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Examining the Nexus of Innovation Traits, Social Influence, and Environmental Sustainability Attitudes of Consumers in Thailand: A Study of 3D-Printed Clothing Adoption Intentions

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Abstract

This study draws from the Theory of Reasoned Action and Diffusion of Innovation Theory to explore factors influencing Thai consumers' attitudes toward environmental sustainability (ATES): social influence, imitating others, open-mindedness, and IT domain innovativeness, and how ATES influences intention to adopt 3D-printed clothing in turn. A survey of students, faculty, and staff at a Thai university was used. The results show that social influence and open-mindedness had significant impacts on ATES, and that ATES had a significant impact on intention to adopt 3-D printed clothing. The results underscore the need for effective education and awareness programs to promote ATES and 3D-printed fashion adoption and advance the understanding of environmentally conscious consumer behavior in Thailand, an important player in the global apparel industry. The conclusions offer insights for researchers, policymakers, marketers, and fashion professionals.

Keywords

Behavioral, Technological Innovation, Technology Adoption, Technological Change, Signals

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Introduction

The fashion industry is a significant contributor to global pollution and waste, contributing 10% of global carbon emissions, accounting for more than 92 million tons of textile waste discarded annually, depleting vital water sources, and polluting rivers and streams (Niinimäki et al., 2020). With consumers increasingly conscious of the environmental impact of their fashion choices, the demand for sustainable alternatives is surging, leading companies such as Patagonia to adopt sustainable practices including incorporating recycled materials into their clothing and providing repair services to prolong the lifespan of their products (Wolf, 2023).

In contrast to conventional textile manufacturing, 3D printing constructs clothing layer by layer from digital designs, which resolves customer size discrepancies through customization thereby resulting in minimal waste and diminished need for large-scale production and excess inventory (Manaia et al., 2023). Furthermore, raw materials for 3D-printed clothing can be sourced from environmentally-friendly materials and dyes, thereby empowering consumers to address environmental concerns and contributing to a further reduction in its environmental footprint. (Sun & Zhao, 2017). Finally, the recyclable nature of 3D printing materials and efficient material usage significantly reduce fabric waste compared to traditional clothing production methods. (Ojogbede, 2022).

The 3D printing market is poised to soar above $150 billion by 2032, growing at a staggering 23.6% annual growth rate (Fortune Business Insights, 2024). Additionally, standardized materials, systems, and applications promise a decreased total cost of ownership (TCO) in comparison to traditional methods: more economical materials, expedited cycles, and potentially reduced prices for consumers (Fortune Business Insights, 2024). However, amidst this transformation, a fundamental question remains unanswered: What factors shape individual attitudes towards environmental sustainability in the realm of 3D-printed clothing, and how do these attitudes drive the adoption of this trend? To foster consumer engagement, there is a need to educate individuals about the possibilities presented by 3D printing in the fashion industry. Overcoming the existing lack of consumer awareness and perception regarding environmental sustainability requires the implementation of effective education and awareness programs (Sun & Zhao, 2017). Thus, this study examines the factors governing individuals' attitudes about environmental sustainability when making decisions when it comes to adopting 3D-printed clothing.

This study focuses on consumers in Thailand. Thailand is a global leader in the apparel industry (Watchravesringkan et al., 2010), so addressing the issues surrounding environmental sustainability in a 3D fashion context could provide key insights for a country that is one of the major points in the global apparel supply chain. The study examines the interplay of personal traits, the persuasive power of social influences, and the commitment to environmental stewardship, all shaping attitudes about environmental sustainability, and in turn, their intentions to wear 3D-printed clothing, drawing upon and integrating two well-developed theories in forming hypotheses: the Theory of Reasoned Action (TRA) (Ajzen & Fishbein, 1975) and the Diffusion of Innovation Theory (DoI) (Rogers, 2003). TRA posits that individual attitudes and social influences wield significant influence over intentions, while DoI sheds light on the role of innovativeness in technology adoption.

The following sections are organized as follows: the paper begins with a literature review, focusing on the DoI and TRA theories and highlighting key factors relevant to understanding how technological (global vs. domain-specific innovation traits) and social (social influence vs. imitating others) elements influence users' attitudes toward environmental sustainability and intentions to adopt 3D printed clothing, which form the foundation of the research model and hypotheses. Next, the research methodology and analysis are provided. The discussion covers both theoretical and practical implications, and concludes by addressing research limitations and suggesting potential directions for future research.

