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A review of 3D design knowledge and its impact on creativity in fashion design education

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ABSTRACT

The rapid technological advancements of Industry 4.0 are reshaping the fashion industry, emphasizing the need for innovative tools and digitally skilled professionals. This study explores the integration of 3D virtual prototyping into fashion design education and its impact on fostering creativity, enhancing technical skills, and preparing students for contemporary industry demands. Drawing upon a detailed literature review and an in-depth case study from the Department of Creative Design & Clothing at the Int. Hellenic University, this research examines the pedagogical and creative outcomes of incorporating 3D design tools. The implementation of a structured course in 3D virtual prototyping provided students with theoretical knowledge and hands-on experience using advanced software. Findings indicate that 3D design knowledge enhances spatial visualization, critical thinking, and problem-solving skills, while fostering sustainability awareness. The open-themed project assignments encouraged individual and collaborative exploration, empowering students to push creative boundaries while honing technical expertise in virtual garment design, fabric simulation, and rendering techniques. Some challenges were observed, including the steep learning curve associated with mastering 3D design tools and difficulties managing time during iterative design processes. Despite these hurdles, the experience fostered a deeper sense of confidence and adaptability among students, equipping them to navigate the demands of the evolving apparel industry.

Keywords
3D Virtual Design,
fashion education,
education 4.0,
digital transformation,
digitalization

1 Introduction / current state

The world is currently undergoing the 4th industrial revolution or Industry 4.0. Technological advancements' rapid progress and integration influence every aspect of everyday life. From artificial intelligence and 3D technologies to robotics and even social media, digital integration has changed the way the world functions [1]. And although the fashion industry is experiencing these changes more slowly, it does not stay unaffected [2].

According to Avădanei et al. [3], digital transformation within the fashion industry entails the systematic redefinition of business paradigms, the digitization of operational processes, structural adjustments, and the broadening of the value chain. This facilitates companies in leveraging technology to explore new possibilities and capitalize on its complete potential. In other words, the amalgamation of the digital world with physical production will transform the way the entire clothing chain functions, with novel methodologies for work processes and communication, utilization of advanced tools for creation, transactional activities, and distribution channels, alongside enhanced strategies for supplier and customer engagement, aligning with the reality of Industry 4.0 [1,4].

An important part of this technological transformation is the integration of 3D technology, and more specifically 3D design and prototyping [5]. 3D technologies have been used for many years by various industries such as architectural, electrical, or mechanical engineering. The delay in their integration within the fashion industry, as opposed to the aforementioned industrial sectors, primarily stems from challenges in visualizing 2D patterns and their corresponding 3D garments, as well as in accurately and comprehensively simulating the intricate interactions among the human body, textiles, and gravity, while also encompassing the nuanced depiction of diverse fabric behaviors [5,6].

With the years passing, the software for 3D prototyping continues to evolve, offering specialists within the apparel industry a variety of advantages across the entire lifecycle of garment production, encompassing design, prototyping, marketing, and merchandising stages, becoming, in that way, increasingly important [7]. From the standpoint of cost-effectiveness, virtual prototyping contributes to the diminishing of the need for extensive physical sampling iterations, thereby restraining expenses related to raw materials and labor [8]. This aspect is also of considerable significance for the sustainability objectives of the industry [5]. Regarding design visualization and communication, digital prototypes offer a more realistic portrayal of the final product compared to technical sketches or two-dimensional drawings. They provide comprehensive garment visualization, enabling a 360-degree view, fabric draping simulation, and visual assessment of garment aesthetics on a human figure. Moreover, they afford flexibility by facilitating real-time design modifications and instant visualization of alterations in both 2D and 3D settings [2,9]. This functionality enhances designers' capacity to articulate their concepts to clients, manufacturers, and other stakeholders engaged in the production process, thereby fostering more efficient collaboration with pattern makers [10].

In the current transformative environment, the modality of both labor and scholarly engagement with the field of fashion also changes [3]. Widely known is the imperative demand within the fashion industry for multi-skilled professionals, who demonstrate proficiency across various areas of clothing creation, such as design, construction, and clothing technology [11]. Furthermore, it is recognized that upcoming employees need to have digital skills to smoothly fit into and add value to Industry 4.0 [1].

