EVALUATION OF THE USE OF 3D DIGITAL DESIGN TOOLS IN APPAREL INDUSTRY

GÖKÇE ÜSTGÜL

Master's Thesis

Graduate School
Izmir University of Economics
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ABSTRACT

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Üstgül, Gökçe

Master's Program in Design Studies

Advisor: Assoc. Prof. Dr. Arzu Vuruşkan

August, 2021

Despite all recent technological developments in the world apparel design, product development, and production still depend mostly on manual, techniques. Use of 3D visual prototyping in apparel industry has been iYüksekneffective and complicated, despite its widespread use in other industries. In garment development, the 3D virtual technology is a significant advancement. It helps designers to express themselves in a real-life simulation of ideas that were previously only imaginable through 2D drawings. It is obvious that the future is becoming more virtual. Within this thesis, use of 3D virtual technology in the field of clothing is investigated. Exploration areas include the vision of apparel production companies, perspectives of professional users and software companies for the apparel industry and the challenges to overcome, suitability of the education system of universities for 3D virtual fashion designers and the effects of 3D virtual sample systems in apparel industry which are examined using qualitative research methods. As a result of this research, it is suggested that integration of 3D CAD systems within their structure and with their customers will

provide improvements in the workflow of textile and apparel companies, and 3D CAD systems should also be included in curriculum for fashion design education.

Keywords: fashion and textile industries, virtual fitting, 3D garment design, 3D virtual fashion education, technology integration, 3D product development

ÖZET

3D DİJİTAL TASARIM ARAÇLARININ GİYİM SEKTÖRÜNDE KULLANIMININ DEĞERLENDİRİLMESİ

Üstgül, Gökçe

Tasarım Çalışmaları Yüksek Lisans Programı

Tez Danışmanı: Doç. Dr. Arzu Vuruşkan

Ağustos, 2021

Dünyada yaşanan tüm teknolojik gelişmelere rağmen tekstil ve moda sektöründe tasarım, ürün geliştirme ve üretim süreçleri çoğunlukla manuel tekniklere dayanmaktadır. Üç boyutlu dijital tasarım sistemleri diğer endüstrilerde yaygın olarak kullanılmasına rağmen tekstil endüstrisinde tam verimle uygulanamamaktadır. Giysi geliştirme sürecinde, üç boyutlu sanal numune teknolojisi önemli bir adım oluşturmaktadır. Üç boyutlu sanal numune sistemleri tasarımcıların, daha önce yalnızca iki boyutlu çizimlerle ifade edebilecekleri tasarımların, gerçeğe yakın simülasyonlarla gösterilmesine yardımcı olmaktadır. Gelecekte sanal uygulamaların hızla artacağı beklenmektedir. Bu tez kapsamında giyim alanındaki üç boyutlu sanal teknolojilere ait uygulamalar incelenmektedir. Araştırma konuları, giyim üretim firmalarının vizyonları, profesyonel kullanıcıların ve yazılım firmalarının giyim sektörüne yönelik bakış açısı ve aşılması gereken zorluklar, üniversitelerin eğitim sisteminin üç boyutlu sanal moda tasarımcıları için uygunluğu, üç boyutlu sanal numune sistemlerinin giyim üzerine etkileri gibi konuları kapsamaktadır. Bu konular

nitel araştırma yöntemleri kullanılarak incelenmiştir. Bu araştırmanın sonucunda, üç boyutlu dijital sistemlerin tekstil endüstrisine entegrasyonunu sağlamak için, tekstil şirketlerinin kendi yapıları ve müşterileri arasında entegre bir iş akışı geliştirmeleri ve moda tasarımı eğitimi verilen üniversitelerde 3D CAD sistemlerinin kullanımına yönelik ders içeriklerine yer verilmesi önerilir.

Anahtar Kelimeler: moda ve tekstil endüstrisi, sanal prova, üç boyutlu ürün tasarımı, üç boyutlu moda tasarımı eğitimi, teknoloji entegrasyonu, üç boyutlu ürün geliştirme

Dedicated to My Mother Figen Üstgül and My Sister Özgecan Üstgül

ACKNOWLEDGMENTS

I would like to express my sincere appreciation to **Assoc. Prof. Dr. Arzu Vuruşkan** for her guidance and insight throughout the research.

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CHAPTER 1: INTRODUCTION

With the rise in demand for mass manufacturing, customization, and e-commerce in the apparel industry, virtual apparel design is becoming increasingly popular as a way to visualize virtual garments on a mannequin in 3D virtual space. The future of the apparel industry is represented by these innovative 3D virtual garment systems.

3D virtual garment systems have developed significantly in the last decade, with the combination of serious technical studies. With these developments, virtual sample systems have reached a reliable stage in visualizing designs before a physical prototype is built. The technology has progressed to the point that the digital expression of different garment types, design specifics, and fabrics or accessories is no longer restricted. These 3D garment systems can be used to produce extremely realistic photographs for advertisement and e-commerce purposes, so several CAD systems have developed software for the fashion industry, including Lectra (Lectra, 2021), OptiTex (Optitex, 2021), Clo3d (Clo 3D, 2021), V-stitcher (Browzwear, 2021) and others (Tao and Bruniaux, 2013).

3D virtual sample systems help both designers and manufacturers to quickly evaluate the product's fit and visual aesthetics problems by transforming 2D patterns into finished garments (Lee, 2013). In addition, 3D virtual garment technology can reduce product prototype development time and save multiple sample development costs. With the advantages of 3D virtual sample systems in the product prototype evaluation process, the efficiency of the technical design process, supplier coordination, and consequently customer satisfaction will also increase.

On the other hand, with the increasing demands of the apparel industry for 3D virtual apparel systems, a simultaneous search for the users of these systems has begun. The question of who could be the users of these new CAD systems has also been the subject of various studies in the apparel industry. User quality with multidisciplinary learning ability is also important at this point. Fashion design students who received design-oriented education both encountered some difficulties while using the new 3D CAD systems and realized some advantages of using these new CAD systems as a result of their training (Baytar, 2017). 3D CAD system requires multidisciplinary working skills. In order to create a 3D virtual sample, it is necessary to have knowledge of pattern, sewing and design.

1.1 Purpose

The overall aim of this thesis is to investigate the advantages and challenges of 3D virtual apparel systems in the apparel industry, through design and product development processes. It is also aimed to make suggestions that might make the software more common and permanent in the industry.

The most important features of 3D virtual software are that they are multidisciplinary, and their effects are visible in all areas of the industry. All objectives of this thesis can be listed as follows:

- To explore the effects of 3D virtual sample systems on the apparel industry, specifically on design processes,
- To determine what is expected from 3D virtual sample systems in the RTW industry in Turkey as a manufacturer country,
- To evaluate the contribution of fashion design education for 3D virtual fashion designers,
- To understand the influences of 3D virtual sample systems for fashion designers, and designers' expectations as user profiles of these systems.

1.2 Methodology

In order to explore the benefits and challenges of 3D virtual garment systems in the apparel industry, with the case of production facilities in Turkey, a qualitative methodology was followed.