Literature Review

Diffusion of Innovation Theory and 3D-Printed Fashion Adoption

Diffusion of Innovation (DoI) Theory illuminates the dynamics of technology adoption among users. As originally formulated, it classifies users into distinct categories based on their adoption timelines, including innovators, early adopters, early majority, late majority, and laggards (Rogers, 2003). It recognizes that innovation impacts individuals differently, with some embracing new technologies enthusiastically while others harbor reservations or fears. Typically, an innovation is first embraced by innovators and early adopters before it gains traction among the majority. Later extensions of DoI theory note that the timeline of adoption varies in relation to the innovativeness of the adopters, signifying the degree to which an individual is relatively early in adopting an innovation compared to their peers (Rogers et al., 2014). Further research has found that the temporal aspect of adoption functions as an indicator of innovativeness, necessitating distinct communication strategies for various types of adopters; for instance, broadcasting is more effective in the early stages of adoption, while virality spreads significantly faster and often works better in the later stages of innovation (Zhai et al., 2021).

However, it's important to acknowledge that some scholars argue against relying solely on the temporal concept of innovation to comprehend innovation dynamics. Innovation encompasses various dimensions, including the type of innovation, its degree of radicalness, and its stage of development (Damanpour & Gopalakrishnan, 1998). Furthermore, this temporal measure may not be well-suited for predicting the adoption and diffusion rates of technologies that are still in their early stages of the adoption life cycle, as early-stage innovation is also influenced by multiple dimensions of innovation. In the context of 3D printed apparel, where adoption is still evolving, the application of traditional DoI theory may have limitations in explaining adoption rates.

To address these limitations, it is important to identify and measure the various forms of innovation that fashion enthusiasts and consumers may exhibit when considering 3D printed fashion adoption. For instance, some individuals may display personal innovation traits, actively seeking out and experimenting with different fashion techniques to enhance their style. On the other hand, technological innovation may attract those who are intrigued by the capabilities of 3D printed fashion, even if they do not possess a strong general innovation trait. Hence, it is crucial to recognize at least two distinct forms of innovation that individuals can employ when making choices between traditional fashion and 3D printed fashion.

Thus, we extend DoI theory to incorporate the two key dimensions of innovation, which are global innovation and context-specific (or domain-specific) innovation (Flynn & Goldsmith, 1993). Global innovation pertains to innovative attitudes and behaviors across various aspects of human behavior, while context-specific innovation pertains to innovative attitudes and behaviors within a specific category, such as fashion. These two dimensions are conceptually distinct and cannot be substituted for one another, as they contribute to different reference points and may yield varying results in terms of behavior (Foxall & Szmigin, 1999).

Global innovativeness reflects the extent to which an individual independently makes innovative decisions, often regarded as a personality trait (Flynn & Goldsmith, 1993). It is shared to varying degrees by individuals and influences their predisposition to behave in innovative ways across various domains. On the other hand, context-specific innovativeness involves learning and implementing innovations specific to a particular domain, in this case, 3D printed fashion (Goldsmith, 2001). This form of innovation is seen as a personality state rather than a global tendency and is influenced by an individual's interest, experience, exposure, and knowledge within a particular product category.

Theory of Reasoned Action (TRA) and 3D-Printed Fashion Adoption

The Theory of Reasoned Action (TRA) is a well-established model that explains how individual attitudes affect behavioral intentions and actions (Ajzen & Fishbein, 1975). Extensions of TRA in a technology context suggest that social influence (SI) and imitating others (IO) are pivotal components, shaping the subjective norms that, in turn, influence behavioral intentions. The critical role of these variables becomes evident when considering their impact on the adoption of 3D-printed fashion. SI refers to the degree to which an individual perceives that important others believe he or she should use a new technology

(Venkatesh et al., 2003). IO refers to the extent to which an individual observes and mimics the behavior of others who have adopted a new technology (Venkatesh & Davis, 2000). Both SI and IO can affect the perceived usefulness, ease of use, and attitude toward a new technology, as well as the intention to use it (Venkatesh et al., 2012).

3D-printed fashion is a novel and emerging technology that offers unprecedented possibilities for design, customization, and sustainability (Bertola & Teunissen, 2018). However, it also faces significant challenges in terms of cost, quality, and consumer acceptance (Sun & Zhao, 2017). Therefore, understanding the role of SI and IO in the adoption of 3D-printed fashion is crucial for both researchers and practitioners who seek to promote and facilitate its diffusion and adoption. Previous studies have shown that SI and IO can have positive effects on the adoption of various technologies, such as Metaverse (Lee et al., 2011) and social commerce (Chen et al., 2021).

