process, and, in this context, design strategies tend to aim at reducing rather than eliminating negative effects (Gwilt, 2014). At the disposal stage, environmental impacts are caused by volumes of waste from discarded clothing. The reuse and recycling of textiles can be a sustainable solution for reducing solid waste in landfills (Sandin and Peters, 2018; Todeschini et al., 2020).

According to Claxton e Kent (2020), a life cycle analysis can map the entire textile sector supply chain to provide criteria and evidence for selecting sustainable fashion design strategies. Gwilt (2014) and Lima et al. (2017) point out sustainable design strategies that contemplate the life cycle of textile products, as described below.

In the (a) design phase, a sustainable strategy is adopted in selecting materials and production processes for clothing development, aiming to minimize processing techniques such as softening and dyeing. Designers must design products through empathic design, find low-impact raw materials, minimize energy and water consumption, and produce fashion items without wasting materials; (b) production: production is sought ethically, in which workers come from the communities surrounding the company and have sufficient working conditions, considering fair wages, sufficient working hours, and safety. Also noteworthy is the choice of low-impact textile processing types to achieve cleaner production; (c) distribution: the aim is to use local labor, not waste packaging, and distribute products through low-impact means of transport. The point of sale must be efficient, have a small inventory, and have a reverse logistics system for users to use; (d) product usage: at this stage, the designer can design garments that require low-impact care, such as less washing, no softening and ironing process, and items that are easy to repair. In addition, they can consider customization to promote the extension of the useful life of the clothes; (e) end of life: as the last step, there are alternatives for recycling fashion items, from refurbishment to reusing the materials used (Gwilt, 2014; Lima et al., 2017).

3.2. Design methodologies for the NPD

The NPD influences all phases of a product's useful life, from its conception to its disposal until the product is withdrawn from the market (Rozenfeld et al., 2012). It involves implementing steps that move the product from concept to launch (Cooper et al., 2016; Kahn, 2018). The main characteristics of the NPD are the use of

cross-functional teams, market planning, and a formal and structured process (Genç and Di, 2015). No single process model fits all projects, and the project's characteristics must determine the process to be followed (Hemel and Cramer, 2002). Several reference models for product development have been proposed in the literature, including specific models for developing green products (de Medeiros et al., 2018a,b).

In the textile industry, NPD is a dynamic process characterized by high seasonal demand, which depends on the seasonal nature of fashion products (Bandinelli et al., 2013). As fashion products have a short life cycle, NPD challenges increase (Dewi et al., 2015). As stated by Bandinelli et al. (2013), the main phases of the NPD in this industry are design, modeling/prototyping, detailed engineering, material supply, and production and distribution. Tran et al. (2011) described five main tasks that characterize the apparel industry NPD: planning, concept development, detailed design, testing, and production. Considering how to insert sustainable aspects into the fashion industry NPD, Fung et al. (2021) highlighted four main stages: planning, design, production, and launch.

In addition, the textile NPD is characterized by some cycles, mainly by increasingly unsustainable consumption practices (Niinimäki and Hassi, 2011) and the growth of industrial production of increasingly cheaper garments. This is the nature of fast fashion, which encourages the retailer to sell large volumes at low prices, stimulating a high frequency of fashion purchases (Defra, 2010; Peters et al., 2021). Increasingly, these buying habits encourage disposable attitudes, and the NPD does not cover and does not encourage the garment disposal process. Dissanayake and Sinha (2015) claim that this textile industry mechanism raises many questions about sustainability. Fashion consumption and sustainability are generally contradictory in nature: the textile industry consumes natural resources and generates waste, while sustainability seeks resource conservation and zero waste.

Given the need for sustainable management and operational practices in companies from different sectors, environmental issues must be included in product development practices, regardless of the reference model used to guide the process (Albino et al., 2009; Baumann et al., 2002; Sihvonen and Partanen, 2016). Furthermore, the addition of environmentally responsible activities at all stages of product development encompasses a significant shift towards a "cradle to cradle" approach (Jacques, 2011).

In this context, design, from the point of view of sustainability, can help guide the path of environmentally sustainable projects. Design development is associated with new technologies, manufacturing processes, and design thinking applied to the business and competitive context (Faludi et al., 2020; Leite and Braz, 2016). Different methodologies coming from design can contribute to the NPD. Some examples are Natural Step, Whole System Mapping, Biomimicry (Faludi et al., 2020), Design for sustainable behavior (DfSB) (De Medeiros et al., 2018a,b), and DT (Redante et al., 2019). For this study, we justified the choice of DT for its contribution to the development of circular and environmentally sustainable solutions, as detailed in the next section.