Since the evaluation of the use of 3D digital design tools in apparel industry is quite up to date, many sources from different disciplines were found during the literature review. While searching the literature, it was determined that the subject was examined from many points of views and that it was interdisciplinary.

Since the technology develops rapidly, up to date research about how 3D virtual technologies work and how they will affect the apparel industry is important. 3D virtual clothing simulation technology has become a very popular CAD system. Literature search is conducted on virtual clothing prototyping, technology integration, new product development model - garment fit evaluation, virtual fitting, 3d virtual fashion education, 3d virtual fashion design through academic papers and books from electronic sources and also through news and articles. News on the latest technical advances can also be accessible by magazines, newspapers, and journals, as well as in

scientific papers. In addition to this, latest information can be accessed in the journals and conference papers about how this market is expanding with new technologies and how this 3D virtual on fashion and textile industries can be applied.

After analyzing the current status through literature review, interviews with 3D virtual sample system users were conducted in order to understand how 3D virtual sample systems can facilitate the integration of the apparel industry and contribute to this integration in a short time effectively.

Such new software systems are developed continuously by the users and in this way their permanence and adaptation to the changing necessities is provided. Thus, by asking open-end questions to the interview participants, the opinions, experiences, and expectations by the demands of the users from their perspectives can be learned. With these findings, 3D virtual sample systems can be brought together with users with the right background and more precise results can be obtained to ensure that they are fast and permanent in the apparel industry. All participants in this research have a fashion design background and have been working in the apparel industry as a 3D apparel designer. The criterion that determines how to select the participants was that they were fashion design graduates and at the same time users of the 3D virtual sampling system. The fact that the participants were from the same professions could provide the opportunity to reach a common and consistent conclusion, which is crucial for the research.

The planned period of interviews coincided with the period when the effects of the coronavirus pandemic increased in the world. This situation has stopped mobility around the world with social distancing, and because of the current social distancing limitations, interviews were conducted with the video conference method with the participants. In order to conduct an in-depth study, semi-structured questions were directed to the participants that they could answer in detail. While interview participants answered the questions, they also provided additional information. During the thematic data analysis, firstly, audio data have been transcribed from the audio records. Finally, all themes are gathered under 5 sections.

1.3. Structure

The thesis is divided into 6 chapters. It consists of one introductory section, four main sections and one conclusive (Figure 1).

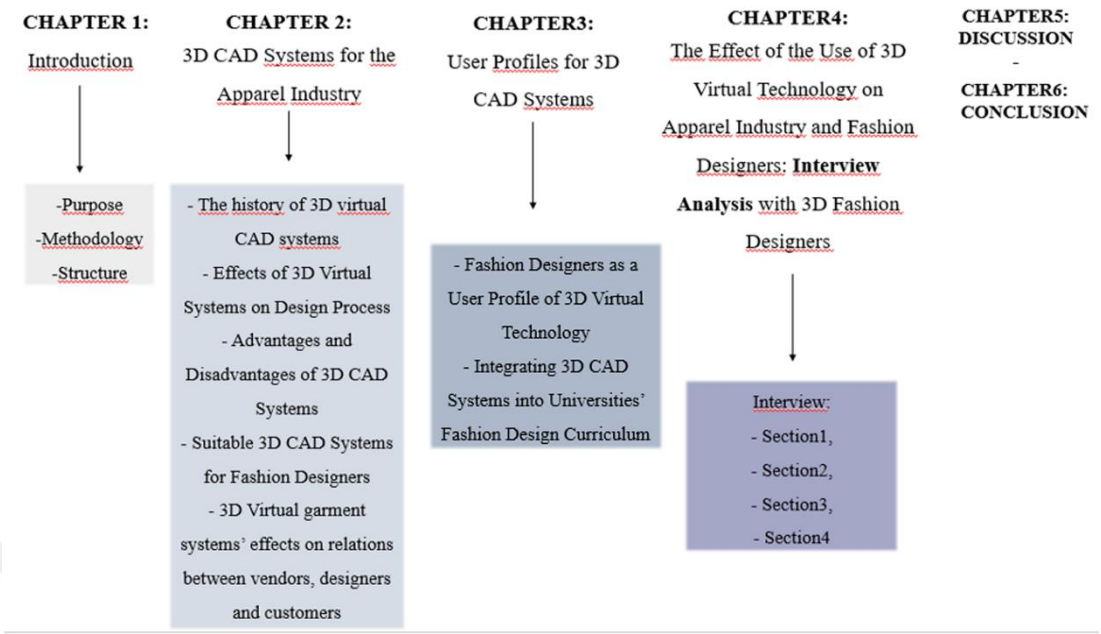

Figure 3. Structure of this thesis

First chapter is introducing the research topic and information on the purpose as well as the methodology of the study.

The second chapter gives a general perspective about 3D virtual CAD systems. The analysis of historical background of 3D virtual CAD systems, effects of 3D virtual systems on design process, advantages and disadvantages of 3D CAD systems, suitable 3D virtual systems for fashion designers and 3D virtual garment systems' effects on relations between vendors, designers and customers, are thoroughly investigated.

The third chapter gives an understanding of the factors that support fashion designers as a user profile suitable for 3D virtual sample systems. At the same time, the research included the education programs of universities in relation to 3D CAD systems.

In the fourth chapter, the effects of the use of 3D virtual technology on apparel industry and fashion designers are examined with using interview analysis method.

The chapter five is discussion part, and the chapter six is conclusion part of this thesis.

CHAPTER 2: 3D CAD SYSTEMS FOR THE APPAREL INDUSTRY

In the textile industry, 3D CAD technology should be used to assist the design process of a clothing product. Unlike industries working on other solid objects, 3D virtual CAD systems in the textile industry are expected to give physical properties of the fabric as a result of this composition structure.

3D virtual CAD systems aim to reduce design duration, garment prototyping costs and provide different collaboration on online platforms in product development (Papachristou and Bilal, 2015). These CAD systems are designed by different companies according to their intended use in the textile and fashion industry. The developers of 3D virtual systems provide to users with new tools and a more realistic look, which shows progress day by day. However, 3D virtual users' role, knowledge and skill is very important for understanding this multidisciplinary CAD system's background and challenges (Papachristou and Bilal, 2015).

If the 2D patterns' parts of a garment are considered, it is expected that the way it is applied to a clothing product will be different than traditional assembly methods in other industries. Although the garment industry seems to depend on 2D patterns, the quality of fit is evaluated according to the 3D image, which is the finished product (Papachristou and Bilal, 2015).

2.1 *The history of 3D virtual CAD systems*

The importance of the fashion and textile industry in human history cannot be underestimated. Fashion is a way to express personality (Spahiu, Shehi and Piperi, 2014). As a result of the desire of those who shape the apparel industry to diversify these opportunities and the technological changes in the textile and fashion industry, new CAD programs have been designed so that apparel designers can express themselves more accurately and precisely.

