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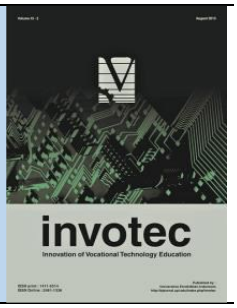

FASHION STUDENTS' PERCEPTION OF CLO3D AS DIGITAL INNOVATION IN SUSTAINABLE DESIGN

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ABSTRACT

The fashion industry currently ranks as the second-largest contributor to global waste, highlighting the urgent need for sustainable solutions, particularly in achieving sustainable design. This study investigates the perceptions of Fashion Design students regarding the use of CLO3D software as a digital innovation that supports sustainable design practices. The study explores how students use CLO3D and their understanding of its relevance to sustainability in fashion. A descriptive survey method was employed, using purposive sampling of 35 students from the Fashion Design Education programs at Universitas Pendidikan Indonesia (UPI) and Universitas Negeri Yogyakarta (UNY), all of whom had experience in learning and using CLO3D. The findings indicate a generally positive response regarding students' perceptions and understanding of CLO3D as a digital innovation that contributes to sustainable design. The study reveals that students are aware of the connection between CLO3D usage and efforts to achieve sustainable fashion practices. However, it also identifies a challenge students perceive CLO3D as more difficult to use and more time-consuming compared to other design software.

1. Introduction

The fashion industry is a significant economic contributor globally, generating around 3 trillion dollars and accounting for 2% of the world's GDP (Akram et al., 2022). However, it also poses substantial environmental and social challenges, particularly in developing countries like Indonesia. The fashion industry is one of the largest contributors to global waste. Specifically, it ranks as the second-largest industry in generating pollution (Dolzhenko & Churakova, 2022). The clothing production process yields various waste namely, cloth scrap, greenhouse gas emissions, and other pollutants. According to data from Statista, the fashion industry emitted approximately 879 million metric tons of carbon dioxide equivalent into the atmosphere in 2022. The United Nations Environment Programme (UNEP) reported that around 92 million tons of textile waste are produced annually, while only about 8% of the fibers manufactured in 2023 were derived from recycled sources (Davis et al., 2024). The textile industry in Indonesia generates substantial amounts of waste. For instance, in Bandung City, the generation of post-consumed textile waste is approximately 19.87

Gg/year, with a significant portion ending up in landfills or incinerators (Prayuda & Sembiring, 2023). Consequently, action is urgently required to reduce the waste generated in the clothing production process. This issue is closely related to the goals of the UNESCO-driven Sustainable Development Goals (SDGs) initiative. The Sustainable Development Goals (SDGs) aim to transform the fashion industry by integrating environmental, social, and economic aspects throughout the entire value chain of clothing production and consumption. This transformation is essential due to the significant environmental and social impacts of the fashion industry, which include high carbon dioxide emissions, extensive water usage, and the release of hazardous chemicals (Ujjawal, et al., 2025;Jones, 2024;Niinimäki, et al., 2020).

The Sustainable Development Goals (SDGs) comprise 17 targets aimed at fostering greater peace and prosperity for people and the planet (Thakker & Sun, 2023). While all 17 SDGs are relevant to the fashion industry to some degree, certain goals are particularly pertinent. SDG 12 (Responsible Consumption and Production) is notably aligned with the fashion industry and is often the most emphasized in relation to it (Gabriel & Luque, 2019; Thakker & Sun, 2023). In addition to SDG 12, SDG 9 (Industry, Innovation, and Infrastructure) and SDG 15 (Life on Land) also demonstrate a strong connection to fashion-related activities (de Oliveira Neto et al., 2019). Based on these connections, actions to reduce industrial waste in fashion must be integrated into product development processes.

The creation of a fashion product involves several stages, including design and prototyping. These early phases are not exempt from generating waste, such as paper used for sketching or pattern making, and fabric used during prototype creation. Traditional design and prototyping processes often produce waste in the form of design sketches, pattern paper, and discarded fabric scraps resulting from repeated revisions. Therefore, inspiration gathering, sketching, material selection, and pattern drafting must be conducted carefully to minimize material waste. Repetitive fitting and evaluation stages can also lead to increased physical waste if manual revisions of prototypes are continually required. Thus, alternative solutions—such as adopting technological innovations to facilitate digital design and prototyping—are needed to reduce pre-production waste.