3.2.1. DT as a productive methodology

DT is a methodology for problem-solving and has the human as a central element (Kimbell, 2011; Liedtka, 2015). DT has increasingly attracted the interest of practitioners and researchers as a prescriptive process where multidisciplinary teams adopt a user-oriented approach to develop relevant solutions to complex problems (Buhl et al., 2019). It is an iterative design methodology and aims to rapidly develop and test multiple possible solutions to arrive at an optimal solution (Brown, 2008; Denning, 2013). The significant differential of DT is how its individual elements are combined, being a set of approaches, attitudes, and tools that, when together, integrate all the aspects in the resolution of problems (Liedtka, 2015).

This approach comprises applying design methods in different environments to improve innovation and create value for people. The DT has a wide range of application possibilities in the business context, becoming a focus of application in the NPD (Redante et al., 2019). In a scenario where everyone needs to reinvent regularly, it can be an essential tool (Drews, 2009; Geissdoerfer et al., 2016) and help solve societal challenges (Liedtka, 2015; Redante et al., 2019).

In this sense, DT has been pointed out as an approach to the development of innovative solutions to the challenges of sustainability (Buhl et al., 2019; Greco et al., 2021; Pruneau et al., 2021). Studies have also reported the application of DT for the development of circular solutions (Andrews, 2015; Andrews et al., 2021; Brown et al., 2021). In addition, as DT brings together components from other design methodologies, its use is appropriate for the success of green innovations (Faludi et al., 2020). Redante et al. (2019) also highlight the importance of using DT for the green qualification of product development processes, especially concerning stakeholder integration.

In the textile industry, for example, many circular practices require cooperation with consumers (Nagano, 2022). As DT is an approach capable of connecting the perspective of the company and the user, it helps to bring different knowledge and perspectives necessary for this context (Greco et al., 2021). In addition, given its creative characteristic, DT can stimulate (Brown, 2008; Shapira et al., 2017) the creative process necessary for developing circular solutions (Hobson et al., 2021; Lahti et al., 2018). Geissdoerfer et al. (2016) confirm that DT assists in the creative development process and helps to harmonize the interests of different stakeholders, facilitating the creation of viable and sustainable business models, even for small companies.

Several authors have described the DT process with distinct phases. However, it is through iterative cycles of exploration that the process occurs (Liedtka, 2015). According to this author, the DT process initially has an exploratory phase to identify user needs and define the problem, a second phase of idea generation, and a third phase of prototyping and testing ideas. Brown (2008) determined this process from three distinct stages: (i) inspiration, which involves the search for problems and opportunities that will guide the search for solutions; (ii) ideation, aimed at generating, developing, and testing ideas that can lead to solutions; and (iii) implementation, phase in which the solution is placed on the market. Each project goes through these fields repeatedly, especially the first two, so the ideas can be refined and improved before they are put on the market.

According to the Interaction Design Foundation (2022), there are five main stages of DT, which are not always sequential but executed in a parallel and iterative way: (i) empathy, which involves empathically understanding the needs and problems of users; (ii) definition, aimed at the accumulation and analysis of information, which culminate in the declaration of users' needs and problems; (iii) ideation, which involves identifying creative and innovative solutions to the problem; (iv) prototyping, experimental phase and creation of solutions; and (v) testing, time to experiment and test the solutions.

3.3. Synthesis of contributions to the coding of field research results

Based on the contributions described in subsections 3.1. and 3.2., Fig. 1 illustrates the main theoretical contributions that guided the analysis of results described in section 4.

4. Results of the multiple case studies

Initially, we seek to understand how organizations operate their new product development processes. Additionally, as the intentional sample of cases focused on adopting green innovations, we investigated how such actions are linked to the NPD. Table 4 summarizes the main findings.

Regarding the involvement of other areas (cross-functional collaboration), all companies highlight the important role of the marketing and production areas so that the development area can be successful. In summary, the cases sampled confirm the importance of the organization's systematization/formalization of an NPD. Furthermore, it can be