In the 1980s, computers were accessible, compact and efficient enough to be used in pattern digitization, manipulation and marker producing (Jaenecke and Tait, 2017). Since the 1980s, many digital clothing projects have been developed by different groups (Taylor, Unver and Worth., 2003). Study on digital 3D modeling and simulated

clothes began in the 1980s, mostly for uses in movies or animations (Wu, et al., 2011). In the beginning of the 1990s, one of the early 3D virtual systems developed by Hinds and McCartney (Sayem, Kennon and Clarke, 2010). One of the first 3D systems developed by Hinds and McCartney (Sayem, Kennon and Clarke, 2010) in the early 1990s, the CAD system included a digital mannequin. In order to adapt the fabrics of the clothes to the system, they used a device that converts the fabrics into numerical values (Hinds and McCartney, 1990). They showed immediate effects of a minimum 5 per cent of fabric savings on its own, but the longer-term implications of this growth have been huge (Jaenecke and Tait, 2017).

Being one of the first versions of 3D virtual systems, this CAD system was working successfully on 3D product development and visualization, automatic adaptation to dimensions and the geometry of the individual surfaces (Sayem, Kennon and Clarke, 2010). Towards the end of the 2000s, they developed a new CAD system, which allowed designing a garment from 2D to 3D and from 3D to 2D. These systems supported with 3 key elements: a user interface for enabling the designer's development of 3D garment requirements, a pattern flattening application, a drape system for effective simulation of materials on a 3D body based on a computational algorithm. Kim and Kang (2013) presented a technique for creating a 3D virtual garment based on body scan information. This supported the create of 2D flat pattern pieces (Sayem, Kennon and Clarke, 2010). Such detailed software developments have come together to create 3D virtual systems. In these directions, currently developed 3D virtual software systems generally include at least one of 5 basic processes: 2D pattern design, pattern preparation, virtual sewing process, fit on body and design revision (Liu, Zhang and Yuen, 2010).

While 3D virtual software systems are now popular in the engineering, industrial, furniture and shoe industries, revolutions in the garment industry have been slower and complicated, primarily due to the draping and stretching properties inherent in the fabric, which are not only fundamentally different between different kinds of fabric and construction, but also in the direction of spinning or stitching inside the piece (Jaenecke and Tait, 2017).The fashion and textile industry is a very large industry and computer-aided garment design programs have also expanded their sectors in this area. Software companies that update and prove themselves in fashion and textile include, AGE Technologies (Age), AMSSystems (amssoftware, 2021), Browzwear (Browzwear, 2021), Gemini CAD (Geminicad, 2021), GRAFIS (Grafis, 2021),

Marvelous Designer (Marvelousdesigner, 2021), OptiTex (Optitex, 2021), Pad Systems (Padsystem, 2021; Spahiu, Shehi and Piperi, 2014).

2.2 *Effects of 3D Virtual Systems on Design Process in the Apparel Industry*

With the support of CAD systems to fabric and product design processes, it has become an indispensable element of industrial design and apparel industries. Until now, many different systems for commercial or individual purposes have been developed especially for virtual clothing modeling and simulation. Software products for garment visualization aim to create images that look realistic for computer animation applications, while cloth design systems concentrate on the definition / construction of complex garment shapes for real production according to different 2D / 3D modeling tools. The purpose of these CAD systems customized for the clothing industry is to provide tools to support the pattern maker and designer in the process of creating a garment, to ensure that they achieve the desired final result. At the same time, the accuracy of the simulation results and fit analysis of virtual clothing designed with virtual apparel CAD systems reduces the number of physical prototypes and the role of the real sample (Fontana, Rizzi and Cugini, 2005).

Even if an apparel design and production process is wanted to be fully automated in the apparel industry, it still progresses depending on human factors. Designers, bespoke tailors or large manufacturers still depend on a clothing production process on traditional production systems. However, it is seen that with the changing world, the changes in the fashion and textile industry, the expectations of the customers, the performance expected by the manufacturing companies from their employees and the innovations that the employees expect from the technological equipment they use have increased. With the financial statements, it is revealed that technological developments such as 3D modeling or 3D printers in other industrial areas affect the people in all this industry chain and provide a significant benefit.

With the increase in digitalization in the world, the traditional business methods of the textile and apparel industry is changing. Especially 3D virtual garment systems are used as an important tool in the modern design and product development process. Virtual garment systems can speed up the design and development process and this integration effects on competition between companies. Virtual prototyping is a process used for shortening the product sales and marketing time and reduce the product cost.

It provides the designers to experiment in short way with a kind of fabric, accessories and materials, patterns on a 3D virtual body before the real garment is manufactured; virtual systems give designers an opportunity to decide their products' specific features in a very short time (Papachristou and Bilalis, 2015). Relatively, using this CAD system by a manufacturer helps to convince and meet their customers' expectations quickly.

On the other hand, Fontana, Rizzi and Cugini (2005) explained in detail an example of a men's jacket that it is very difficult to use 3D systems with full efficiency in all areas of the textile industry. According to the article, it is not yet possible to realize such hand-made products that require tailoring work in existing 3D systems, taking into account the combination of various materials (cotton, canvas, linen, horsehair, etc.) in the men's jacket to form layers and the effects of the positions and functions of the seams on the fit of the jacket (Fontana, Rizzi and Cugini, 2005).

According to the Fontana, Rizzi and Cugini (2005), in reality, the method of working of stylists and manufacturers can be analyzed as a 3D-to-2D-to-3D process. The process starts with the designers designing the model in the 3D CAD system, and then the pattern maker works on the corrections of the pattern in the 2D CAD program, after making the corrections for a producible correct 2D pattern design. Before the real product is sewing, it is finalized by working in the 3D virtual sample system one more time. This system works differently in every area of the apparel industry (Figure 2).

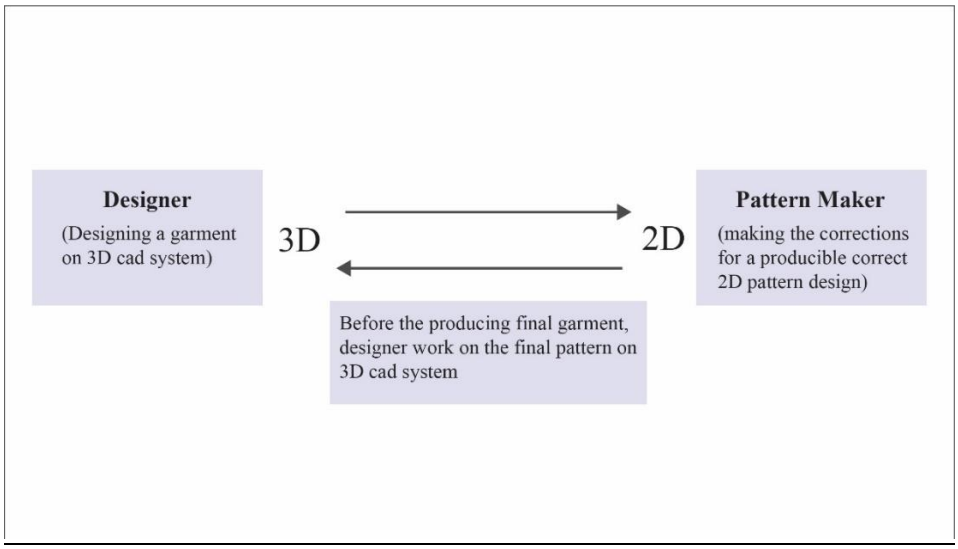

Figure 4. Manufacturer’s 3D design process (Source: Fontana, Rizzi and Cugini, 2005)

2.3 *Advantages and disadvantages of 3D CAD systems*

Digitalization in the fashion and textile industry has the potential to take the industry in a completely sustainable, new direction, given the industry's tradition. Greater market dynamics and rapid trend and consumer behavior changes of fashion product cycle in fashion and textile industry has directed competitive companies towards digitalization (Papachristou and Bilal, 2015). The fact that 3D CAD systems allow any change in color, fabric, texture, pattern and sewing techniques in a short time also enables pattern designers and clothing designers to work simultaneously (Papachristou and Bilal, 2015).