As posited by D'Itria and Vacca [12], there exists a pressing imperative for institutions of higher education to grasp this shift and apprehend the needs of both the industrial landscape and the student body, while upholding educational integrity. Moreover, Crittenden et al. [13] underscore the critical role of higher education in ensuring students' exposure to pivotal technologies and in nurturing their capacity for critical thinking skills, empowering them to discern and differentiate among the vast array of informational resources available to them. Overall, universities are tasked with discerning the innovative currents of this era and facilitating the development of students into adept professionals equipped to navigate the evolving dynamics of the market [14].

The integration of 3D prototyping into the academic curriculum not only functions as a learning tool for students to explore and evolve [5], but also ensures the endowment of students with a primary requisite

digital competency crucial for contemporary employment within the apparel industry [15]. The purpose of this paper is to explore how this technology is studied in fashion universities and its influence on students' learning and creativity, providing an extensive literature review, while also proposing a successful teaching approach that was applied at the Department of Creative Design and Clothing of International Hellenic University and help enrich the limited literature around the pedagogical aspects of virtual prototyping.

2 Literature review

A study published in 2010 [16], a time when the prevalence of 3D virtual technology within the fashion industry and fashion education was limited, aimed to assess the effectiveness of 3D simulation technology in augmenting spatial visualization within the context of apparel design education. The primary objective did not entail students learning how to use this technology; rather, it focused on the educator's utilization of 3D simulation as an auxiliary instructional aid to enhance student learning experiences. The participants of the study were students enrolled in an introductory patternmaking course, in order to limit previous knowledge and experience, at a prominent Midwestern University in the United States. They were exposed to three instructional methods: lecture-based instruction, utilization of 3D simulation instruments, and traditional patternmaking. The integration of animated 3D simulation instruments had a positive impact on spatial visualization skills, underscoring the potential of this technology as an effective educational tool in apparel design. Participants expressed a favorable disposition towards the benefits of 3D simulation technology, highlighting its promising role in enhancing pedagogical practices.

Siersema [17] explores in her literature study (2015) the integration of 3D technology in higher education and its effects, focusing on its application in fashion education at the Amsterdam Fashion Institute (AMFI). More specifically, AMFI has been incorporating 3D virtual prototyping into its curriculum for 3rd and 4th year fashion students. Initially, students primarily used 3D simulation in the final phase of prototyping, but the process has evolved to integrate 3D simulation software from the conceptual phase onward.

The study emphasizes how an innovative attitude is crucial for students aspiring to work in fashion and highlights the benefits of this approach, including positive influence in the design process, and enhancing interaction, visualization, and thinking. Students were assisted to understand 2D to 3D translation and fitting complexity. Also, the need for physical prototypes was reduced. In conclusion, the study suggests a structured learning progression, from basic digital skills in 2D to specialization in 3D CAD design by the final year and states that the integration of 3D technology offers students a more innovative and efficient way to learn and create in the fashion industry [17].

Another study [18] conducted at a large public university in the Midwestern United States (2017) underscores the necessity for advanced digital education and investigates the impact of learning 2D and 3D CAD on students' patternmaking skills within student-centered fashion programs. The researcher conducted a case study involving 13 fashion design students enrolled in an upper-level patternmaking class. Over the course of 5 weeks, these students utilized 2D patternmaking and 3D garment simulation software for their design projects. The case study methodology was employed to evaluate the efficacy of both 2D CAD patternmaking and 3D garment simulation programs. Data was collected through surveys employing a 5-point Likert scale, along with open-ended questions, to gather both qualitative and quantitative insights into student attitudes and perceptions regarding the software programs.

In general, students displayed a favorable disposition towards both 2D and 3D CAD programs in contrast to traditional manual techniques. They exhibited comprehension of the advantages of pattern interpretation, identifying design issues, assessing fit and aesthetics, and conveying ideas. Notably, students regarded the 3D program as more demanding than its 2D counterpart, fostering heightened peer engagement and collaboration in small-group settings. Additionally, students sought more guidance from the professor when utilizing the 3D program, likely due to their limited familiarity with this technology and the visual representation of clothing. Finally, the author concluded that integrating both 2D and 3D CAD programs into fashion design curricula would better equip students for future technological

advancements and sustainability practices within the fashion industry [18].

A different study [19] in the same year showed comparable results, but there were differences in the way 3D was integrated into the curriculum. The students had preexisting pattern-making knowledge, and they were familiar with vector-based design software, such as Adobe Illustrator. The class took place during a whole semester. The students were introduced to the overarching concept of this technology (e.g., 3D body scanning, parametric avatars, digital twins, etc.), before learning the 2D patternmaking and 3D simulation programs. Furthermore, they engaged in three consecutive projects that required the creation of both virtual and actual garment samples. Utilizing 3D simulations, they assessed design concepts, examined fit, and adjusted patterns accordingly.