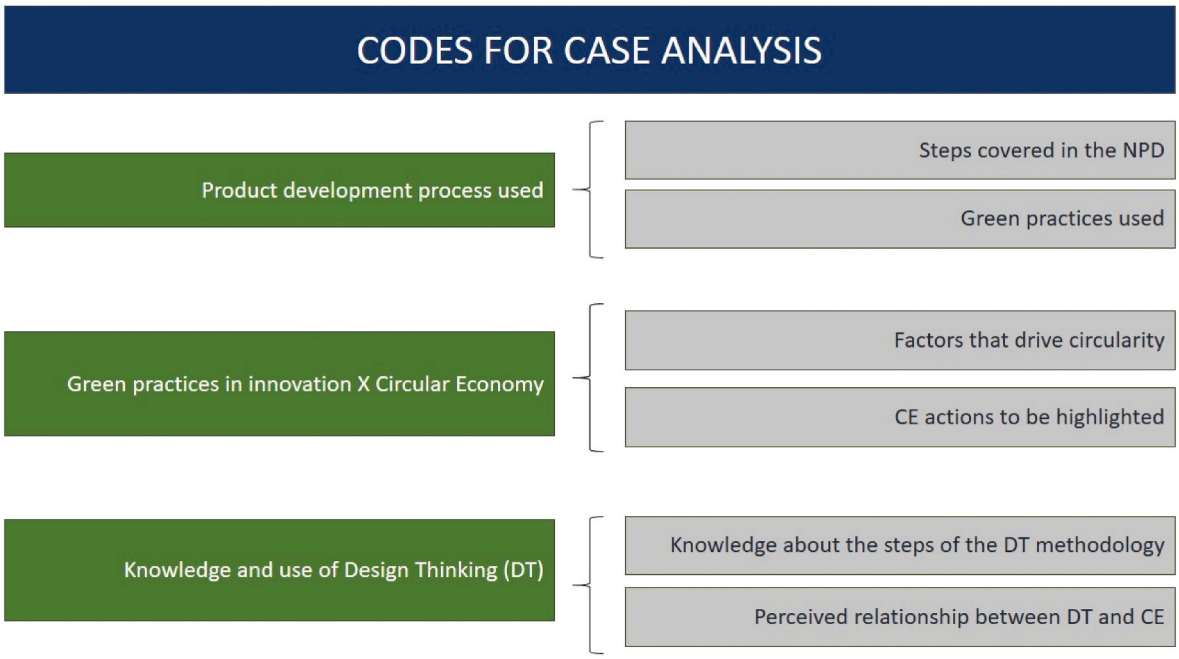

Fig. 1. Codes for analysis of results. Source: Authors' elaboration.

Table 4
NDP and green innovation practices (source: authors' elaboration).

Unit	NPD Stages	Green Innovation Practices
Company 1	Generation of ideas and concepts; Definition of the most viable market opportunities; Creating a business plan; Testing and prototyping; Validation; Launch.	Selection of eco/organic raw materials; development of products without trimmings such as buttons and zippers; reverse product logistics at the end of the life cycle.
Company 2	Generation of ideas and concepts; Creation of engineering drawings; Testing and prototyping; Validation; Launch.	Using DT methods and massive use of customer journey data; use of practices such as Customer Journey Design User Experience, and also Agile processes such as Kanban; a multidisciplinary team meets to define the goals and indicators of the life cycle of a product in order to minimize the environmental footprint/impact.
Company 3	Generation of ideas and concepts; Definition of the most viable market opportunities; Creating a business plan; Testing and prototyping; Validation; Launch; Evaluation.	Sustainable brainstorm, pilot project; development aiming to use biodegradable raw materials.
Company 4	Generation of ideas and concepts; Creating a business plan; Testing and prototyping; Validation; Launch and Media.	Development of vegan shoes (no raw materials of animal origin). The process is based on mining used clothes and through an artisanal process, this material is transformed into shoes. Some shoes are produced by fabrics made from recycled PET bottles.

seen that both the steps contemplated by the marketing models (generation of ideas with the market and tests) and the steps contemplated in the engineering models (prototyping) are part of the described NPDs. However, it is noteworthy that only Company 3 has the evaluation stage in its process.

Subsequently, and through the use of an image (Annex 1 of the Supplementary Material), the concept of CE was formally described to the interviewed of the analyzed companies. In its entirety, the interviewees claimed to know its principles and perceive actions within their businesses related to such principles.

Organizations have aspects inherent to sustainability in their value propositions. Consequently, all macro stages of their NPDs tend to consider green and socially correct aspects (pre-development, development, and post-development). Furthermore, the pre-development stage is very relevant for the insertion of circularity. The cases analyzed allowed us to identify that the success of closed-chain actions strongly depends on the strategic business plan, product portfolio planning, and the sustainability-oriented project draft (Table 5).

Finally, the researchers presented a figure summarizing the DT methodology to the interviewees (Annex 2 of the Supplementary Material). All interviewed claim to know the same and understand as important the five main steps contemplated in the DT (empathy, definition, ideation, prototype and test). In addition, all interviewed described in their speeches that this methodology could indeed qualify the NPDs developed in their organizations. Likewise, the interviewed corroborate the perception that this methodology can facilitate the adoption/incorporation of other sustainable practices and related to CE. Finally, all interviewed explained that the use of DT can increase competitiveness, as it makes projects closer to the day-to-day market and integrates the possibility of constant evaluation, as shown in Table 6.

5. Methodology proposition

According to Nagano (2022), small and medium-sized fashion companies represent 90% of businesses worldwide and cause approximately 70% of global pollution. While larger organizations are able to deal with environmental issues, financial limitations, professional experience, knowledge, and technology limit the adhesion of small and medium companies. Therefore, innovative and viable ideas are vital for such organizations to minimize their impacts and evolve from linear to circular practices (Elf et al., 2022).

In this context, and based on the results observed in our study, this section describes the proposition of a methodology arising from the DT to qualify the NPDs of the textile industry in light of CE precepts (in particular small and medium-sized ones). It is important to note that the methodology aims to guide sustainable practices in NPDs in a simple and logical way.