On the other hand, according to the Papachristou and Bilal (2015), 3D Virtual Garment Systems will not replace real garment prototypes. Because the successful textile industry until now make progress with real garment prototypes. Considering that mass production is made by manpower, a preliminary discovery of a product should still be produced in a real process so that problems that may occur in production can be avoided with that sample. In addition, the response of the fabric during the sewing process, the seam allowances must be measured according to different sewing machines and techniques, and the thread tension settings must be discovered beforehand. The unit cost of the product is calculated by considering the product yarn and labor costs from the sewn sample. A technology that can make these calculations without sewing a product has not yet been developed. It is necessary to sew prototypes samples not only for the sewing phase of a sample, but also for technical operations such as printing or embroidery work and washing tests of washed products. In other words, it seems that real sample sewing will not be completed totally, especially for vendors.

Technical designers using the 3D virtual sample system shared their experiences with the product design and creation processes in the 3D CAD program as follows: They stated that they can quickly intervene in any product-related problem and therefore communicate more efficiently with overseas buyers (Shin and Lee, 2020). A 3D CAD system should collect all the stitch types, fabric types, and features of the garment. This type of CAD provide convenience to designer when he/she design a garment. This system helps to bridge the communication gap not only for the designer, but also between retailers, manufacturers, sourcing offices and suppliers' platform (Sayem, Kennon and Clarke, 2010).

Some research shows that, labor market differences around the world have shown a highly uneven distribution. For this reason, apparel retailers in Europe and The U.S. have turned to overseas countries with high production capacity but low-cost labor (Bartolo, et al., 2019). The geographical distance between the manufacturers and retailers may cause a disconnection in communication, causing the sample product to be far from the desired physical appearance and a waste of time during sample recovery. During the pre-production sample preparation process, 2 to 10 samples are sewn for a model (Lectra). Preparation of these real garment prototypes is a waste of time and money (Sayem, Kennon and Clarke, 2010). Also, 3D virtual prototypes provide to marketing aid for online collection presentation and digital retailing. This situation will prevent customers visits in order to present real samples called 'suitcase travelling', which is the traditional product marketing (Sayem, Kennon and Clarke, 2010).

All these traditional textile applications can be facilitated by the technical features available in 3D CAD systems. 3D systems must provide some application features to the users in order to make product fit checks correctly. For this reason, software developers have added some features to the 3D CAD software in order to measure the reality of the product created in the 3D system (Papachristou and Bilal, 2015). These features allow users to see fit problems while making product reality comparisons. A "tension map" tool is used in the 3D Virtual CAD system, which checks the fit of a 3D avatar and the garment on a simulated product. This tool consists of a color map with color transitions from green to red. Depending on the design and fabric characteristics of each product, changes are observed in this color map according to the parts of the body. For example, a sports legging is expected to envelop the body, and if a color change is seen in the waist part of the legging that grips the body the most, rather than green, it can be assumed that there is a fit problem. In a classic hoodie sweatshirt, the most touching point of the product is expected to be the shoulders, and that the colors can be seen in this area on the avatar are between yellow and green in Figure 3. Because of that, by making fewer physical samples, a more efficient process management can be achieved in terms of both time and cost.

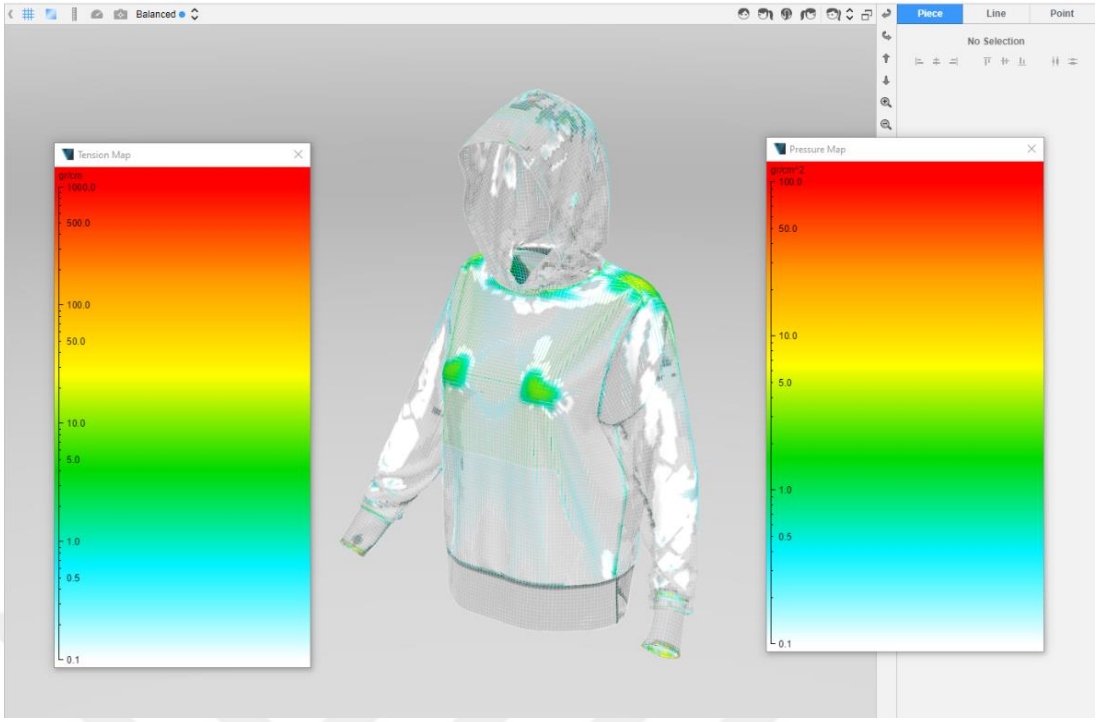

Figure 3**.** V-stitcher- Browzwear virtual CAD system pressure maps (Source: Browzwear, 2021)

At the same time, another advantage of 3D virtual system is that it allows to create avatars that can be customized in size and can be scaled according to certain parameters. In Figure 4, 'Edit Avatar' panel is illustrated. In the traditional fit method, designers make their product fit on live models because they need real human form instead of dummy. But this method is quite expensive. It is also insufficient for some of the expectations required by the rapidly changing industry. With this traditional method, a live mannequin must also be traveling with you to promote the collection on any customer trip. This is not a sustainable working method either.