The advancement of digital technology has significantly transformed the fashion industry, especially in terms of enabling more efficient, environmentally friendly, and sustainable design practices. There are several software that can be used to create digital fashion designs, including CLO3D, Marvelous Designer, Browzwear (VStitcher & Lotta), TUKA3D, and Style3D. Among the various technological applications in the fashion sector is the use of CLO3D software. CLO3D's combination of realistic simulations, efficiency, cost-effectiveness, ease of use, and versatility makes it a preferred choice in both educational institutions and the fashion industry. Its ability to integrate with other technologies further enhances its appeal, providing a comprehensive tool for modern fashion design and education (Melek and Sözüer, 2023; Choi, 2022; Wang and Liu, 2020; Song, et al., 2022). CLO3D is a digital tool that facilitates the rapid and efficient creation of fashion prototypes, saving both time and production costs. It allows virtual 3D garment editing on customizable human avatars that can be rotated and viewed from multiple angles (Widya & Setyowati, 2023). As a 3D garment simulation platform, CLO3D empowers designers to virtually create and modify clothing designs without the need for repetitive physical samples. Utilizing CLO3D in the design and prototyping process aligns with the objectives of UNESCO’s sustainability agenda by significantly reducing production-related waste. One compelling case highlighting the effectiveness of digital prototyping is from Stella McCartney’s Autumn/Winter 2023 collection, where the adoption of digital prototypes reduced physical prototypes by 83%, resulting in a reduction of fabric waste by approximately 1.2 tons (Khomariah et al., 2025).

A comparative analysis of product development workflows, illustrated in Figure 1, highlights the differences between processes utilizing CLO3D and those that do not. The prototype visualizations generated by CLO3D closely resemble those produced through conventional means.

However, the key difference lies in the efficiency and linearity of the workflow. CLO3D-enabled processes streamline the sampling, reviewing, and prototyping stages by relying on 3D design previews prior to prototype development. Once the 3D design is finalized and approved, physical prototyping proceeds accordingly. In contrast, traditional processes require multiple rounds of physical sampling based on iterative reviews, which significantly impacts time and costs. Expenses associated with fabric and paper materials during the sampling phase escalate with each revision, resulting in both increased expenditure and higher waste generation.

Figure 1. The difference in the process with CLO3D and without CLO3D (Prisma Tech)

Through its implementation, the use of CLO3D has demonstrated the potential to significantly reduce textile waste and raw material consumption, thereby contributing to the principles of sustainable design in fashion. Supporting reports have shown that the consistent use of CLO3D can reduce fabric waste by approximately one-quarter, lower the carbon footprint throughout the prototyping process by nearly one-third, and bring about substantial cost reductions (Khomariah et al., 2025). CLO3D facilitates the design, pattern making, and sample development processes in a way that saves both time and financial resources when compared to manual techniques (Hartanto, 2020). In terms of production timelines, the use of CLO3D can accelerate garment production, which traditionally takes between one to three months, to as little as three to five days through the use of digital design (Guo & Hou, 2022).

In light of the above, fashion designers are among the key stakeholders who can support and drive waste reduction in the fashion industry. As future designers, Fashion students must understand their roles and responsibilities in addressing fashion industry waste, particularly during the production phase. This study seeks to analyze Fashion students' perceptions regarding the use of CLO3D in the design process in relation to sustainable design practices. Moreover, CLO3D usage among students offers additional educational benefits. According to Prasetya et al. (2025), an analysis of 80% of relevant journals revealed that CLO3D significantly enhances the development of students' design skills, allowing them to better comprehend form, proportion, and detail in their creations before entering the physical production stage.