Table 5
CE Practices in the NPD (source: authors' elaboration).

Unit	Factors driving circularity in the NPD	Outstanding CE actions
Company 1	Raw materials selection and the way the product is designed.	Reverse logistics and waste reuse.
Company 2	From the pre-project, choosing sustainable materials to the care with reducing the use of plastic in delivery packaging. Low energy use and the search for waste reuse.	It adopts some practices in the product chain, but there are no re-entry or recycling practices for the products sold. However, it is working with partnerships to develop the circular process and wants to launch the "100% circular" positioning in 2023.
Company 3	Win-win, traceability of raw materials and the production process. Search for compostable materials.	As the return logistics do not apply to the brand's products, in 11 years in the company, the same parts from the beginning of the brand were still used, and they are still intact. Exchange thrift stores were held before the pandemic. Currently, shared cabinets are recommended, or, in the case of the end of the product's useful life, it is placed in the compost bin.
Company 4	Handmade products are produced from vintage clothes and fabrics from recycled PET bottles. The keyword of the company's NPD is reuse: increasing the useful life of what already exists worldwide.	At all stages, there are reuse practices in the production chain. The stakeholders involved with the brand's activity are strategically chosen so that this practice is consolidated in the inputs and outputs of the process. The design and production are made from the reuse of clothes mined in different locations. The soles of the shoes are made of 100% recycled rubber. In addition, all the rest of the materials used are market surpluses, things that would be discarded by the industry.

Table 6
DT, NPD and CE (source: authors' elaboration).

Unit	DT steps that can qualify the NPD	DT and its relationship with CE practices
Company 1	Empathy and ideation are the most significant steps to be integrated into the NPD.	Flexibility and generation of solutions to real problems.
Company 2	Company already uses DT in NPD. Empathy, ideation and testing are the main contributions of the methodology.	Facilitates the integration of people from inside and outside the organization so that circular solutions are possible.
Company 3	All steps are relevant, but the test phase stands out as all operations in the company are based on sustainable development, with no stock, that is, production is on demand.	DT is a methodology that helps in problem solving.
Company 4	Empathy, in view of the lifestyle for which the business is positioned.	Ideation.

We emphasize that when we propose a methodology that inserts circular thinking in the textile industry, we observe the five main stages of the DT (Interaction Design Foundation, 2022) and the three macro phases that encompass the process of developing and managing the life cycle of textile products in organizations. Additionally, we divide the methodology into two main cycles: the design cycle, which encompasses the DT stages, and the consumption cycle, which encompasses the subsequent stages. The idea is to have a fluid connection between the two cycles so that circular solutions are possible. Fig. 2 presents the proposed model.

For the macro phase of (i) planning, we consider the DT steps (a) understand and (b) define. Analyzing the cases that support our study, as well as having as a reference the findings of Elf et al. (2022), it is a fact that small and medium enterprises in the textile sector, as they advance in CE practices, tend to exhibit highly creative and innovative thinking to actively change the 'status quo'. Therefore, in step (a) understanding, we reinforce the importance of organizations to understand the needs and behaviors of customers of products derived from the textile industry.

Although there is a sociocultural environment favorable to green innovation, we know that the usual behavior of consumers sustains a strong barrier to the implementation of CE in the textile industry (Hugo et al., 2021). Consumers are still attached to fast fashion consumption and do not see the negative consequences associated with high levels of consumerism. In addition, there is a negative perception of second-hand and/or rented clothes (Moorhouse, 2020). Finally, few sustainable fashion brands exist, and many existing ones do not convey credibility (Mauro et al., 2020). Thus, we suggested an empathic analysis of the process of buying and consuming products from the textile industry, in particular motivations (utilitarian and hedonistic) and attitudes (cognitive, affective, and conative) (Blackwell et al., 2005).

In step (b) define, we must point out the problem and/or issue that we intend to solve from understanding the user's needs. In this context, we must establish a definition for sustainable consumption in the textile industry. Such a definition tends to support decisions not only about what should be offered (products and services) but also alternatives to manufacturing (such as raw material for remanufacturing from oriented disposal, for example). Moreover, companies need to be informed about sustainable materials and designated suppliers. They must phase out substances of concern and microfibre release (Ellen MacArthur Foundation, 2017). Companies can choose to use natural dyes with a lower environmental impact, and organic and recycled fibers as a sustainable materials strategy (Claxton and Kent, 2020). Brydges (2021) exemplified the use of natural fibers, such as cotton and hemp (plant-based) or wool and cashmere (animal-based).

Additionally, at this stage, it is necessary to identify existing options for reuse, remanufacturing, or recycling in the textile industry to apply these actions in later stages. Therefore, at this point, it is important to consider the existing alternatives and opt for the use of materials that facilitate recycling, reuse or remanufacturing and avoid those that make these processes more difficult. Incrementally, as pointed out by Ellen MacArthur Foundation (2017) and Harmsen et al. (2021), it may be necessary to reduce the complexity of the materials used, as the mix of materials makes it difficult to capture the value of materials through recycling, for example.