3D-printed fashion is a relatively new and unexplored domain, so understanding the roles of SI and IO within TRA is important for the investigation of 3D-printed fashion adoption for several reasons. First, the examination of SI and IO provides a foundation for understanding whether 3D-printed fashion is regarded as a desirable personal value (Lyu et al., 2018) and socially accepted trend. Second, SI and IO exert substantial influence on the formation of subjective norms, which, according to the original TRA, affect behavioral intentions (Ajzen & Fishbein, 1975). Third, for fashion brands, marketers, and policymakers, comprehending the impact of SI and IO can inform tailored communication and promotional strategies, the absence of which is a significant factor contributing to the commercial failures of environmentally sustainable products (Gifford & Nilsson, 2014). Targeting influential individuals or opinion leaders who drive the adoption of 3D-printed fashion can prove to be a highly effective marketing approach (Lyu et al., 2023). Fourth, peer effects play a pivotal role in the adoption of new fashion trends, as individuals are often more inclined to embrace innovations when they observe others around them doing the same (Mun et al., 2006). Investigating the extent of peer effects through IO provides a quantitative perspective on the potential ripple effect of adoption within social groups (Lee et al., 2013).

Attitudes Towards Environmental Sustainability and 3D-Printed Fashion Adoption

3D-printed clothing is a novel manufacturing technology that allows the creation of customized garments from digital models by adding successive layers of materials (Spahiu et al., 2020). This process has been associated with sustainability benefits, such as reducing waste, energy consumption, and emissions, as well as enabling the use of biodegradable and recycled materials (Javaid et al., 2021). However, the adoption of 3D-printed clothing faces several challenges, such as high costs (Laplume et al., 2016), limited availability, technical complexity, and consumer acceptance (Mavri et al., 2023).

One way to overcome these barriers and foster the adoption of 3D-printed clothing is through the power of social influence. For instance, people often look up to role models for sustainable consumption, whether they are celebrities, public figures, or influential individuals within their social circles (Grabs et al., 2016). Moreover, social influencers who are seen as credible sources of information hold significant sway over their followers' beliefs and actions, regardless of the source's credibility (Kim & Dennis, 2019). When experts or trusted figures endorse sustainable products (Young et al., 2010), such as 3D-printed clothing as an environmentally friendly option, they could enhance the credibility of this choice in the eyes of their audience. Additionally, when friends, family members, or colleagues express support for environmentally sustainable practices, individuals may be more inclined to align their attitudes and behaviors accordingly (Lazaric et al., 2020). Hence:

Hypothesis 1: Social Influence (SI) positively influences users' attitudes toward environmental sustainability (ATES).

Alongside the broader concept of SI, the act of imitating others (IO) is a fundamental aspect of human behavior that can significantly impact attitudes and actions. In general, people have a natural tendency to conform to social norms and expectations (Cislaghi & Heise, 2020). For example, people often emulate role models, such as celebrities, public figures, or influential individuals within their social circles (Hammond et al., 2022), meaning when these role models endorse environmentally sustainable choices like 3D-printed clothing, their followers are more inclined to imitate their behavior (Zhao, 2022). Imitation is also closely linked to trust and credibility. Social influencers who are perceived as credible sources of information wield substantial influence over their followers (Lou & Yuan, 2019). When these influencers endorse 3D-printed clothing as an environmentally friendly choice, their audience is more likely to imitate this behavior, leading to a positive shift in attitudes.

Imitation is also prevalent within closer social networks of friends, family members, and co-workers: individuals are more likely to adopt environmentally sustainable practices to align their attitudes and behaviors with those of their peers (Lazaric et al., 2020). If a significant portion of a person's social circle embraces green lifestyle, such as wearing 3D printed clothes for environmental sustainability, it creates a perceived social norm that encourages imitation, ultimately shaping positive attitudes towards sustainability (Chwialkowska, 2019). Hence:

Hypothesis 2: Imitating Others (IO) positively influences users' attitudes toward environmental sustainability (ATES)

Global innovation traits encompass innovative attitudes and behaviors that span various aspects of human conduct and has been recognized as a driving force behind the development of positive attitudes towards environmental sustainability. Personality traits and green entrepreneurial intentions are closely related (Qazi et al., 2020). Among the key attributes associated with global innovation, open-mindedness (OM) plays a central role in influencing individuals' attitudes and behaviors. Open-minded individuals are characterized by their readiness to explore new ideas, adapt to changes, and seek unconventional solutions (Al-Abrrow et al., 2023). Global innovation traits, like open-mindedness, have a positive influence on attitudes towards environmental product innovation (Cegarra-Navarro et al., 2019). Open-minded individuals exhibit a greater sustainability concern (Shephard et al., 2021) and show a propensity to explore pioneering approaches to environmental sustainability , such as the adoption of 3D-printed clothing.