Therefore, the objective of this study is to ivestigate the perceptions of Fashion students regarding the use of CLO3D software as a digital innovation that supports sustainable fashion design in the current industry landscape. The findings of this study are expected to inform improvements in educational strategies aimed at preparing a new generation of fashion designers who are equipped to navigate and address the sustainability challenges of a fashion industry that increasingly prioritizes digital technology integration.

2. Methods

This study is a descriptive survey research aimed at analyzing the perceptions of Fashion students regarding the use of CLO3D software as a digital innovation that supports sustainable design. A cross-sectional survey approach was employed to measure students' perceptions at a specific point in time. The chosen data collection instrument was a questionnaire consisting of closed-ended questions using a five-point Likert scale (ranging from 1 to 5), focusing on perceptions related to the use of CLO3D in supporting sustainable design innovation. The questionnaire was distributed online via the Google Forms platform.

The population and sample of this study were selected using purposive sampling, involving 35 students from the Fashion Education programs at Universitas Pendidikan Indonesia (UPI) and Universitas Negeri Yogyakarta (UNY), all of whom had prior experience in learning and using CLO3D software. The selection of participants was not limited by academic level (e.g., first-year, second-year, etc.), but was instead based on the students having already learned and used CLO3D software and having acquired knowledge and understanding of sustainable design. The data collected through the questionnaire were then analyzed using descriptive statistical methods to determine the perceptions of Fashion students regarding the use of CLO3D software as a digital innovation in support of sustainable design.

The data collection tool, distributed via Google Forms under the title *"Perceptions of Fashion Students on the Use of CLO3D Software as a Digital Innovation in Supporting Sustainable Design,"* comprised five main sections:

(i) Section A: Demographic Information
This section collects basic demographic details of the respondents, such as name, student identification number (ID), and other relevant personal information
(ii) Section B: Items Measuring User Experience Perception
(iii) Section C: Items Measuring Perceived Benefits
(iv) Section D: Items Measuring Perception of CLO3D in Supporting Sustainable Design
(v) Section E: Items Measuring Reflection and Perceived Relevance of CLO3D to Sustainable Design

3. Result and Discussion

3.1 Result

This section will present the results obtained from the distribution of the questionnaire, which consists of five sections.

3.1.1 Demographic Information

The findings obtained from the 35 respondents indicated that all participants had prior experience using the CLO3D software. An interesting highlight from this data is the dominant role of academic institutions (particularly lectures) as the primary medium through which students are introduced to CLO3D. This underlines the importance of integrating digital design software into the fashion design curriculum. However, the relatively short period of use among most respondents suggests that students are still in the early stages of familiarity and skill development with CLO3D. Regarding the duration of CLO3D usage, the data reveal that most students had relatively limited experience with the software. Over half of the respondents (n = 19, 54.3%) reported having used CLO3D for less than six months. Meanwhile, 10 students (28.6%) indicated a usage period between six and twelve months, and the remaining 6 students (17.1%) had been using the software for more than one year.

Table 1. Respondents' Demographic Information

ITEM	Answer	
	%	Indicator
Have you ever used the CLO3D software	100	Yes
	0	Never
How did you first learn about CLO3D	91.4	Lectures
	5.7	Social Media
	2.9	Vocational School
	0	Others
How long have you been using CLO3D	54.3	<6 months
	28.6	6 – 12 months
	17.1	>1 year

3.1.2 Student's Perception of CLO3D Software

Table 2 presents findings related to student's perceptions of their experience with the CLO3D software. The results showed that Fashion students rarely use CLO3D for design purposes. Indicated by mean value of 2.94. This might be due to perceived difficulties in operating the software as supported by half of the students answer on question "How difficult is digital fashion design using CLO3D" with mean value of 3.63. Interestingly, despite of students difficulties in learning CLO3D, they still get benefit form this software and would recommend this software to others.