The reuse of clothes occurs when the clothes are reused again in their same state with no (or minimal) reworking (Ellen MacArthur Foundation, 2017). It can occur through stores that sell second-hand and rented clothes (Hugo et al., 2021) or through donations to acquaintances or needy people. Companies can also think about new business models that involve, for example, rental subscription, short-term rental, sale of highly durable clothes, and resale (Ellen MacArthur Foundation, 2017). Reuse also includes waste from the production process and reusing raw materials, such as leather scraps, cotton waste, wool scraps, or reused fabrics (Colucci and Vecchi, 2021). According to Dissanayake and Sinha (2015), remanufactured fashion involves making garments from reclaimed fabrics, which can be post-industrial waste (generated in fabric or apparel manufacturing processes), post-consumer waste (clothes discarded by end consumers), or a combination of both. For example, replace few panels of a dress with new fabrics to allow a new look and fashion updates (Dissanayake and Sinha, 2015).

Recycling is usually considered the last alternative, as it generally uses a high-energy processor, but it is still considered an important alternative to implementing CE (Todeschini et al., 2017). Guidelines for recycling would need to consider aligning the design of clothing with

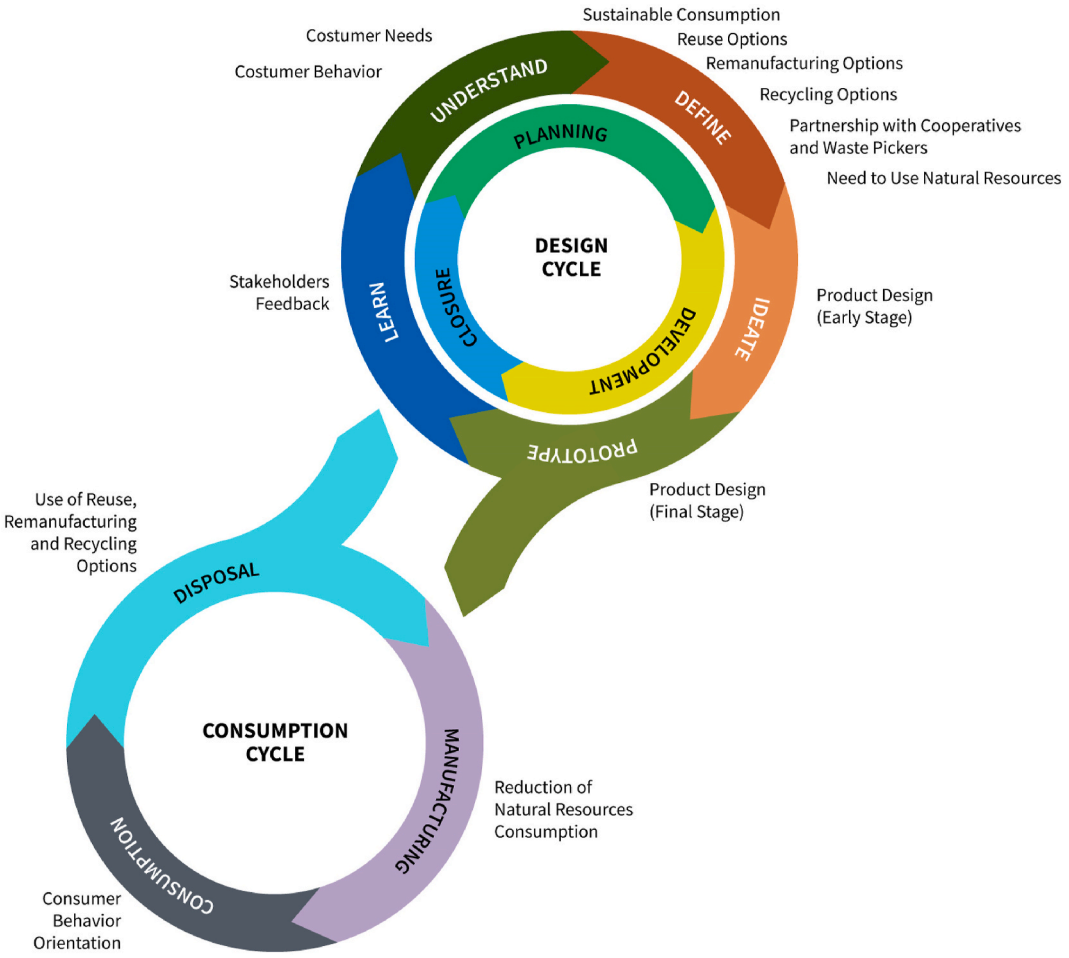

Fig. 2. Methodology for circular thinking in the textile industry. Source: Authors' elaboration.