Open-mindedness also entails appreciating different viewpoints and actively listening to others (Southworth, 2021). In addition, open-minded individuals engage in critical reflection and demonstrate adaptability in the face of change (Riggs, 2015). This characteristic allows them to periodically reassess their attitudes and behaviors in response to evolving environmental challenges, rendering them more responsive to sustainability issues. Furthermore, open-mindedness fosters an individual's inclination toward calculated risk-taking and creative thinking (Xu et al., 2022) in their selection of green products, including 3D-printed clothes. Building upon the insights garnered from the reviewed literature:

Hypothesis 3: Open-mindedness (OM) positively influences users' attitudes toward environmental sustainability (ATES)

Context-specific or domain-specific innovation traits refers to innovative attitudes and behaviors that are tailored to a particular category or domain, such as IT and the fashion industry (Vishwanath, 2005). One of these domain-specific innovation traits is Information Technology Domain Innovativeness (ITDI), which involves applying innovative practices within the realm of information technology. ITDI encompasses the integration of cutting-edge technology, including 3D printing, into various domains, including fashion. The utilization of 3D printing technology in clothing production offers numerous sustainability advantages, such as reduced waste, resource optimization, and personalized manufacturing (Khajavi, 2021). Individuals with high ITDI are more likely to appreciate and embrace these technological advancements (Lyu et al., 2018).

Moreover, consumers possessing high innovativeness traits tend to be more inclined towards risk-taking behavior and are attracted to 3D printing because it enables them to experience the joy of self-designing to a significant extent (Guo et al., 2022). As consumers experience the benefits of tailored clothing and reduced environmental impact, they are more inclined to view sustainable fashion practices positively. Thus:

Hypothesis 4: Information Technology Domain Innovativeness (ITDI) positively influences users' attitudes toward environmental sustainability (ATES).

3D printing represents a relatively novel manufacturing technology that is associated with sustainability as it reduces waste. Studies have consistently shown that individuals with a strong ATES tend to be more environmentally aware and feel a greater sense of responsibility (Gifford & Nilsson, 2014), and have positive emotional associations with sustainable products choices, such as green restaurants (Hwang & Lee, 2019). This heightened awareness translates into a willingness to make sustainable choices, such as opting for 3D-printed clothing because of feelings of satisfaction, pride, and fulfillment when trying a sustainable choice (de Lima et al., 2019). The consumer's awareness of eco-friendly products has the most significant impact on translating environmental concern into the intention to purchase such products (Hojnik et al., 2019). Users with a high ATES hold personal values related to environmental conservation and social responsibility (Hojnik et al., 2019), and understand that 3D printed fashion choices contribute to reducing waste, conserving resources, and minimizing the carbon footprint of the fashion industry (Ikram, 2022). Thus:

Hypothesis 5: Attitude towards environmental sustainability (ATES) positively influences users' intention to wear 3D-printed clothes (INT)

The literature review informs the creation of the research model, shown in Figure 1.

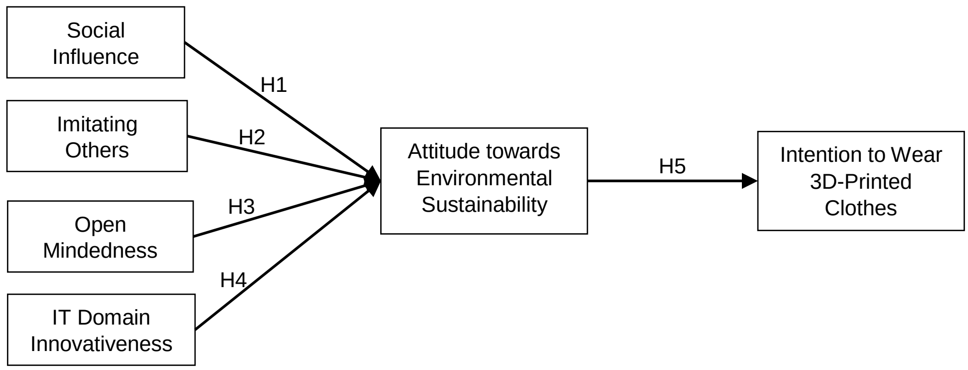

Figure 1 Research Model

Source: Authors, 2024

Research Methodology

A survey instrument grounded in the principles of the diffusion of innovation theory (DoI) and the theory of reasoned action (TRA) was used to assess the validity of the proposed hypotheses.

Data Collection

The sample consists of 120 respondents who were students, faculty, or staff from a public university in Thailand. People affiliated with universities are expected to be aware of coming trends in the apparel industry such as 3-D printed clothing (Qazi et al., 2020), and Thailand is a major participant in the apparel industry (Watchravesringkan et al., 2010). The purpose of this study is to examine the decision-making process of consumers with freedom and purchasing power who are interested in emerging trends in fashion; therefore, university students, faculty, and staff in Thailand are an appropriate sample population (Vantamay, 2018). The online survey link was distributed to faculty and staff. Additionally, four classes of undergraduate students taking an introductory information systems course at the same university were asked to participate for extra credit. The respondents viewed a two-minute video about 3D-printed clothing before taking the survey. Both the video and survey were validated via a pilot study before data collection. Responses were reviewed for completeness, and data with incorrect answers to attention questions consistently were removed. A total of 120 valid responses were used for analysis.