Table 2. Perceptions of CLO3D Software Usage Experience

ITEM	1		2		3		4		5		Mean
	F	%	F	%	F	%	F	%	F	%	
1) How often do you use CLO3D	0	0	8	22.9	21	60	6	17.1	0	0	2.94
2) How important is digital fashion design using CLO3D	0	0	1	2.9	7	20	22	62.9	5	14.3	3.89
3) How useful is digital fashion design using CLO3D	0	0	0	0	2	5.7	27	48.6	16	45.7	4.40
4) How difficult is digital fashion design using CLO3D	0	0	4	11.4	13	37.1	10	28.6	8	22.9	3.63
5) Despite the difficulty, do the benefits of using CLO3D make it worthwhile	0	0	0	0	2	5.7	17	48.6	16	45.7	4.40
6) After using CLO3D, would you recommend digital fashion design using it	0	0	0	0	5	14.3	14	40	16	45.7	4.31

3.1.3 Student's Perception of Benefits of Using Digital Design Creation with CLO3D

Table 3 presents findings related to student's perception of benefit of using CLO3D. The description in this table uses a Likert scale ranging from Strongly Disagree (SD) to Strongly Agree (SA). The results indicated that Fashion students generally have a positive perception of CLO3D in supporting their design work. This is particularly evident in its ability to help visualize and communicate design ideas effectively, such as creating mock-up designs without physical samples. Interestingly, students showed disagreement with the statement that CLO3D is easier and quicker

to learn compared to other design software. This suggests that while students acknowledge the advantages of CLO3D in the design process, they also find it time-consuming and challenging to learn.

Table 3. Perceived Benefits of Using CLO3D for Digital Fashion Design

ITEM	SD		D		N		A		SA		Mean
	F	%	F	%	F	%	F	%	F	%	
1) CLO3D requires less time to learn compared to other design software	7	20	11	31.4	11	31.4	3	8.6	3	8.6	2.54
2) CLO3D makes it easier to create design mockups without sewing	0	0	1	2.9	8	22.9	13	37.1	13	37.1	4.09
3) CLO3D helps me save time during the fashion design process	0	0	4	11.4	8	22.9	17	48.6	6	17.1	3.71
4) CLO3D facilitates 3D visualization of designs	0	0	0	0	3	8.6	11	31.4	21	60	4.51
5) CLO3D helps me better understand garment construction compared to manual methods	0	0	2	5.7	8	22.9	15	42.9	10	28.6	3.94
6) CLO3D allows me to quickly test various design variations	1	2.9	0	0	9	25.7	14	40	11	31.4	3.97
7) CLO3D provides accurate visualization of fabric drape and shape	0	0	0	0	3	8.6	17	48.6	15	42.9	4.34
8) CLO3D facilitates communication of design ideas with others (lecturers, clients, peers)	0	0	1	2.9	7	20	16	45.7	11	31.4	4.06

3.1.4 Student's Perception of CLO3D Usage towards Sustainable Design

The results indicated that Fashion students responded positively in terms of their understanding of sustainable design and its relevance to the use of CLO3D. All items received mean scores above 4.00, suggesting widespread agreement that CLO3D supports sustainable practices, such as reducing textile waste, increasing material efficiency, and enabling the creation of environmentally friendly fashion designs. An interesting from these findings is that CLO3D is not only viewed as a practical design tool, but also as an influential platform for cultivating sustainable thinking among future fashion designers. The majority of students agreed that CLO3D encourages consideration of environmental impacts and supports the development of alternative solutions for eco-friendly fashion.