recycling options, the requirements for new material innovations, the convergence towards a reduced palette of materials, and cross-industry alignment on systems for labeling, tracking and tracing (Ellen MacArthur Foundation, 2017). According to Harmsen et al. (2021), there are good recycling options for mono-material. There is some complexity regarding recycling options for each type of textile fiber, as each fiber has its own optimal recycling strategy. Therefore, it is important to evaluate the various recycling possibilities for each material (Harmsen et al., 2021). There are different recycling types, most of which include reclaiming the fibers and using them in other textile products. Some types of textile waste can also be processed into nonwovens for the automotive industry, appliances, drainage systems, and geotextiles (Do Amaral et al., 2018; Ellen MacArthur Foundation, 2017; Harmsen et al., 2021).

Another relevant point when we look at the process from the CE centers on the establishment of partnerships with cooperatives and waste pickers. In Brazil, the focus of this study, there are between 800,000 and 1 million waste pickers (Zanatta, 2022). According to the National Movement of Recyclable Material Collectors, this portion of the population is responsible for the selective collection of 90% of recyclable materials in the country. An approach to this audience can help the textile industry to identify different materials that can be reused, recycled, or remanufactured.

As for the macro phase (ii) development, we consider steps (c) to idealize and (d) to prototype. To (c) idealize, we must generate product concepts in view of the requirements identified in the previous step. The logic of UX Design must be considered for the idealization of the product design. That is, from a deep understanding of users' needs, their objectives, abilities, and limitations, possible solutions must be aligned with the business objectives, in this case, circularity objectives (Xue et al., 2022). Product design needs to focus on reducing, reusing, and using organic materials (Hugo et al., 2021).

Regarding step (d) prototyping, we suggested that the ideas perceived with greater viability be operationalized in product models. Here we seek tangibility, aiming for the experimental model to make it possible for everyone involved to "see" the concept and, from there, propose new solutions and/or improvements (Brown, 2008; Liedtka, 2015). It is important to note that the more popular sustainable fashion tends to be, the stronger the aesthetic appeal becomes, and there is, therefore, a growing need for such products to be desirable and contemporary (Mauro et al., 2020).

Next, we advance the DT phases to the new cycle. In the (e) manufacturing stage, in order for us to use natural resources optimally, as well as for recycling and remanufacturing to be possible, technologies need to be accessible (Hugo et al., 2021). Furthermore, sorting and recycling technology can be improved with digital technologies, which would also provide transparency, traceability, and automation (Sandvik and Stubbs, 2019). In the manufacturing stage, the implementation of practices that increase process performance, save materials, energy, water, downtime on the production line, and use renewable sources can be contemplated (de Medeiros et al., 2018a,b). For example, the use of rainwater, cleaner energy, and waste treatment. Textile companies can save water and energy in factories by detecting and repairing leaks in water systems, insulating equipment such as dye baths, and recovering heat and water for reuse. Companies can also reduce the waste of offcuts materials through new methods and direct reuse in the production

process (Ellen MacArthur Foundation, 2017). The environmental impacts of production can also be reduced by limiting water waste or the number of chemicals used in dying processes (Brydges, 2021).

Afterward, in the (f) consumption phase, it is necessary to guide the behavior of consumers, especially in the sense of stimulating sustainable consumption. We need to assess what the development delivers to the final consumer before, during, and after the consumption stage. Achieving circularity in the textile industry represents a complex challenge. While more than 80% of a product's environmental impact is determined at the design stage, responsibility should not fall solely on this step (Mauro et al., 2020). According to Elf et al. (2022), sharing, repair, and resale are actions relevant to circularity and can be planned as added services by the textile industry. Additionally, it is important to encourage consumers to take better care of their clothes by using more detailed clothing care labels and providing more extensive information, advising consumers to wash clothes less frequently, use colder water and avoid dry cleaning (Brydges, 2021). Finally, in the (g) disposal, the previously defined reuse, remanufacturing, and recycling options are applied at the end of the consumption cycle. Through this, the process returns to the manufacturing phase or advances to the learning phase.

In the macro phase of (iii) closure, there is (h) learning. At this point, it is necessary to collect feedback from all stakeholders involved in the process (employees, customers, waste collectors …) so that improvement opportunities can be applied in both cycles. In this way, we highlight that both the prototyping phase moves toward learning (when issues from the design cycle are learned) and the discarding phase (when lessons from the consumption cycle are learned). This process allows returning to previous stages to make changes or improvements, add new value propositions or functionalities to products and services, and find or discard alternative solutions.

As described by Kolling et al. (2021), in addition to the textile sector, although companies are developing sustainable actions, greater emphasis is perceived on environmental issues and the design and supply stages, while less effort has been directed to social aspects and other stages of the life cycle. We, therefore, need development models to be more comprehensive and integrated. We must avoid the prevailing economic view in which services are aggregated to strengthen customer relationships and increase competitive advantage (Kolling et al., 2022). We need to focus on inclusive and educational issues (Mies and Gold, 2021). We must establish new value chains and new partnerships (de Medeiros et al., 2022). We need entrepreneurs willing to articulate ecosystems capable of sustaining/anchoring circular business models (Marcon and Ribeiro, 2021).

