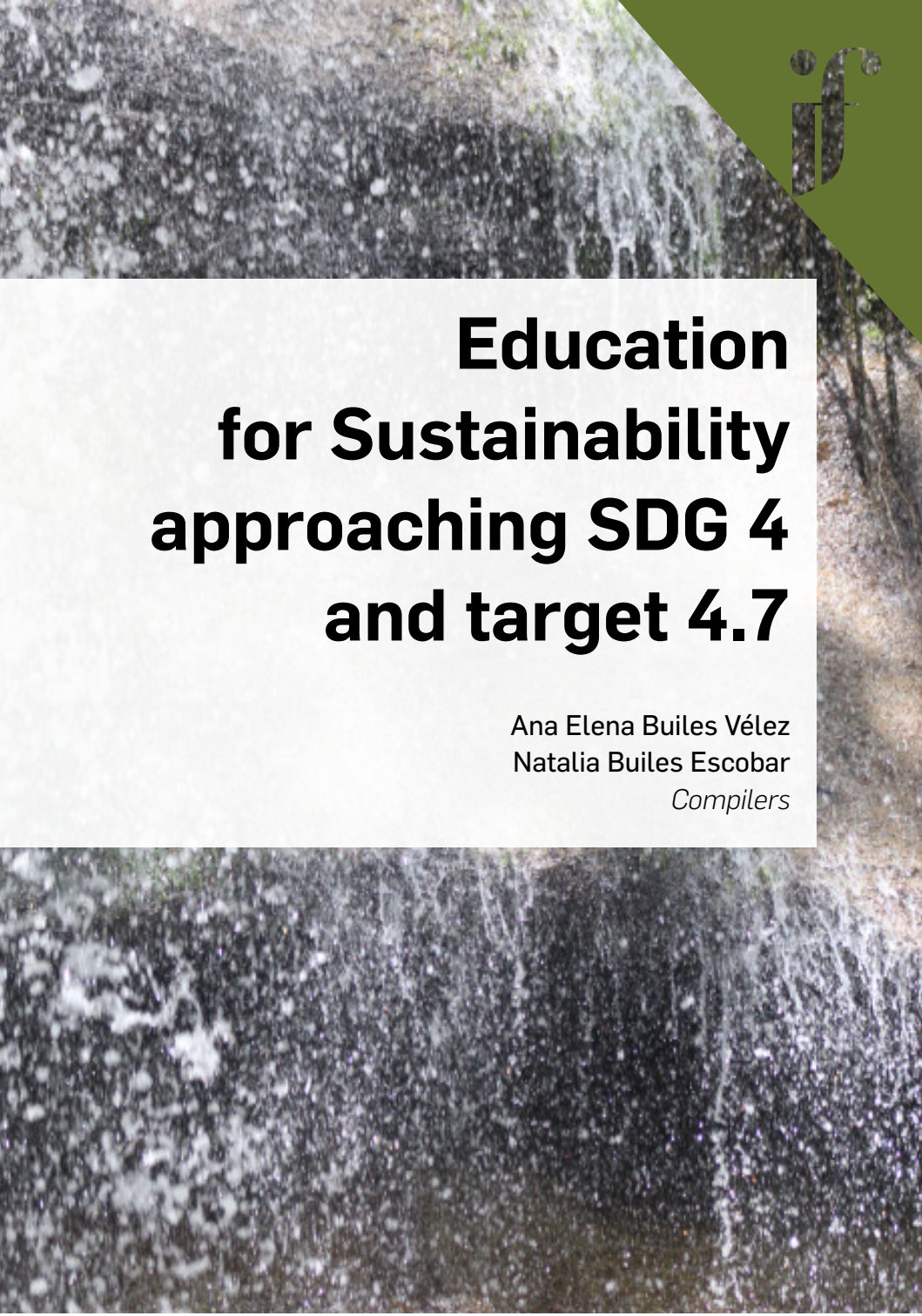

Education for Sustainability approaching SDG 4 and target 4.7

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Challenges to wearable design education from a sustainability perspective

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Abstract

Current clothing purchasing behavior is not sustainable. Consumers are buying more clothes and wearing them for less time, leading to higher levels of carbon dioxide in the production, use and disposal of clothing. As sustainability becomes the norm in the fashion industry, consumers who play an important role in the life cycle of clothing need to understand the environmental impact of their clothing choices. Researchers call for more research on practices and methods to educate consumers and therefore apparel designers about the environmental impact of textile and garment consumption to determine and define design methodologies that lessen that impact (Abner et al., 2019; Armstrong et al., 2016; Connell & Kozar, 2012; Ha-Brookshire & Norum, 2011; Kang & Kim, 2013; McNeill & Moore, 2015).