Table 4. Perception of CLO3D Usage towards Sustainable Design

ITEM	SD		D		N		A		SA		Mean
	F	%	F	%	F	%	F	%	F	%	
1) I understand the concept of sustainable design in the fashion industry	0	0	1	2.9	5	14.3	22	62.9	7	20	4.00
2) I understand the importance of sustainable design principles in fashion	0	0	0	0	5	14.3	22	62.9	8	22.9	4.09
3) I know that one of the goals of sustainable fashion is to reduce textile waste	0	0	0	0	3	8.6	15	42.9	17	48.6	4.40
4) I am familiar with concepts such as zero waste, slow fashion, and eco-friendly design	1	2.9	0	0	5	14.3	11	31.4	18	51.4	4.29
5) Using CLO3D can reduce textile waste in the design process	0	0	0	0	3	14.3	17	48.6	13	37.1	4.23
6) CLO3D helps reduce the need for physical sampling during the design process	0	0	0	0	3	8.6	17	48.6	15	42.9	4.34
7) CLO3D enables more efficient and low-waste design practices	0	0	0	0	3	8.6	17	48.6	15	42.9	4.34
8) CLO3D encourages me to think more about environmental impacts in design	0	0	0	0	6	17.1	16	45.7	13	37.1	4.20
9) I believe CLO3D can be an alternative solution in developing environmentally friendly fashion	0	0	0	0	3	8.6	19	54.3	13	37.1	4.29
10) CLO3D helps prioritize material efficiency in my design process	0	0	0	0	2	5.7	18	51.4	15	42.9	4.37
11) CLO3D allows me to try out different designs without using real materials	0	0	0	0	5	14.3	14	40	16	45.7	4.31
12) CLO3D helps me calculate fabric requirements accurately	0	0	0	0	9	25.7	17	48.6	9	25.7	4

ITEM	SD		D		N		A		SA		Mean
	F	%	F	%	F	%	F	%	F	%	
13) CLO3D enables the creation of more adaptive and functional designs (modular, zero-waste, etc.)	0	0	0	0	7	20	21	60	7	20	4
14) I believe using CLO3D is a first step toward a more environmentally conscious fashion industry	0	0	0	0	1	2.9	23	65.7	11	31.4	4.29
15) CLO3D allows me to experiment with designs without needing printed patterns or physical prototypes	0	0	0	0	6	17.1	13	37.1	16	45.7	4.29

3.1.5 Student's Reflection and Perceived Relationship Between CLO3D and Sustainable Design

Table 5 presents students' reflections and the perceived relationship between CLO3D and sustainable design. The results indicated that Fashion students perceive CLO3D as a valuable tool in supporting sustainable fashion design practices. All items received mean scores above 4.00, with the exception of two Item 5 and Item 9. An interesting highlight is the strong student agreement on CLO3D's role in reducing material waste and enabling design reuse, which points to their recognition of digital prototyping as a sustainable alternative to traditional physical sampling methods. Furthermore, students clearly view CLO3D not just as a design tool but as a medium for fostering environmental awareness.

However, the comparatively lower scores in Item 5 and Item 9 suggest that while students acknowledge CLO3D's potential after use, they may lack prior awareness or still feel uncertain about their readiness to apply sustainability concepts independently.

Table 5. Reflections on the Relationship Between CLO3D and Sustainable Design

ITEM	SD		D		N		A		SA		Mean
	F	%	F	%	F	%	F	%	F	%	
1) I feel that using CLO3D directly contributes to more sustainable fashion design practices	0	0	0	0	3	8.6	22	62.9	10	28.6	4.20
2) CLO3D is not only a design tool but also a medium to support environmental awareness in the fashion industry	0	0	0	0	2	5.7	20	57.1	13	37.1	4.31
3) I see a strong connection between using CLO3D	0	0	0	0	3	8.6	19	54.3	13	37.1	4.29

ITEM	SD		D		N		A		SA		Mean
	F	%	F	%	F	%	F	%	F	%	
and the future implementation of sustainable design principles											
4) Using CLO3D has changed my perspective on the importance of efficiency and waste reduction in the design process	0	0	1	2.9	5	14.3	18	51.4	11	31.4	4.11
5) I feel more prepared to create sustainability-oriented works after using CLO3D	0	0	0	0	10	28.6	17	48.6	8	22.9	3.94
6) Using CLO3D allows me to reuse existing designs and transform them into new ones	0	0	0	0	3	8.6	16	45.7	16	45.7	4.37
7) CLO3D helps reduce (Reduce) physical materials in prototyping since designs can be digitally visualized	0	0	0	0	3	8.6	14	40	18	51.4	4.43
8) I can adapt (Recycle) digital assets from previous designs for new models without recreating from scratch	0	0	1	2.9	2	5.7	15	42.9	17	48.6	4.37
9) Before using CLO3D, I was already aware of its potential to support sustainable principles	0	0	2	5.7	10	28.6	14	40	9	25.7	3.86
10) After using CLO3D, I now understand that it can support sustainable fashion design practices	0	0	0	0	5	14.3	17	48.6	13	37.1	4.23