6. Validation with experts

In general, we can say that the experts welcomed the proposed methodology. The three researchers highlighted the method's usability in terms of guidance, visual, language, and inspiration. However, all commented that there was a need for prior knowledge about NPD and CE for better use. In addition, they also highlighted the importance of developing and implementing public policies to promote EC practices and support ecosystems. Based on the above, Table 7 summarizes the requirements assessed by the experts.

Two points we consider relevant to highlight, especially after the validation of the method, focus on the idea of prior knowledge and the political-legal environment favorable to circular proposals. A series of other studies focused on research on green product innovation supports the relevance of organizational skills and resources for the success of sustainable practices (de Medeiros et al., 2022). Likewise, studies that address the essential role of establishing policies to encourage and support circular practices are frequent, especially in the textile sector (Hugo et al., 2021).

Green innovation requires broader organizational capabilities than traditional new product development activities. In addition to sustainability orientation, governance skills, green leadership, and knowledge are necessary competencies for organizations that wish to undertake in a sustainable way, especially in a logic of circularity (Sassanelli et al., 2020; Xue et al., 2022). Organizational resources are also important. Understood as the stock of factors that the company owns or controls, these resources enable the proper operationalization of the organizational strategies (Khan et al., 2020). People, tangible resources (such as financial and physical), and intangible resources (culture, management, brand reputation, and innovation) are pieces that support the necessary background.

Regarding the favorable political-legal environment, Hugo et al. (2021) highlight the lack of government support for the textile industry

Table 7
Usability requirements from the propositions of Lofthouse (2006) (source: authors' elaboration).

Requirements	Expert 1	Expert 2	Expert 3
Guidance	It is simple but, at the same time, presents complete content.	The model guides the actions of the process. However, it requires supplementation.	It works as a guide. But it depends on prior knowledge.
Information	At first, it may seem "like a lot". Nevertheless, when the subject follows the visual path, he understands the phases and each suggested stage.	The subject is complex, but the figure simplifies. I like the established labels. The synergy between the different contents. There is complementation and logic.	The division by phases helps understanding.
Visual	The colors help to understand the phases.	I find the visual intuitive. It drives the idea of circularity.	There is a certain "confusion" in the first look. "Seconds" of confusion ("I don't understand this"). But soon, the circles and the colors make the reading be conducted according to the proposed circular process.
Language	Clear.	The terms are the domain of those who work in development processes. Language is adequate.	Clear terms. The language is concise.
Education	I believe it works. It helps different employees understand what the business wants. It helps to understand that product development is not just design but also the whole.	It educates, mainly because of the form, in my view. Usually, models follow steps, a funnel idea. Here you generate important movement when circling. As we see it, we are already learning to get out of the sequential steps in line.	Depends on prior knowledge.
Inspiration	In my perception, it stimulates curiosity. Moreover, there is something semiotic when I saw the image. I remembered a sunflower.	The model is intuitive (in my opinion, its main facilitation).	Yes, there is an "association tool" in the model. Circles, phases, inside-out, or outside-in.
Dynamic access	The model allows customization, especially due to the flexibility of the outer circle.	More of the second circle out. But yes, there is dynamic access.	It can certainly be adapted to specific realities.

to create openness, guide efforts and reduce costs in implementing greener solutions. Other studies, in addition to the textile sector, indicate that government incentives are more effective than regulations (de Medeiros et al., 2022). Usually, studies link government support to financial subsidies and incentives. The incentives can be related to the reduction of bureaucracy and facilitations, such as establishing programs that accelerate and qualify the granting of green patents and technological support systems (Wang, 2022). Another incentive that the studies found focuses on stimulating the green chain (Peng et al., 2021). The enactment of policies to encourage the establishment of alliances between companies is fundamental for the engagement of different stakeholders in new chains, especially circular chains (Nurdiawati and Agrawal, 2022).

Finally, we highlight that the three experts agree that the method can be customized to different contexts. We understand that this point is relevant since circular practices require adaptability and creativity (Sassanelli et al., 2019). In addition, the challenge of connecting micro and macro levels remains when thinking about EC methodologies, given the cultural, economic, and social differences of countries across the globe (Harris et al., 2021).

7. Conclusions

This paper analyzed how DT can be used to insert the practice of circular thinking in developing products in the textile industry. To this aim, we first conducted a narrative bibliographic review covering the topics of CE, green innovation, and design methodologies for NPD, focusing on DT. Second, we mapped good practices of green innovations and related to the circular economy in NPD of brands that operate in the textile sector. Then, we systematized, based on the precepts of the DT and the knowledge generated by the field study, a methodology that can be used in the NPD of the textile industry aiming at the transition to CE. In the end, we evaluated, together with experts, the applicability of the proposed methodology for use in practical cases.