Awareness of the environmental issues associated with increased apparel consumption has influenced how the textile and apparel industry responds. As fashion sustainability issues have become more public and politicized, companies that produce and sell apparel and textiles have developed standards to determine the preferred attributes of sustainable products (REI Staff, 2018).

Consumer use of so-called wearables - portable or wearable technology - makes up 10% of part of the apparel product lifecycle, growing at 4% per year globally. The use, care and disposal of this type of wearable has a significant impact on the environment through the use of energy, water and textile waste (Ellen MacArthur Foundation, 2017). Part of the responsibility lies in the hands of consumers and another part in the hands of designers who generate wearables to solve high impact issues but need to include sustainability practices to ensure the sustainability of this new category of products.

This chapter aims to show a synthesis of the characteristics that must be met in the design of wearable products, and the drivers that are considered in the purchase of garments developed under sustainability criteria, in order to understand the fit of the two models.

Keywords: Apparel design, wearables, technology, consumer.

The design of wearables

The term wearables refer to electronic and computer technology that is incorporated into wearable accessories or clothing and generates an organic interaction with the body. These devices can perform many of the same tasks and functions as smartphones, laptops, and tablets. However, sometimes, these devices perform tasks

more conveniently and efficiently than portable and wearable devices. They also are more complex in terms of sensory feedback and actuation capabilities than traditional technology equipment. The goal of wearable technology is to provide reliable, consistent, convenient, continuous and hands-free digital services for their operation, which makes these features fundamental requirements for the design of such wearables, and given the scrap nature of some parts used for batteries, microcontrollers, sensors and other wearable components, it is important to incorporate sustainability features to ensure the low impact of such products.

Wearable devices often provide a communication and feedback to allow users to view/access information in real time. A user-friendly interface is also an essential feature of these devices, as well as an ergonomic design, understanding from this point of view the inclusion variables that generate high impact social sustainability.

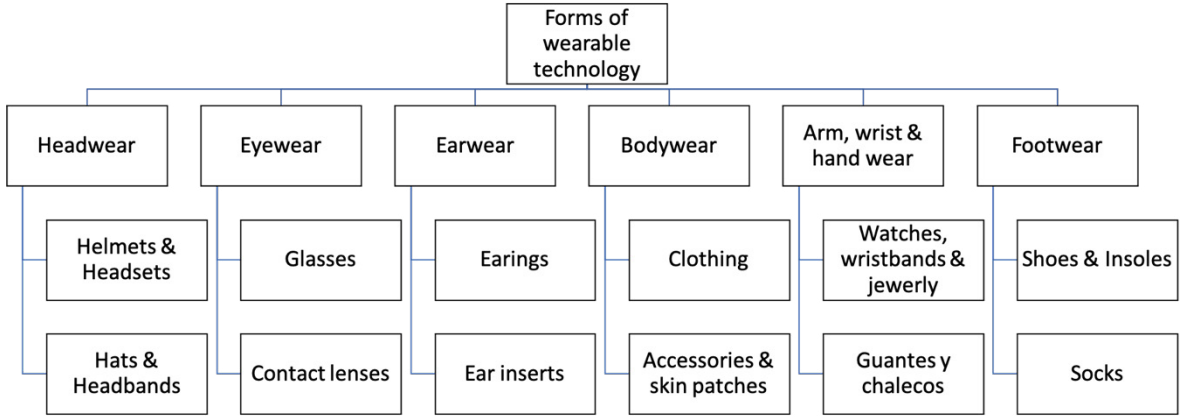
Figure 1 shows the most important representations of wearables usage occasions in apparel design.