Demographics Overview

The demographics analysis is shown in Table 1. Gender distribution indicates 63% as female, 31% as male, and 6% choosing not to disclose. The sample is representative of the entire population at the university, which has a total of 1,531 students, with 33.4% males and 66.6% females. The majority of the sample (74%) falls within the 18-23 age group (i.e. Generation Z), while 26% are aged 31-54. About 42% have virtual reality experience, and 58% do not. Educational backgrounds vary, with 44% holding an undergraduate degree. According to the World Bank, 40% were in the poverty category, 38% low-income, 14% middle-class, and 8% high-income. On average, respondents shopped 4.75 times per month, with the most common range being 0-5 monthly shopping occasions.

Table 1 Sample Demographics

(n = 120)	Statistics	Count	%
Gender	Female	76	63%
	Male	37	31%
	Do not want to answer	7	6%
Age	18-23 years	89	74%
	31-54 years	31	26%
Virtual Reality Experience	Has	51	42%
	No	69	58%
Education	High school diploma	9	8%
	Associate degree	15	13%
	Undergraduate degree	53	44%
	Graduate degree	3	3%

Table 2 Sample Demographics (continued)

(n = 120)	Statistics	Count	%
Monthly Income in Thai baht	< 20,000	48	40%
	20,000 – 50,000	46	38%
	50,000 – 150,000	17	14%
	150,000+	9	8%
Shopping Frequency	Average = 4.75 / per month (0-5 is the most frequent range)	4.75	100%

Survey Instrument

The survey instruments are shown in Table 2. Items used a seven-point Likert scale, ranging from 1 = "strongly disagree" to 7 = "strongly agree." *Social Influence (SI)* consisted of items drawn from Venkatesh and Davis (2000), including "People important to me think I should wear 3D-printed clothing." *Imitating Others (IO)* measured respondents' inclination to follow societal norms regarding 3D-printed clothing adoption, using items influenced by Ajzen (2002) and Rivis & Sheeran (2003), including "It seems that 3D-printed clothing is the future dominant product; therefore, I would like to wear them as well." *Attitude toward Environmental Sustainability (ATES)* measured respondents' environmentally conscious attitudes, using items adapted from Haws, Winterich, and Naylor (2014). For example, "It is important to me that the products/services I use do not harm the environment." *Open-mindedness (OM)* was assessed using items influenced by Baker and Sinkula (1999) and Cegarra-Navarro & Cepeda-Carrion (2008). For example, "I often reflect critically on my thinking." *Information Technologies Domain Innovativeness (ITDI)* gauged respondents' propensity to adopt emerging information technologies within their peer group, utilizing items inspired by Agarwal & Prasad (1998). For example, "If I heard about a new information technology, I would look for ways to experiment with it." *Intention to Wear 3D-printed Clothing (INT)* drew from the work of Venkatesh and Davis (2000). For example, "Given the opportunity, I predict that I would wear 3D-printed clothing."

Table 3 Survey Instruments

Variables	Code	Items	Source

Social Influence (SI)	SI1	People important to me think I should wear 3D-printed clothing.	(Venkatesh and Davis, 2000)
	SI2	People who influence my behavior suggest that I should wear 3D-printed clothing.	
	SI3	People whose opinions I value prefer me to wear 3D-printed clothing.	
Imitating Others (IO)	IO1	It seems that 3D-printed clothing is the future dominant product; therefore, I would like to wear them as well.	Ajzen (2002), Rivis & Sheeran (2003)
	IO2	I would follow others in accepting 3D-printed clothing.	
	IO3	I would choose to wear 3D-printed clothing because many other people are wearing it.	
	IO4	If I know that a lot of people have already accepted 3D-printed clothing, I might wear it.	
Attitude toward environmental sustainability (ATES)	ATES1	It is important to me that the products/services I use do not harm the environment.	Haws, Winterich, and Naylor (2014)
	ATES2	I consider my actions' potential environmental impact when making decisions.	
	ATES3	My purchase habits are affected by my concern for the environment.	
	ATES4	I am concerned about wasting nature resources.	
	ATES5	I would describe myself as environmentally responsible.	
	ATES6	I am willing to take the inconvenience and more environmentally friendly actions.	
Open-mindedness (OM)	OM1	I often reflect critically on my thinking.	Baker and Sinkula, 1999 Cegarra-Navarro & Cepeda-Carrion, 2008)
	OM2	When trying to get things done, I consider new and novel approaches.	
	OM3	I listen to others while trying to solve problems.	
	OM4	I take necessary risks.	
	OM5	I often try to think outside of the box.	