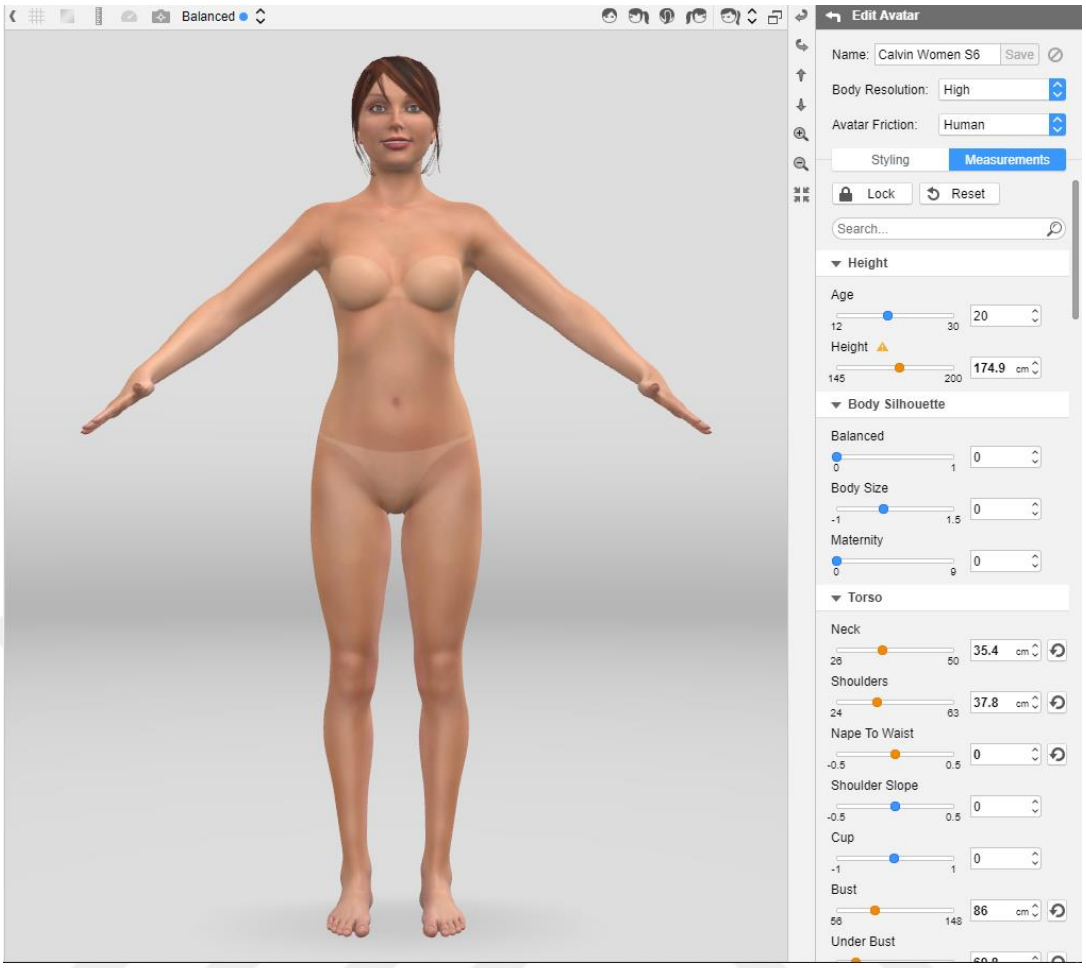

Figure 4. V-stitcher- Browzwear virtual CAD system: 'Edit Avatar' panel (Source: Browzwear, 2021)

The fact that a fabric, which is desired to be used in the real sample, can be transferred to 3D virtual garment systems by easily passing it through the fabric analysis devices of the system (Figure 5). Fabric properties are transferred as a numerical table to the 3D CAD system (Figure 6). Fabric transfer will enable fit evaluations to be made more precisely and reliably at this point and will also increase the interest in 3D systems over time.

Figure 5. Fabric analysis devices of the systems (Source: Browzwear, 2021; Clo 3D, 2021)

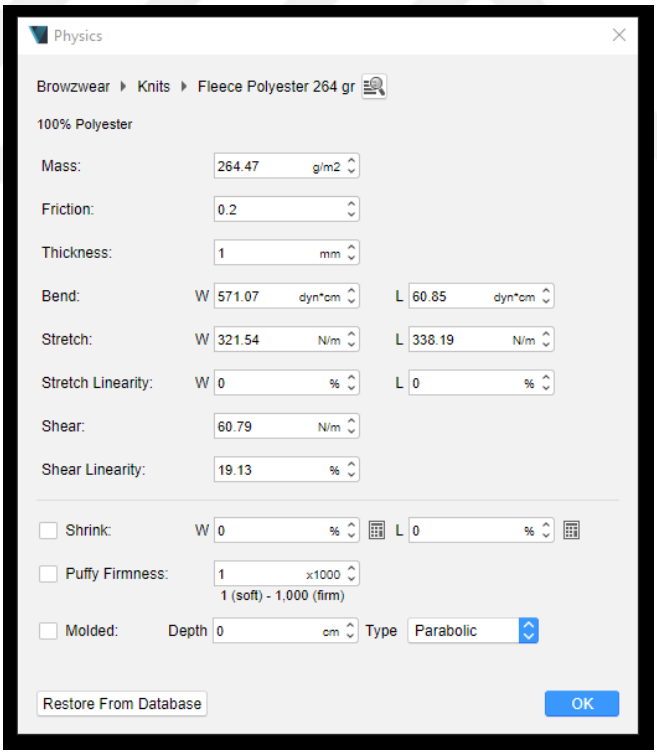

Figure 6. Numerical table for fabric properties (Source: Browzwear, 2021)

On the other side, 3D samples, which go directly from the manufacturer to the customer with 3D simulation systems, quickly meet with the final consumer as well as in online shopping (Kim and LaBat, 2013). In other words, before the product goes

into production, the reaction of the consumer can be measured in online sales channels with the virtual sample, the number of productions can be determined according to the demand, and in this way, excessive stock is not made. 3D product can reach sales channels faster than real sample. For example, the Tommy Hilfiger brand uses 3D virtual garment renders, rather than photo shoots, in its online sales channels in Turkey and in many other countries (Figure 7,8). In the image below, a render image of the products is uploaded to Trendyol online sales channel (Figure 9,10) and their own websites. Considering the ethical sales rules, there is a statement in the product information stating that they are 3D renderings.