While typical wearables refer to elements that can be attached to the surface of the body or clothing, there are also more invasive forms, such as implantable electronics and sensors. These types of parts have not been considered in the analysis given their complexity of bio-compatibility and their bioengineered design nature.

Characteristics of wearables

Wearables must be versatile garments with application potential for recording variables associated with medicine, health, sports, aging, disability, education, transportation, business and entertainment. In these fields, the principal aim of wearables is to seamlessly integrate functional and wearable electronics into the daily lives of users. Before

Figure 1. Representations of wearables



the consumer market, wearables were mainly used in military and high-precision healthcare technology. Portable devices share many aspects of observation, connectivity, automation and intelligence with IoT devices.

In the design of this type of wearables the morphological factor is an aspect associated with the hardware design in the electronic packaging that defines the size, shape, weight of the part, almost always determined by assembly of the controller, battery and sensors of the system. While wearables, by design, require a smaller form factor, this relationship is actually determined by the biomechanics of their use. Smaller form factors can provide lower material usage, easier handling and simpler logistics; however, they often result in higher design and manufacturing costs, as well as signal integrity issues and maintenance limitations.

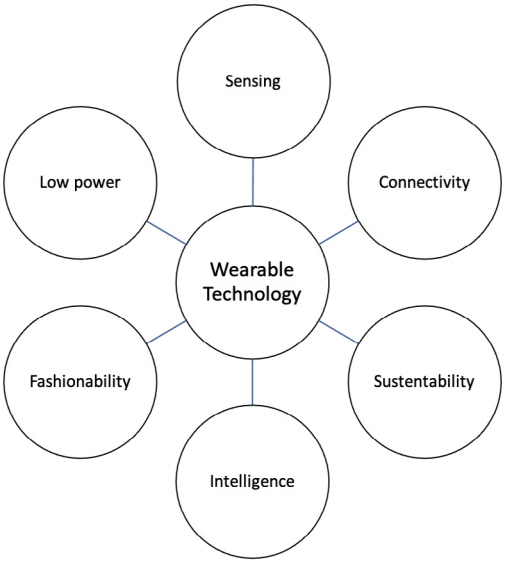
The durability factor is fundamental as it determines the cost of technology involved with the perceived obsolescence of the piece, giving rise to one of the important items in the design of wearables, associated with the exchange of parts that allow to change the aesthetics of the piece from the technological core that processes the information, in the design it is important to consider the final disposition of this core, given the materials that comprise it, from lithium batteries, to biopolymers of high mechanical performance.

Ergonomics factors are also important considering the miniaturization process that wearables must develop in their design process. Figure 2 shows the most important features to consider in the design of wearables.

Challenges of wearable design

While wearables continue to transform our lives in the 21st century, significant challenges are emerging from their design that, if not considered in their design education, can prevent them from realizing

Figure 2. Characteristics of wearables



their full potential. These are the fundamental challenges that require full attention:

Security education

Security is one cornerstone of the Internet and the most important challenge facing wearables. Hacking of fitness trackers, security cameras, baby monitors and other abuses has drawn the attention of many of the world's leading tech companies and government agencies. While security considerations are not new to the world of information technology, the characteristics of many wearable design implementations present unprecedented security challenges. As the design of these types of products become ubiquitous and integrated into our daily lives, users must keep these devices and associated data safe from vulnerabilities such as cyber-attacks.

Concerns about the design of wearables at this level will no longer be limited to protecting our data and intangible assets; this challenge is magnified by other considerations, such as the mass production of identical devices, the capabilities of identical devices to determine the behavior of their users, the ability of certain devices to automatically pair with other devices and the potential use of those devices in unsecured environments.

Privacy education

While many emerging wearables are generating innovative applications and uses, as well as promising and attractive benefits, they also raise unexplored privacy concerns, most of these devices need to interact and share data with access points (i.e., smart watches to smart phones, medical monitoring devices to home servers, light bulb home assistants to home controllers) and other sensors and peripherals will certainly generate a new class of privacy and security de-risking.