Table 4 Survey Instruments (continued)

Variables	Code	Items	Source

	OM6	Different perspectives are valuable for understanding.	
Information technologies domain innovativeness (ITDI)	ITDI1	If I heard about a new information technology, I would look for ways to experiment with it.	(Agarwal & Prasad, 1998)
	ITDI 2	Among my peers, I am usually among the first to try out new information technologies.	
	ITDI 3	I like to experiment with new information technologies.	
Intention to wear 3D-printed clothing (INT)	INT 1	Given the opportunity, I predict that I would wear 3D-printed clothing.	(Venkatesh and Davis, 2000)
	INT 2	I am willing to wear 3D-printed clothing in the future.	
	INT 3	Given the opportunity, I intend to wear 3D-printed clothing the same as regular clothing.	
	INT 4	The likelihood of me wearing 3D-printed clothing is high in the future.	

Data Analysis and Results

Partial Least Squares – Structural Equation Modeling (PLS-SEM) using SmartPLS 4.0 was used to validate the measurement and test the hypothesized relationships among the various constructs. PLS-SEM is widely recognized for its ability to test and predict causal relationships between constructs (Henseler et al., 2009). It is particularly advantageous for exploratory research studies (Hair et al., 2011). Additionally, PLS-SEM is less restrictive in terms of sample sizes, measurement scales, and residual distribution assumptions (Chin, 1998).

Measurement Model Reliability and Validity

All constructs were assessed for their reliability and validity using various statistical indicators, including Cronbach's alpha, composite reliability, and average variance extracted (AVE). These are shown in Table 3. Cronbach's alpha measures for each construct ranged from 0.601 to 0.923. Composite reliability (rho_c) ranged from 0.832 to 0.941. AVE values ranged from 0.667 to 0.841. All surpassed the recommended thresholds (Sarstedt et al., 2023).

Table 5 Construct measurement reliability and validity

Variables	Cronbach's alpha	Composite reliability (rho_c)	Average variance extracted (AVE)
ATES	0.923	0.94	0.723
ITDI	0.853	0.909	0.769
INT	0.905	0.941	0.841
IO	0.601	0.832	0.713
OM	0.833	0.889	0.667
SI	0.883	0.927	0.809

Discriminant validity was confirmed because the heterotrait-monotrait ratio of correlations (HTMT) was less than .85 for all instruments (Sarstedt et al., 2023), as shown in Table 4, indicating clear distinctions among all constructs. Additionally, variance inflation factor (VIF) analysis investigated the potential presence of common method bias (CMB) and multicollinearity among the constructs. The VIF values range from 1.226 to 3.627, well below the conventional cut-off value of 5, suggesting that the variance is primarily attributed to the constructs themselves rather than measurement issues.

Table 6 Discriminant Validity (HTMT)

	ATES	ITDI	INT	IO	OM
ITDI	0.495				
INT	0.633	0.344			
IO	0.461	0.431	0.402		
OM	0.716	0.71	0.48	0.459	
SI	0.631	0.439	0.604	0.58	0.444

Hypothesis Test Results

Bootstrapping was used in SmartPLS to test the significance of the paths between constructs. Table 5 summarizes the results. The results for Hypothesis 1 show a significant positive influence of SI on ATES ($t = 2.319$, $p = 0.02$), confirming that when important individuals, behavior influencers, or valued opinions advocate for the adoption of 3D-printed clothing for environmental sustainability, it positively affects users' attitudes towards sustainability.

The results for Hypothesis 2 indicate that the influence of IO on ATES is not statistically significant ($t = 0.136$, $p = 0.892$). In other words, the act of imitation, in this context, does not significantly impact individuals' attitudes towards sustainability.

The results for Hypothesis 3 reveal a highly significant positive influence of OM on ATES ($p = 5.909$, $p < .001$). This implies that individuals who exhibit open-mindedness, characterized by critical reflection, innovative thinking, and appreciation of diverse viewpoints, are more likely to have positive attitudes towards environmental sustainability, particularly when advocating for 3D-printed clothing as an eco-friendly option.

The results for Hypothesis 4 suggest that ITDI as a context-specific innovation does not have a statistically significant influence on ATES ($t = 0.968$, $p = 0.333$). In other words, exposure to ITDI and its associated technological advancements does not significantly impact individuals' attitudes towards sustainability in the context of 3D-printed clothing.