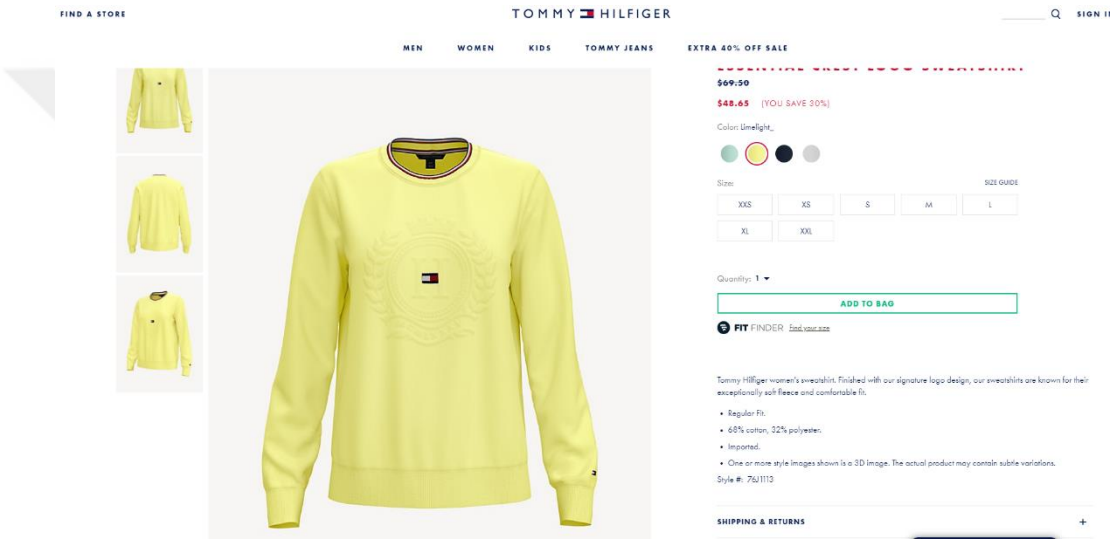

Figure 7. Tommy Hilfiger 3D garment (Source: Tommy Hilfiger, 2021)

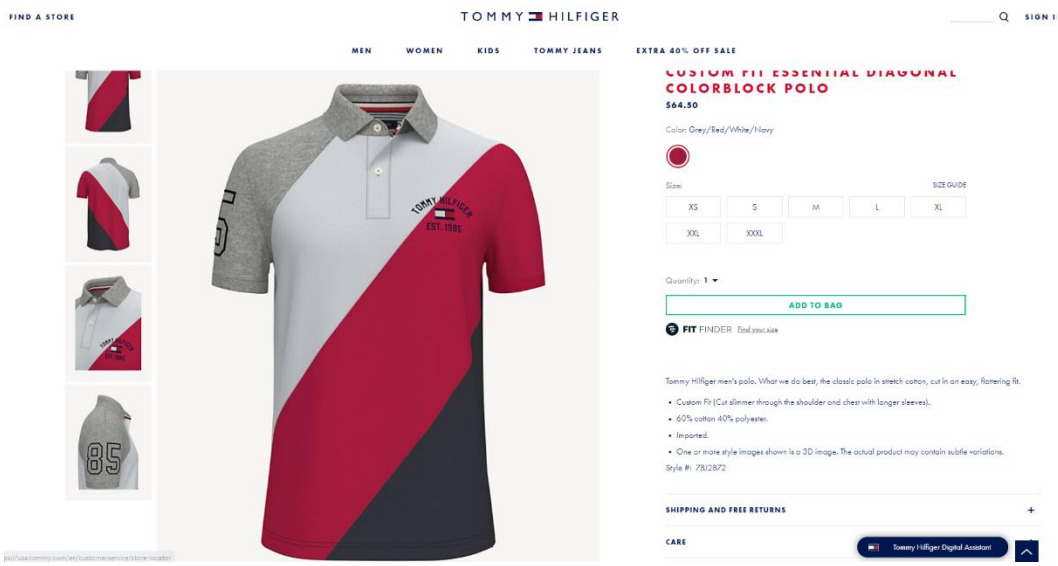

Figure 8. Tommy Hilfiger 3D garment (Source: Tommy Hilfiger, 2021)

Figure 9. Tommy Hilfiger 3D garment in Trendyol, Turkey (Source: Trendyol, 2021)

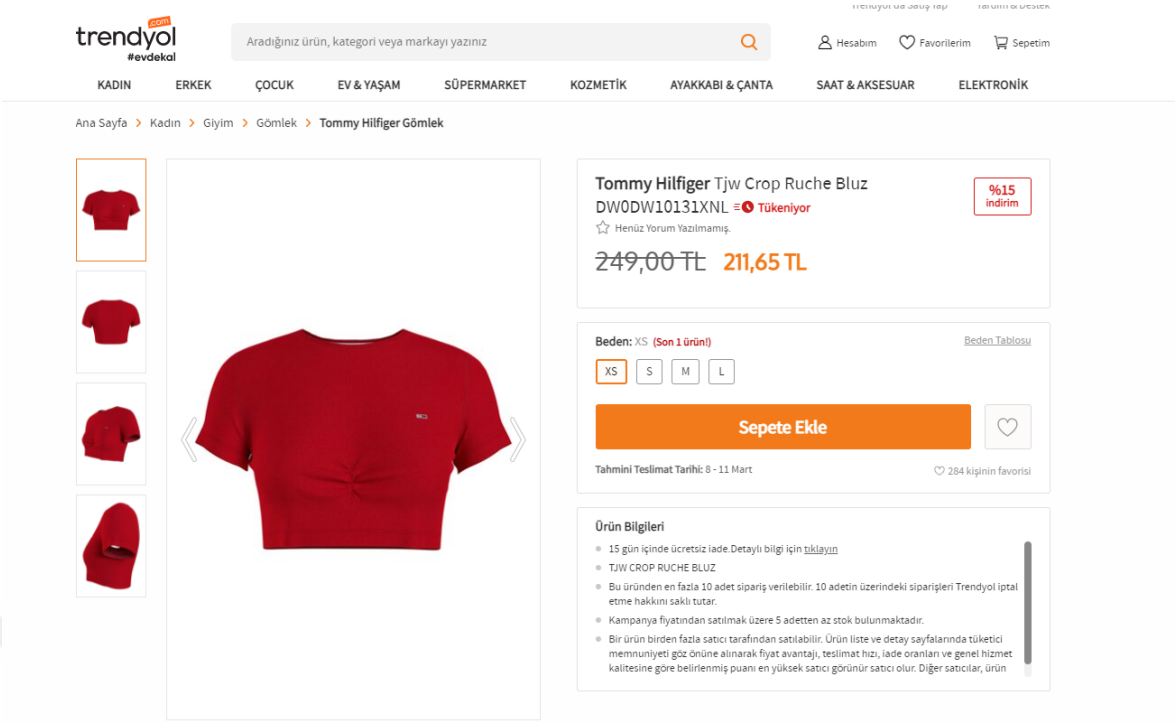

Figure 10. Tommy Hilfiger 3D garment in Trendyol, Turkey (Source: Trendyol, 2021)

In the following section, while comparing the advantages and disadvantages of 3D virtual sample systems, all below examples are based on real and virtual sample comparison. The 3D digital vs. real sample comparison studies made in the following examples will also refer to a summary of the advantages and disadvantages of 3D systems.