Some of these devices implement, by design, multiple sensors to collect a wide range of biological, environmental, behavioral and social information from and for their users. Obviously, the more they become part of our daily lives, the more sensitive information they store, process and transmit, which also raises privacy concerns. Built-in surveillance or voice recognition capabilities constantly eavesdrop on conversations or video recording activity and selectively transmit this potentially sensitive data to cloud services for processing, sometimes involving third parties. Processing and interacting with this information demonstrate the legal and regulatory challenges facing privacy and data protection laws.

The challenge for educating design models will increase when these devices are integrated with facial recognition programs that allow users

to see people's names, personal information and even access their social media accounts in plain sight.

Education of the norm

The lack of standards and documentation of best practices is a major limitation to the potential of wearables. Without standards to guide designers, these often-disruptive products can lead to interoperability issues and, if not designed and configured correctly, can have negative consequences, affecting, for example, the network to which they are connected and possibly the Internet. Unfortunately, this is mainly due to cost constraints and the pressing need to get the product to market before the competition, and with versatility governed by today's fast fashion.

Legal issues related to wearables may include conflicts between government oversight and civil rights. Considering that the technology is developing much faster than the associated regulatory and policy environment, which can make products and their interactions with users conflicting.

In addition, the cloud or even the Internet itself is not limited by a specific geographic location and the sheer volume of wearables comes from many different sources, including international partners and suppliers, making quality control or standardized testing impossible for local regulators.

Sustainability education from "Energy issues".

Increasing data rates and the number of Internet-enabled services, along with the exponential growth in wearables, are driving networks to

consume more power. In addition, the drive for smaller size and lower power consumption is creating more signal integrity and power issues in wearables, rendering their performance faulty in the short term and leaving a scrap and buyback trace much higher than even the current market dynamics.

Common problems include distortion, excessive losses, impedance mismatches, and generator noise. If these issues are not addressed, these devices could be adversely affected and create consumption dynamics beyond the capabilities of current sustainable standards.

Education in “connectivity

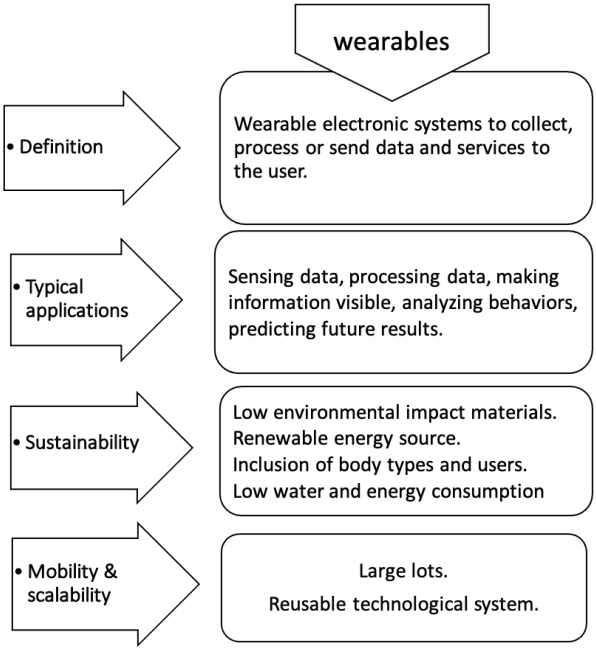
It is only a matter of time before users experience major bottlenecks in connectivity, competency and performance of their wearables with the current rate of growth in wearable design and development. Today, a large percentage of connected devices rely on centralized client/server platforms to authenticate, authorize and connect to other nodes in a network. This model is sufficient for now, but as billions of devices are added to the network, these platforms will become the bottleneck. These systems will require upgraded cloud servers to handle such a high volume of information traffic.

Figure 3 shows the dimensions of wearables and their impacts on sustainability.

Education of wearable design with sustainability.

The basic concept of sustainability applied to wearable design is given by “meeting current needs without compromising needs in the future”

Figure 3. Dimensions of sustainable wearables



(Johnson et al., 2016). McKeown and other researchers identified three principles of sustainability, where these three principles are necessary to address education for sustainable development, the first principle is economically based, the second is environmentally based, and the third is socially based.

Protecting the environment while adapting to economic development is an important ecological trend currently affecting the training of apparel designers, especially those focusing on the area of wearables with a strong emphasis on consumer trends (Harden et al., 2014).