To assess students' interaction, imagination, and critical thinking skills when using 3D simulations, along with their evaluation of software efficacy and inclination toward its utilization, a mixed-methods methodology was followed. This approach included questionnaires before and after each project, incorporating a Likert-type scale and open-ended questions to estimate student reflections. The results showed that students' interaction and critical thinking skills significantly increased when using 3D virtual prototyping. Additionally, it was discovered that as students' competencies advanced, their perceptions of the software's performance and the intention to use it again in the future also increased. It is worth mentioning that, although a favorable impact was noted on imaginative capabilities, the majority of participants did not venture significantly beyond their design and pattern skills knowledge level, with a few exceptions who pushed their boundaries in both areas, thereby challenging themselves in patternmaking/design and 3D virtual prototyping skills [19].

Hodges et al. [20] conducted a separate study (2020) aimed at examining an instructional methodology for teaching virtual technology and evaluating the pedagogical process and outcomes utilizing Kirkpatrick's training evaluation model. The main differentiation of this study was the active participation of industry experts throughout the project duration. The participants in the study were in a freshman/sophomore level apparel studies course at a large university in the Southeastern US.

The study unfolded in three distinct phases. During phase I, students were introduced to virtual prototyping software by representatives from an apparel corporation that uses the software in their product development process. Phase II was a two-week training, when students got acquainted with the 3D software, and phase III was a period of in-depth interviews. Students were asked to reflect on their learning experience and how it related to their personal and professional goals.

Once more, the general attitude towards 3D technology was overall positive. The only major concern voiced by the students pertained to the inadequacy of the allocated time for a comprehensive exploration of the design software's capabilities. Nonetheless, feedback underscored the considerable benefits and positive reception associated with the integration of 3D design within the project. Observable outcomes encompassed the advancement of skills and creativity, augmented spatial visualization abilities, and the attainment of personal and educational goals. Finally, the involvement of industry stakeholders facilitated a deeper understanding of professional expectations among students and influenced their future career goals [20].

Kolosnichenko et al. [11] did an educational experiment aimed at evaluating the efficacy of a vocational education and training (VET) system tailored for fashion designers and technologists, employing contemporary digital technologies. 80 students from Kyiv National University of Technologies and Design (KNUTD) took part in the experiment, which lasted 4 years, a full cycle of bachelor's degree training (2017-2021).

Throughout the experimental phase, students were divided into two distinct groups: a control group (CG), which adhered to the conventional curriculum, and an experimental group (EG), which engaged in supplementary learning activities utilizing digital technologies, such as digital creative collage, development of sketches of models of the clothes and use of 3D programs for virtual simulation. It is pertinent to underscore that to mitigate potential confounding variables, both groups underwent the same level of basic training, duration of the training, received equivalent durations of instruction, were taught by the same pedagogical teams, and utilized identical educational facilities within the institution [11].

The study revealed that exposure to 3D technology and design among students in the experimental group (EG) facilitated a heightened proficiency in executing professional tasks through technological means, developing creativity and innovation in solving problems, and reducing the time of tasks' completion. As a result, the study concluded that the experimental system of training specialists in fashion design was more effective and contributed to the acquisition of competencies requisite for contemporary fashion industry demands. The study advocates for the integration of licensed software and 3D design programs within VET curricula about fashion design and technologies [11].

It is evident that the effects of 3D prototyping and incorporation in fashion universities' curricula have preoccupied the educational and scientific community. Considering this, An et al. [21] delineate the challenges associated with 2D computer patternmaking and 3D virtual prototyping as perceived by students in their research. To accomplish that, and concurrently aiming to illuminate the multidimensional perspective of fashion design, an experimental project was assigned.

The participants were sophomore students studying clothing science, technology, and cultural studies at a women's university. They were tasked with collaboratively crafting an innovative design within groups of four individuals, with the intention of stimulating creativity and incorporating elements of contemporary fashion trends, as well as utilizing both 2D and 3D computer-aided design (CAD) software. Additionally, a questionnaire was administered to gather quantitative data. The best practices showed conceptual designs with aesthetic styles, complex-shaped pattern pieces, decorative elements, and combination of materials. Through the examination of the questionnaires, ten challenging aspects of 2D pattern making and sixteen impediments to learning 3D virtual prototyping were identified. The overarching aim of this study was to facilitate the development of forthcoming fashion education initiatives and cultivate creativity via innovative technologies, underscored by an emphasis on the significance of scientific backgrounds in apparel design.