The results of the study indicated that the companies surveyed tend to consider environmental and social aspects at different stages of the development of their products, but there is scope for improvement. The cases analyzed allowed us to identify that the success of closed-chain actions strongly depends on the strategic business plan, product portfolio planning, and the sustainability-oriented project draft. Although the companies surveyed understand the importance of DT, not all of them apply it in practice. The interviewees believe that the DT is a tool that can generate a competitive advantage and that it can be an ally for the sustainable transition in developing new processes and practices already carried out by companies related to environmental issues.

We conclude that companies demonstrate advances concerning sustainable issues, but there are opportunities for improvement, especially through the use of ideas from DT. The proposed production methodology can help companies in the sector develop green and sustainable innovations and implement CE's ideas in developing their products. The validation stage carried out with specialists confirms that the proposed methodology has adequate usability.

The limitations of this study should be acknowledged. Since our field study prioritized textile companies in Brazil, future studies could be conducted with more companies from different countries to enrich the research and reinforce the results. Likewise, future research could be conducted in companies from other sectors to extend the application of DT to developing sustainable solutions. Given the qualitative approach used, future studies could explore quantitative data and statistical analysis to enrich the research and complement the results. There are research opportunities concerning the incorporation of performance measures into the proposed methodology (environmental, economic, and social spheres) so that it is possible to periodically verify the impacts generated on the company's sustainability level, which will allow the evaluation of the effective contribution to the circular economy of the proposed methodology.

It is also suggested the application of the methodology through action research studies, which would allow its visualization in the practical context, generating information for its improvement. Moreover, future research should provide broader insights regarding the challenges of textile companies implementing sustainable and CE practices, which would provide helpful information to improve the proposed methodology. Also, studies could investigate which competencies are necessary for companies to implement CE practices and the indicated methodology.

7.1. Research implications

The research contributes to theoretical knowledge by advancing discussions on NPD in the textile sector, especially its potential to contribute to the transition to CE. In addition, the study explores how DT assists in inserting circular thinking into the NPD. Specifically, it advances in the recognition that the characteristics of DT, such as interaction with users, creativity, and focus on the human being, help develop circular solutions, which require creativity and cooperation with customers. The proposed production methodology also enriches research on how a shift toward sustainability in the textile and apparel industry can be achieved.

In addition, we empirically investigated green and CE-related innovations in greater depth from companies operating in the textile sector. We also highlight the factors that drive circularity in the companies' NPD. In addition, we have advanced research on CE in the textile industry in countries of emerging economies. The contributions add value to current research on sustainability in the textile industry and can guide future research on the topic.

As for practical contributions, we highlight the proposed production methodology, which aims to provide guidance and better clarify the procedures necessary for implementing a sustainable NPD for the textile sector based on the ideas arising from the DT. We highlight essential steps and factors that should be considered in the companies' NPD, allowing them to expand their understanding and adherence to sustainable and circular initiatives. The idea is that the proposed methodology can be used as a guide and each company may customizes it according to its products, production environment, and available resources. Additionally, research can encourage and assist large and small companies in implementing these actions in their NPD.

To facilitate the transition towards sustainability and CE within the textile industry, there is a need for management to focus on the user experience, not only regarding the purchase of the product but also consumption and disposal. We confirm that consumers are not passive, requiring companies to find ways to influence them to adopt sustainable purchasing and consumption habits. Companies must establish and strengthen partnerships with different actors, in addition to consumers, so that the proposed circular initiatives can be achieved. Moreover, companies must have a strategic business plan focused on sustainability, oriented toward CE and DT aspects.

We highlight that policymakers and regulators should offer incentives for companies in the sector to develop sustainable initiatives and consumers to encourage sustainable consumption in the textile industry and the development of new business models. Specifically, considering the representativeness of small and medium-sized fashion companies and their greater difficulty in dealing with environmental issues, different incentives could be proposed to encourage these companies to develop circular initiatives. Government should recognize and support the role and potential of small and medium companies in contributing to circularity. Additionally, governments can engage with policymakers from other countries, seeking good practice in legislation or standardization of regulations in favor of the environment. Policymakers can create enabling conditions and be important partners in initiatives related to textile collection and processing.

Additionally, the research provides insights into the circular perspective and prospects for the fashion industry in countries with

emerging economies. We believe that companies from other industries with similar structures can use our results to insert DT and EC into their business models. Thus, we understand that our results may be relevant to other contexts, especially those that have institutional characteristics, laws, and cultural values similar to the country investigated in this study.

CRediT authorship contribution statement

Thomas Germano Battesini Teixeira: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Janine Fleith de Medeiros:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Camila Kolling:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **José Luis Duarte Ribeiro:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Donato Morea:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2023.136588.

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