The results for Hypothesis 5 demonstrate a highly significant positive impact of ATES on INT ($t = 6.512$, $p < .001$). This implies that individuals with positive attitudes towards environmental sustainability are more likely to express an intention to wear 3D-printed clothing, driven by their awareness, perception of benefits, alignment with personal values, positive emotional associations, and social influence.

Table 7 Hypotheses Results

Hypothesis	Path Coefficient	STDEV	t-statistic	p-value
H1: SI -> ATES	0.415	0.179	2.319	0.020
H2: IO -> ATES	-0.013	0.095	0.136	0.892
H3: OM -> ATES	0.627	0.106	5.909	< 0.001
H4: *ITDI* -> ATES	-0.126	0.13	0.968	0.333
H5: ATES -> INT	0.633	0.097	6.512	< 0.001

Discussion

The results provide theoretical implications for understanding attitudes toward environmental sustainability (ATES) in the context of 3D-printed clothing adoption. These findings shed light on the influence of various factors and their interplay in shaping individuals' attitudes and intentions, offering valuable insights for both theoretical and practical applications.

Theoretical Implications

The results of hypothesis 1 demonstrate the significant impact of Social Influence (SI) on ATES. This positive correlation indicates that individuals who perceive important figures or influential sources promoting 3D-printed clothing as environmentally sustainable develop more positive attitudes towards sustainability themselves. This finding supports both the Theory of Reasoned Action (TRA) and the Social Cognitive Theory (SCT). TRA postulates that social influences, such as "champions" who advocate for new technologies, play a key role in shaping individual attitudes and behaviors (Rogers, 2003). Our findings align with this principle, suggesting that influential figures promoting 3D-printed clothing's sustainability act as champions, positively influencing individuals' environmental attitudes. SCT highlights the importance of observing others' behaviors and attitudes in shaping one's own beliefs and actions (Bandura, 2009). Our results resonate with this theory, suggesting that individuals witnessing influential figures embracing 3D-printed clothing as sustainable may be more likely to develop similar positive attitudes themselves.

The relationship between Imitating Others (IO) and ATES within the context of 3D-printed clothing adoption was not significant, providing no support for hypothesis 2. This implies that, simply mimicking others who adopt 3D-printed clothing may not automatically translate to positive sustainability attitudes, which challenges the traditional "herding theory" positing increased conformity when personal values align with group norms (Sunder et al., 2019). In the realm of social commerce, the discounting effect of private self-awareness regarding herd behavior has been documented (Chen et al., 2023). Therefore, the findings suggest that IO may hold less sway compared to other self-driven factors, such as individual awareness of the environmental impact of 3D-printed fashion. This result provides a nuanced understanding of the limited role of imitation in driving sustainable fashion choices, which may have implications for strategies aimed at promoting eco-conscious behavior.

The results for hypothesis 3 show a significant role of Open-mindedness (OM) in shaping ATES. Individuals characterized by OM, including critical reflection, innovative thinking, and appreciation for diverse viewpoints, are more likely to hold positive attitudes toward environmental sustainability, especially in the context of 3D-printed clothing adoption. This highlights the importance of individual traits and cognitive factors in shaping sustainability attitudes. The current literature supports this finding. Agarwal and Prasad (2000) demonstrated that open-mindedness positively predicts individuals' willingness to adopt new technologies, paralleling the observation of OM influencing 3D-printed clothing adoption, a novel technology. Furthermore, De Groot and Steg (2010) confirmed that openness to experience (related to OM) positively correlated with environmentally friendly behaviors, further corroborating the results.

Information Technologies Domain Innovativeness (ITDI) did not significantly impact Attitude Toward Environmental Sustainability (ATES), providing no support for hypothesis 4. The finding suggests that awareness of technological advancements alone might not be a primary driver of sustainability attitudes within this context. This aligns with existing research that highlights the limitations of technology awareness in driving sustainable behavior. Knowledge about environmental issues does not always translate to pro-environmental actions (Karlsson & Lindström, 2020). Similarly, studies like those by Veleva (2021) argue that promoting the green attributes of technological innovation in 3D fashion alone cannot solve sustainability challenges. Instead, systemic changes in other factors—such as social impact, sustainability networks, policies, and consumer awareness—are essential. These findings indicate that policymakers should not focus on the technology aspect of 3D-printed clothing as much as emphasizing its environmental benefits.

In support of hypothesis 5, there was a significant, positive impact of Attitude Toward Environmental Sustainability (ATES) on Intention to Wear 3D-printed Clothing (INT). Individuals with favorable attitudes toward environmental sustainability are more likely to incorporate 3D-printed clothing into their wardrobes. This underscores the importance of environmental concerns, alignment with personal values, and positive emotional associations in driving intentions related to sustainable fashion choices. Notably, positive environmental concerns significantly predict purchase intentions for eco-friendly apparel (Abrar et al., 2021), aligning with this study's finding that ATES influences INT for 3D-printed clothing. Additionally, Joshi et al. (2021) highlight the emotional component of sustainable consumption, suggesting that positive emotional associations with eco-friendly products can drive purchase intentions. This further supports the notion that emotions play a role in influencing INT for 3D-printed clothing.