With the rise of the global fast fashion trend, wearable consumption continues to increase, creating dangerously high levels of carbon dioxide emissions and other toxins in the global ecosystem and this dynamic is

being a consumption odel that determines the behavior of wearables in the marketplace. Both industry and consumers must act to reduce carbon dioxide (CO2) emissions and textile waste (Ellen MacArthur Foundation, 2017). The industry is increasingly aware of sustainability issues and is implementing practices to improve sustainability. As awareness increases, many companies are working to improve and innovate many aspects of their industries to meet and comply with sustainability standards (Cattermole, 2018; Fashion United, 2020; REI Staff, 2018).

Consumers have been slower to change behaviors associated with apparel consumption. Although customers support companies changing be more sustainable, 71% are not willing to pay more for sustainable clothing (NOSTO, 2019).

Sustainable wearables type products have specific characteristics that are determined by: sustainable raw materials, reduced use of fossil fuel energy, reduced use of toxic chemicals, and reduced water use. The supply of sustainable clothing is increasing and the option of wearables in the same category is an important alternative. It is important to embrace the steps that companies in the apparel industry are taking to improve the environmental impact of apparel production. In examining the associated risk factors that significantly influence consumers purchasing sustainable garments, the same categories of perceived risk were used. Kang and Kim's (2013) research assessed risk perceptions of such sustainable garments among young consumers. The risks examined are: financial, performance, psychological and social risks. The hallmark of financial risk is high-priced clothing that also includes low-cost use and care (Kang and Kim, 2013). Psychological risks are closely related to performance risks; however, these risks are associated with negative perceptions of self-image (Kang & Kim, 2013). Friends and family consider these fashionable or popular garments to define social risk (Kang & Kim, 2013).

For the developed research we adopted the measurement of the same variables in current market wearable systems (smart watches, monitoring bands, etc) with emphasis on their sustainable design and found that financial risk is the most important barrier to purchase this type of product, that psychological risk directly determines attitudes towards wearable use, that social risk has little impact on wearable purchases because of the observation that it is difficult to determine if it is a sustainable product without a label or logo and performance risk was not significant.

These perceived risks fit easily with the factors of Ajzen's (1991) theory of planned behavior; the theoretical framework used to guide this research. Although economic and environmental sustainability factors are two of the three principles of sustainability, social aspects must also be considered.

Sustainable and consumer-focused wearables

Fast fashion trends coupled with an increase in textile waste have reinforced the need for sustainable-based education for new product categories. Teaching about sustainability and using teaching strategies and methods that encourage sustainable behavior is one way to combat overconsumption (Harden et al., 2014).

Certain areas of wearable design are better for teaching sustainability issues. For example, Ulasewicz and Vouchilas (2008) studied courses at the University of California and found that courses in wearable design with technology and interior design vary widely in the application of sustainability topics. Interior design includes sustainability in most aspects of the curriculum, while apparel design with technology courses address sustainability in only one of their courses and nurture the curriculum with the implications of technology. Courses with a strong

sustainability background influence students' knowledge, causing them to consider sustainability options more often, from a technological standpoint, which leaves sustainability not as a design option but as a prerequisite of the system to be designed. Before teachers can develop curricula and choose teaching methods to disseminate information on how to better manage the earth, wearable design professionals need a better understanding of the factors that guide consumers in their product choices to turn sustainability into a product's competitive advantage.

Variables influencing the purchase of sustainable wearables:

Knowledge about impacts.

Increasing students' knowledge of social and environmental issues related to wearables is one way to influence sustainable consumer behavior (Connell and Kozar, 2012). The concept identified by Thompson et al. (2012) posits that a focus on environmental issues such as exploring carbon footprints of materials and processes, solid waste, and water should be used. The U.S. Environmental Protection Agency annually reports facts and figures on waste materials, waste and recycling of textiles on its website, being a significant source of information to monitor the performance of wearable-type products that are manufactured and discarded.