Garment fitting process: conventional vs. virtual fitting: A comparison of real and virtual samples in this section of the thesis. The fit of the garment means the comfort and appearance of the garment on the body. According to previous studies (Bye and LaBat, 2005), 94% of ordinary apparel products go through the fit phase 2 or 3 times before production. This fit process can be repetitive several times until the desired result is achieved (Figure 11). The process of a garment at the fit stage and sewing with fabric can take approximately 37 days (Clo 3D, 2021). Previous studies have also reported that there are multiple different types of samples producing for a model. In addition, although apparel companies and sourcing agents hold online meetings based on sewn, real product photos, it is very difficult to decide the entire production process of a product in this way. For these reasons, 3D virtual fit technology has now been included in the apparel industry. According to the report of Clo company, it has been

reported that the 3D virtual technology reduces the production and decision-making process of the product at the fit decision stage from 37 days to 27 hours (Clo 3D, 2021).

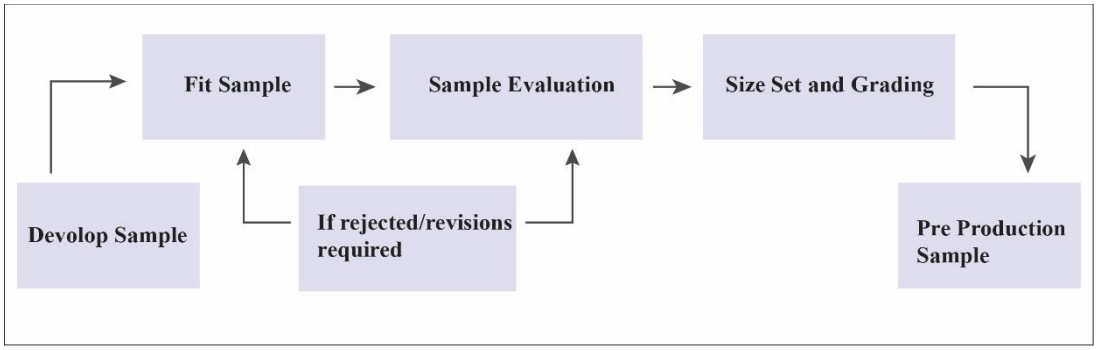

Figure 11. 3D virtual prototype cycle in manufacturer company (Source: Sul, et al., 2010)

Digital fitting tools may be helpful to correct patterns with a real-time fit simulation before creating real garment (Sul, et al., 2010). 3D virtual fitting systems improve the communication in better way between pattern makers and technical designers (Yoon and An, 2013; Shin and Lee, 2020).

However, in a previous study, the accuracy of product fit assessment was tested using 3D systems, and as a result, it was stated that the fabric simulation results in 3D systems did not yet yield accurate and satisfactory results and were not ready to replace traditional methods with virtual samples (Wu, et al., 2011). In this research, after 20 kinds of woven fabrics are passed through standard fabric laboratory tests, a simulation trial is performed on a classic flared skirt in 3D program. Real samples were also sewn so that this fit comparison can be made simultaneously. In this research, the main goal is not only to prepare a garment in 3D virtual CAD systems, simulate it and evaluate it in terms of design, but to make sure that the behavior of the fabric gives the most realistic result in 3D virtual systems. This investigation was carried out with Optitex (Optitex, 2021). In order to compare the results of the research, the images of the tension maps and the renderings of the product, front, back and side, were recorded as a result of the simulation of the 20 fabrics simulated. In addition, by using 3D body scanning technology, the real dummy has been transferred to the CAD program virtually for use in the 3D system. When the dressing process and the simulation phase were completed, certain angles were calculated from the photographs, and the

differences between the measurements in the real sample and the measurements in the virtual sample were determined (Figure 12).

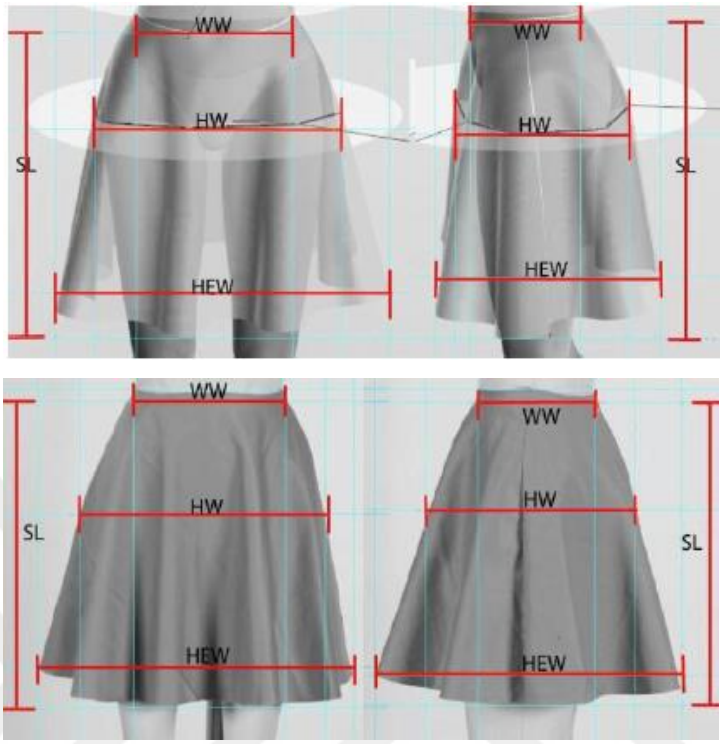

Figure 12. Measurements Definition: 3D Simulation (Source: Wu, et al., 2011)

As a result of this research, while it was determined that the simulated 3D virtual samples have smaller hip widths than real products, it was concluded that waist measurements are exactly the same, especially between the virtual sample and the real sample. The length of the skirt sample was measured in a way that the real and virtual samples were the same (Wu, et al., 2011) validity of 3D clothing simulation (Figure 13). In addition, for 3 out of 20 fabric scans, realistic results could not be obtained in simulation. As a result of other fabric simulations, the size differences of the product are less.