Conlon and Gallery's study [22] posited that the acquisition of learning 3D clothing design could help the advancement of students across various fields within the fashion industry, beyond fashion design. Specifically, the research aimed to assess the advantages of 3D visual prototyping for students specializing in the fashion business. A university-industry approach was followed by a short, 4 days masterclass aimed to afford students a learning environment conducive to acquiring novel 3D virtual prototyping skills, while concurrently fostering a deep comprehension of proficiently managing digital technologies in modern fashion product development, thereby elucidating its pivotal role in generating commercially viable products.

As all participants originated from a non-design background, they lacked technical skills for designing and patternmaking, yet they possessed familiarity with software applications like Photoshop and InDesign. Thus, the students were asked to modify an existing virtual garment rather than initiate one from inception. It was observed that students evinced a notable surge in self-assurance, creativity, and a profound sense of achievement. They comprehended the technology's importance within the domain of designers while also acknowledging its potential within their own field. They also appreciated the learning-from-experience approach, while also proposing the development of a mixed media resource bank to aid students alongside the integration of small-group dynamics to facilitate collaborative peer engagement [22].

3 Unveiling the creativity potential: 3D design proficiency's impact on fashion design education

3D Virtual prototyping is taught at the Department of Creative Design & Clothing of International Hellenic University (Kilkis, Greece) during the third year (sixth semester) of a four-year bachelor program, alongside a 2D CAD patternmaking course. At this point in their studies, students are familiar with traditional patternmaking, and basic clothing construction, while also knowing how to work with 2D design programs (e.g. Adobe Photoshop/Illustrator, CorelDraw). The course is divided into two parts: a theoretical one and a practical/laboratory one. The main goal of the course is to familiarize students with the current technological advancements, spark their interest in the potential possibilities, and equip them

with the practical skills that are needed in the apparel industry.

The theoretical part of the course is conducted in parallel with the laboratory, so that the students come into contact with the wider context of the specific technology, while they specialize in the use of 3D prototyping. In further elaboration, the initial segment of the course acquaints students with the fundamental principles of 3D design and its prospective applications across various industrial domains. Emerging technological terminologies, including AI (Artificial Intelligence), VR (Virtual Reality), AR (Augmented Reality), blockchain, and digital twins, are elucidated and explored. Students are prompted to articulate their perspectives and insights concerning the assimilation and deployment of these technologies within the apparel industry and its prospective advancements. Subsequently, in the applied segment, students acquire practical exposure by engaging with innovative software tools for crafting and manipulating digital garment designs. This firsthand experience empowers students to envisage and refine clothing concepts within a virtual environment before actual production, thereby streamlining the fashion design process and fostering creative exploration.

To provide greater precision, this paper pertains specifically to the cohort of students taking the class in the year 2023. During the spring semester, they were introduced to VStitcher by Browzwear. The first two weeks were dedicated to familiarizing with the software and getting accustomed with its different tools and functions. Custom-tailored exercises were administered during class sessions for this purpose. At the start of each lesson, the instructor presented distinct facets of the software relevant to the exercise objectives. Then students were left to try to complete the exercises independently in groups of 2 or 3, to enhance peer interaction and team spirit. The professor provided oversight and intervened as needed to address any challenges or inquiries.

At the end of the semester, students have mastered the program at an equivalent level of the 101 & 201 training courses offered by Browzwear University. More precisely, students acquired proficiency in manipulating parametric avatars and modifying their attributes, generating, and refining 2D clothing patterns within V-Stitcher, and simulating the construction and stitching of garments in a virtual environment. Additionally, they gained competency in assigning fabric properties and adjusting them to achieve desired characteristics, applying diverse patterns and artworks (e.g., artistic stamps) uniformly across garments, and integrating hardware elements and trims such as zippers, buttons, and various seam types. Lastly, students were instructed on the appropriate rendering techniques to optimize the final output quality and enhance procedural efficiency.

For their final assessment, students were assigned an open-themed assignment. The goal was not to limit their creativity but to allow them autonomy in applying recently acquired knowledge [23]. The assignment encouraged individual exploration, intending to reinforce experiential learning and promote self-regulated learning processes [24]. Despite the provision of a specific design program by the university, no restrictions were imposed, thereby granting students full latitude in their creative endeavors.