In 2010, about 13.2 million tons of textile waste and technology waste were generated, 8.9 million tons were landfilled, and about 2 million tons were recycled. Non-durable goods waste (products with a useful life of three years or less) has decreased since UNESCO established sustainability standards in 2005, but textile and technology waste has increased. The facts and figures further illustrate the enormous need to

address the environmental impact of clothing consumption habits and the birth of wearable consumption.

Sharing knowledge about textile waste has the potential to reduce waste generation, formal methods of sustainability education significantly influence behavior change more than informal education methods.

Environmental concern

Yeung (2004) defines environmental concern as "an emotional attribute that expresses an individual's concern, empathy, likes and dislikes for the environment." Environmental concerns are easily translated into action because of emotional connections. Researchers Joshi and Rahman found a very large connection when examining consumer awareness of environmental issues related to apparel production and consumption. Lundblad and Davies (2016) found significant patterns of motivation to address environmental problems among environmentally concerned consumers, including responsibility and a desire to protect the planet. Those who feel responsible for addressing environmental problems do so by taking responsibility for how they consume and hope to educate others to develop similar habits. These habits include buying products made from natural materials, learning about eco-friendly production techniques and buying recycled clothing, where repaired wearables are an option. Post-purchase habits or activities that are positively associated with environmental concerns involve greater use of apparel products, including wearables (care, repair and recycling).

Attitude.

The individual meaning associated with attitude comes from the "like or dislike" paradox (Ajzen & Fishbein, 1980). Ajzen and Fishbein recommend

using a bipolar rating scale when assessing attitudes. The more positive the attitude toward the expected behavior, the more likely the individual is to perform it.

When assessing attitudes towards sustainable clothing and sustainable wearables, the determinants of attitudes should be identified. There are several research studies that cite lack of consumer knowledge, product availability, financial resources, retail environment and social norms as reasons for people's poor attitudes toward these types of products. Color and style are powerful influencers of choice. These performance factors outweigh the ethical factors associated with the sustainability of apparel and wearables.

An individual's perception of sustainable product consumption depends on the "perceived relevance and value of products, perceived effectiveness for impact on the environment or society, and perceived losses and gains", these perceptions influence people's attitudes towards consuming these types of products.

Subjective normativity

Subjective normativity refers to an individual's perception of his or her commercial validator's willingness to buy or not to buy sustainable products. According to Ajzen and Fishbein (1980), "The more a person thinks that other people who are important to him believe he should take a certain action, the more he intends to do so." In assessing subjective norms, a measure to align intentions and actions is recommended.

There is a negative relationship between consumer knowledge and subjective norms about sustainable wearables, the greater the knowledge of this type of product and its generation, the more it is negatively associated with subjective norms, this finding suggests

that informed consumers are less influenced by subjective norms that do not support this type of purchase. The worst enemy for the sale of wearable-type products based on sustainable design models is consumer misinformation.

In addition, an emphasis on positive and sustainable "lifestyles, values and self-image" will increase an individual's perceived self-importance and consumers who associate fashion with identity, especially younger consumers, are the least concerned about the environmental and ethical considerations associated with these types of products. Thus, efforts to promote subjective norms and attitudes toward sustainable clothing consumption may have the greatest impact on changing perceived behavioral control and purchase intentions.

Conclusion

Apparel design education for wearables emphasis should have a fundamental category as a pillar of their training in sustainability seen as a prerequisite for product performance in the marketplace, but also as an argument in their marketing. Consumers are currently determined by consumption variables that try to shape the conscious purchase of the sustainable product; therefore, the development of wearable products must generate communication dynamics that enhance this change because they handle the textile impact associated with their product and the technological impact that is another source of detriment to the planet.

In short, wearables are members of the new group of environmental impact of the recent industrial revolution. As we move forward and develop by turning data into information, knowledge and wisdom, these technologies have the potential to transform the world as we know it today in new and exciting ways, but leave a very negative footprint if they are not designed from sustainability standards and sustainability is not

included as a fundamental platform of design education for this category of products.

Discussions on how to educate sustainability of technology-based apparel design show a lack of evidence on what teaching practices and learning activities develop better competencies in students and generate changes in technology-enabled apparel purchasing behavior. The research developed has merged the wearable design model with sustainability and reading from the planned behavior method to understand end-consumer dispositions.

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