Practical Implications

The results have direct practical implications that policymakers can use to develop targeted interventions and strategies aimed at promoting sustainable fashion, leveraging these insights into the complex dynamics of attitudes toward environmental sustainability (ATES) in the context of 3D-printed clothing adoption. The identification of SI and OM as significant influencers of ATES means policy initiatives that emphasize open-mindedness, leverage influential individuals, and tap into social norms can be designed to encourage consumers to adopt eco-friendly clothing options like 3D-printed garments.

Social Influence: The significant impact of Social Influence (SI) on ATES indicates that individuals who perceive important figures or influential sources promoting 3D-printed clothing as environmentally sustainable develop more positive attitudes towards sustainability themselves. Leveraging these results, policymakers can incentivize the use of social media platforms and influencers via grants and tax breaks to create positive word-of-mouth and social proof for sustainable clothing options, showcasing the environmental benefits and advantages of 3D-printed clothing via testimonials and reviews from satisfied customers. Guidelines can be developed for influencer marketing campaigns to ensure transparency and accurate sustainability claims. In addition, opinion leaders can serve as gatekeepers for interventions, contribute to shifting social norms, and expedite behavior change processes (Valente & Pumpuang, 2007). Fashion professionals can collaborate with celebrities and opinion leaders to endorse and promote 3D-printed clothing, such as featuring them in fashion shows and magazines, creating exclusive collections and collaborations, and offering discounts and incentives for referrals and recommendations.

Open-mindedness: Policymakers can implement educational programs and campaigns that foster open-mindedness among consumers, such as exposing them to diverse perspectives and cultures, encouraging them to explore new ideas and experiences, and challenging them to question their assumptions and biases. Policies aimed at fostering an open-minded culture can exert both direct and indirect (via knowledge sharing) influence on users' willingness to embrace emerging technologies (Michna & Kmieciak, 2020). For example, policymakers can encourage educational media campaigns that promote critical thinking and environmental awareness by showcasing innovative and sustainable fashion options like 3D-printed clothing alongside discussions of their environmental benefits.

Limitations

One limitation of this research is that the sample used for data collection may not be fully representative of the global population. The study's participants were members of a university community in Thailand and were expected to have higher awareness of the apparel industry as well as forward-looking characteristics and interests related to sustainability and fashion that would influence their responses. However, the majority of the resulting sample is comprised of persons who identify as female (63%), and a majority are aged 18-23 (74%). Future research can ensure a more comprehensive understanding of populations outside of Thailand, attitudes of male fashion consumers, and older consumers who may have less interest in fashion and less progressive viewpoints about environmental sustainability in the context of 3D-printed clothing. Complementing quantitative findings with qualitative research, such as in-depth interviews or focus groups, can provide a richer understanding of the underlying motivations and barriers to sustainable fashion adoption (Sebele-Mpofu, 2020).

This study primarily focused on attitudes toward environmental sustainability of consumers with freedom and purchasing power who are interested in emerging trends in fashion in the context of 3D-printed clothing. While this focus is valuable, future research should explore how the identified factors operate in diverse sustainability domains and with other populations. Particularly, the scope and applicability of the findings may be influenced by the specific characteristics and features of 3D-printed clothing, such as its novelty, customization, and functionality, that may not be present or relevant in other types of sustainable products or services.

Conclusion

Overall, these results contribute to a deeper understanding of the multiple facets influencing environmentally conscious consumer behavior in the context of 3D-printed clothing adoption, bridging the gap between theory and practice and offering guidance for researchers, policymakers, and businesses seeking to promote sustainable fashion choices and leverage innovative technologies like 3D printing. Theoretical and practical implications of the results were discussed, revolving around understanding individual traits, social influence, and the integration of innovation and sustainability within the fashion industry. For future researchers, the integration of social influence, individual traits, and environmental attitudes into a theoretical model provides a more comprehensive framework for studying sustainable fashion adoption. Policymakers wanting to increase attitudes toward environmental sustainability can leverage these results by collaborating with celebrities and fashion influencers to promote 3-D printed clothing and other sustainable fashion choices, and by creating awareness and education campaigns that encourage consumers to be open minded about their fashion choices. Although this research focuses on 3D-printed clothing, policymakers can leverage these findings as a springboard to discuss the need for broader policy changes that incentivize sustainable production and consumption across the entire fashion industry.

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