Students were given a one-month timeframe for the completion of the assignment. In addition to submitting their final work, they were required, post-deadline, to deliver a presentation to both the assessor and peers. This instructional approach aimed to acclimatize students to public speaking before a diverse audience and foster engagement with their peers' work [25,26]. During the work's implementation, the professor provided technical assistance and guidance regarding the program; however, students were encouraged to independently tackle challenges to enhance their problem-solving skills. Notably, despite the independent nature of the assignment, students frequently collaborated, pooling their resources to address common or individual issues collectively.

The implementation of 3D virtual prototyping within the academic curriculum and the open-themed project assignment brought forth a plethora of significant benefits that profoundly influenced the developmental trajectory and educational journey of the students involved. From the creativity

perspective, the project functioned as an experimental platform, providing students with an avenue to unleash their imaginative power. Encouraged to explore innovative concepts and express their unique ideas, participants experienced a surge in their confidence levels as they witnessed the realization of their creative visions. This newfound confidence not only boosted their self-esteem but also instilled a deeper belief in their capabilities and potential, paving the way for greater academic and personal achievements.

Looking at it through the lens of skillsets, the project acted as a catalyst for the cultivation of critical thinking skills, serving as a fertile ground for students to refine their problem-solving abilities. The extended exposure to 3D simulation also contributed to the enhancement of their spatial visualization skills across varying degrees. Finally, by immersing themselves in experiential learning, students not only gained theoretical knowledge but also acquired practical expertise in patternmaking and the utilization of 3D technologies, thus augmenting their proficiency in fields relevant to their studies.

Moreover, beyond individual growth, the project fostered a sense of collective morale and collaboration within the academic community. Through collaborative efforts and shared experiences, students developed strong bonds and a spirit of cooperation, enhancing the overall cohesion and synergy within the academic environment. This sense of unity not only enriched the learning experience but also contributed to a supportive and nurturing educational ecosystem wherein students could thrive and flourish.

Throughout the course and the subsequent completion of the project, several challenges emerged. Engaging in 3D virtual prototyping entails adherence to an iterative design methodology, necessitating considerable reserves of patience and perseverance. It was observed that some students faced frustration when initial simulations did not accurately represent their design visions, necessitating multiple iterations and adjustments to achieve the desired results. Additionally, a subset of students grappled with assimilating the underlying principles and methodologies of this technology, necessitating prolonged periods of acclimatization to proficiently execute project tasks.

A noteworthy impediment pertained to the open-ended nature of the project itself. For some individuals, the absence of prescriptive directives resulted in cognitive dissonance. This subset found themselves entangled in a web of indecision, grappling with an excess of conceptual ideations or beset by self-doubt at each stage of the creative process, thus seeking structured guidance and reassurance. Finally, students found it demanding to manage time effectively to meet project deadlines while navigating the complexities of virtual simulation, while balancing multiple assignments and responsibilities of other courses in the same semester.

4 Achievements

The virtual prototype’s lesson served as a catalyst for actions and participation of students outside the university context. Creative curiosity and a desire for progress led some students to achieve distinctions for themselves and for the institution.

In the year 2022, two students from our university, Eleni Sidiropoulou and Natalia Stoumpou, took part in the 1st International Design Competition – Digital Fashion, organized by the Kyiv National University of Technologies and Design. Subsequently, Sidiropoulou won the first prize (Fig. 1a, 1b), while Stoumpou secured the third prize (Fig. 1c, 2a, 2b).

Next year, in 2023, two other students, Nefeli Zolota Tatsi and Alice Papadimitriou, participated in the 2nd International Design Competition. Zolota Tatsi attained the second prize on this occasion (Fig. 3a, 3b, 3c), whereas Papadimitriou, along with Dr. Evridiki Papachristou, seized the opportunity to present a study titled “Renaissance: A Romantic Story with a Twist in Three Dimensions” at the VII International Scientific Practical Conference in Textile and Fashion. Finally, at the same year, the two authors of the present paper took part in the 10th International Textile Conference & 4th International Conference on

Engineering and Entrepreneurship 2023 (Tirana, Albania) with the study “Encouraging 3D Virtual Design in Fashion Education: Best practices” (Fig. 4-9) [27].

a.

b.

c.