3.2 Discussion

Based on the findings from students' perceptions above, it is evident that they recognize the relevance of CLO3D in relation to sustainable design. As shown in Table 4 and 5, students not only understand the importance of sustainable design principles in the fashion industry, but also acknowledge that CLO3D can significantly contribute to reducing textile waste, enhancing material efficiency, and facilitating design exploration without the need for physical prototypes. These findings align with the recognized advantages of the CLO3D program, which is CLO3D has proven to be a key innovation in sustainable fashion by accelerating production, reducing costs and material waste, and enhancing design variation through virtual prototyping (Vrljanac et al., 2023; Widiyawati et al., 2024; Mohamed, 2025; Khomariah et al., 2025).

Based on the students' perceptions, although it is evident that they are aware of CLO3D's potential as a tool to support sustainable design objectives, they still encounter certain barriers. These barriers include their infrequent use of CLO3D and the lack of application in design projects due to difficulties in operating the software. An interesting highlight from these results is the central role of formal education in introducing students to CLO3D. The overwhelming majority of students were exposed to the software through university coursework, suggesting that academic institutions play a critical role in integrating advanced digital tools into the fashion design curriculum. However, the generally short duration of use among most respondents also suggests that students are still in the early stages of developing proficiency with CLO3D, which may contribute to their perception of its steep learning curve. This challenge is in alignment with previous research noting that one of the barriers in adopting CLO3D in fashion education lies in the lack of structured guidance within the curriculum, as well as hardware limitations that may hinder students' practical experience with the software (Prasetya et al., 2025).

These findings suggest that while technical and instructional barriers remain, the perceived value and relevance of CLO3D in supporting fashion design particularly within a sustainability framework remain strong among students. To address the identified barriers in CLO3D adoption, educational institutions should implement structured, curriculum-integrated training that provides progressive, hands-on learning experiences with the software. This includes extending instructional time, incorporating project-based assignments, and ensuring access to adequate hardware infrastructure. By embedding systematic guidance and technical support into fashion design programs, students can develop the necessary proficiency and confidence to utilize CLO3D effectively as a tool for sustainable design innovation.

4 Conclusion

Based on the findings, it can be concluded that students of the Fashion Education Program at Universitas Pendidikan Indonesia (UPI) and Universitas Negeri Yogyakarta (UNY) who have studied the CLO3D software generally hold positive perceptions toward its use as a digital design innovation that contributes to sustainable design. These positive responses are also influenced by students' understanding of the concepts and principles of sustainable design. Therefore, when assessing the relevance between CLO3D usage and sustainable design in the fashion industry, it is evident that students already possess a foundational knowledge and awareness of sustainability in design practices. The application of sustainable design principles through CLO3D is evidenced by students' agreement that the software facilitates efficient, accurate, and rapid processes for designing and prototyping fashion products digitally. Students experienced ease in 3D visualization, creating mockups without sewing, and testing multiple design variations more conveniently than with conventional methods. Moreover, CLO3D enhances communication between students, as designers, and their clients, instructors, and peers by providing realistic visualizations that improve the clarity and understanding of the presented designs.

However, challenges remain in the operational use of CLO3D. Students still perceive the software as difficult and time-consuming to learn even though nearly all of them were introduced to the software through university courses. Therefore, a viable solution is to optimize the time allocated for introducing and practicing CLO3D during lectures. This study recommends that, in order for students to become proficient in using CLO3D, adjustments must be made to the instructional approach within the curriculum. Recommended actions include facilitating training opportunities for lecturers to enhance their readiness in teaching CLO3D, developing learning materials such as video tutorials or multimedia modules that allow students to study CLO3D independently outside of class hours, and revising the course curriculum to better integrate CLO3D instruction.

Conflicts of Interest

The authors declare no conflict of interest regarding the publication of the paper.

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