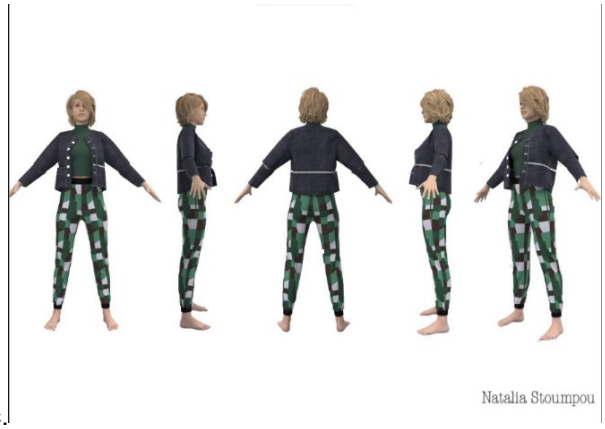
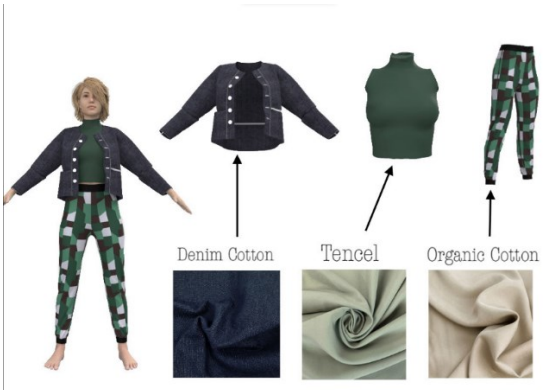


Fig. 1(a) Design development; (b) final artistic poster, Eleni Sidiropoulou; (c) final 3D design, Natalia Stoumpou.

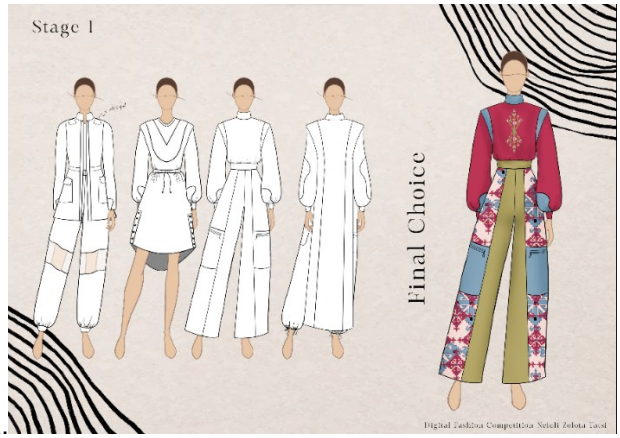
a.



b.

Fig. 2(a) Final design analysis; (b) final artistic poster, Natalia Stoumpou.

a.



b.

c.

Fig.3 (a) Design development; (b) final artistic poster; (c) 3D design, Nefeli Zolota Tatsi.

a.

b.

Fig. 4 (a) Example of design analysis: description, Pantone colors, fabrics, technical drawing and 3D prototype; (b) outfit 1 / colorway 1&2 (front, right, back, left), Nefeli Zolota Tatsi.

Fig. 5 Outfit 2 / colorway 1&2 (front, right, back, left).

Fig. 6 Outfit 3 / colorway 1&2 (front, right, back, left).

Figure 7. Outfit 4 / colorway 1&2 (front, right, back, left).

Fig. 8 Outfit 5 / colorway 1&2 (front, right, back, left).

Fig. 9 Outfit 5 / colorway 1&2 (front, right, back, left).

5 Conclusions

The dynamic landscape of the fashion industry is transforming, necessitating the integration of novel technologies and a commitment to innovation for its continued sustainability. This paradigm shift extends to the realm of fashion education. The literature review reveals the evolving nature of pedagogy and specifically, the growing recognition of the significance of 3D virtual prototyping within academic curricula. This recognition is not merely rooted in the imperative to equip students with requisite skills for their professional futures but also underscores the pedagogical value of such tools in fostering cognitive development and nurturing creativity.

This study also highlights a successful pedagogical approach employed during the spring semester of 2023 and its results, while also presenting the possibilities that flourished throughout the inclusion of the Virtual Prototyping course in the curriculum. Observations from this endeavor illustrate that students have developed heightened skills in visualizing designs, enhanced communication efficiency, and a greater consciousness of sustainability practices within the industry. Moreover, beyond mastering technical skills, the project facilitated critical thinking and inspired creative expression among participants. The successes indicate students' enthusiasm to interact with emerging knowledge, bridge the gap between traditional design principles and cutting-edge 3D modeling techniques and propel advancement into the future.

Conflicts of Interest

The authors declare no conflict of interest.

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