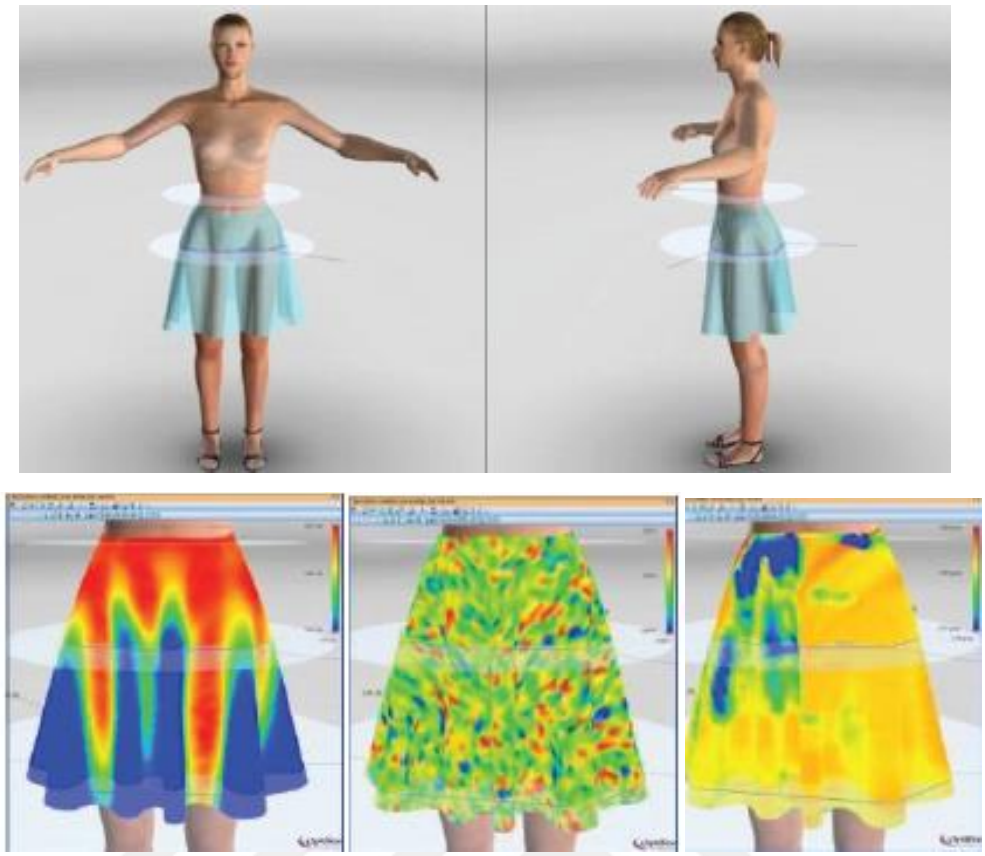

Figure 13**.** Distance, stretch and tension maps (Source: Wu, et al., 2011)

According to the Kim and LaBat (2013), virtual 3D garment fit evaluation has been criticized based to on fabric, size, shape, and critical locations and the result of the research arose question marks about the validity and credibility of 3D systems in the textile industry.

However, 80% of 3D technical designers who took part in the research in to by Shin and Lee (2020), also expressed the difficulties of using 3D CAD programs. One of these difficulties concerns its reliability. They also took a critical approach to issues that it is difficult to fully rely on 3D virtual sample technologies, the limitations of body movements with the virtual dummy, and also the inadequacy of fabrics and accessories in the system. They also stated that it is crucial to make a real sample, even if only one, after confirming the model with the 3D virtual sample system. As a result of this research, it is suggested that these CAD programs need further development and improvement. In addition, suppliers, sourcing offices and local manufacturers have stated that the purchase prices of these 3D software systems are very expensive, and it takes time to get used to these systems (Shin and Lee, 2020).

There is a pressure from the retail sector to reduce the costs and number of prototypes,

to overcome with the rapid fashion trends' changes. For this problem's solution, 3D virtual prototyping system is offered. Software suppliers believe that virtual prototypes reducing real prototype productions and product development (Lectra Customer Success Story, 2021; Tukatech, 2021; Sayem, Kennon and Clarke, 2010). So, 3D virtual garment systems will not only incorporate the fashion design and pattern generation into one step, but it will also reduce the prototype development duration and labor force contribution consequently for create commercial advantage (Sayem, Kennon and Clarke, 2010).

However, while the solutions offered by 3D systems provide the opportunity to use many features such as tension map, transfer of fabric physical properties, etc., to verify each other technically, the systematic accuracy of these features in themselves is still questioned. As a result, these comparisons between the real sample and the virtual sample still make 3D systems question the accuracy, that is, their closeness to reality.

2.4 Suitable 3D CAD systems for fashion designers

There are many varieties of 3D virtual CAD systems software which are commonly used in apparel industry today. Each of these 3D virtual systems are specially designed to serve different intended uses. CAD acquisition preferences should also change according to the field of the industry (knitting, denim, weaving etc.), to the purpose (fit sample, design sample etc.) and to the users (pattern maker, designer, product quality control specialist, customer representative etc.).

The main features of the available CAD solutions are summarized in Table1. Based on previous research on users, Table 1 was created by Sayem, et al. (2010). The efficiency, ease and user satisfaction of the features of this 3D software that are currently accessible are summarized in the Table 1 with feature comparisons from 1 to 5.

Table 1. Software features compares according to being user-friendly 1 to 5 (Sayem, et al., 2010)

SOFTWARE / FEATURES	Modaris 3D Fit - Lectra	V-stitcher - Browzwear	Vidya - Assyst Bulmer	Clo - Marvelous	Optitex	Accumark - Gerber
Wrapping 2D patterns on 3D body	2	5	4	5	3	4
Developing 3D design on 3D body	3	5	4	4	5	5
Realistic fabric draping	3	5	3	5	3	4
Adjustable virtual dummies	1	4	3	5	4	3
Dynamic pose / virtual fashion show	1	3	4	5	4	1
Online fit session	4	3	4	2	4	4
Vectorial Integration with Adobe Illustrator	3	5	0	5	5	0
Allows pattern makers to display 3D modeling while making 2D designs	5	5	4	5	5	5

One of the simulated fitting technologies, Gerber Technology's Accu-Mark, Browzwear's V-stitcher and Marvelous's Clo 3D allows pattern makers to display 3D modeling while making 2D designs. In addition, VStitcher, OptiTex 3D, and CLO can manipulate vector images from Adobe Illustrator and enables designers to create streamline workflow from design to production and Modaris 3D Fit software also works integrated with Adobe illustrator, but it is not vector-based, it can only transfer render images (Optitex, 2021; Shin and Lee, 2020).

If current CAD systems need to be examined by different researchers, Modaris 3D fit from Lectra is a 3D virtual garment prototyping system. This software system correlate with 2D patterns, fabric data and 3D simulation. Especially for designers, Modaris 3D fit provide to validate fabrics, motifs, and colors. There is a broad library of over 120 kinds of materials in 3D forms in Modaris. In addition, this software system allows the designer to add new fabric properties for use difference drape (Sayem, Kennon and Clarke, 2010).

VStitcher from Browzwear is 3D design and virtual prototyping system. VStitcher provide to 2D patterns design, grading, fabric data and 3D simulation as Modaris. this software system can turn 2D patterns into 3D virtual garments on adjustable virtual dummies that is from age and gender, body measurements and posture, to skin tone and hair style. VStitcher from Browzwear also supports a 2D/3D simulation capability with a rebalancing workflow that strengthens garment fit by changing patterns and clothing fit at the same time (Russell, 2019).

So, this program helps the designer to quickly integrate any necessary improvements to the 2D pattern parts that are displayed in the 3D design. Also, this software system uses map base for create 3D fabric and accessory texture, this feature of this software allows to see us more realistic simulations using with also stitches, prints and any other attachments. VStitcher allows and helps customer or partner to communicate and easily making fit garments on internet platform (Sayem, Kennon and Clarke, 2010). This virtual CAD system provides sharing 3D virtual garments on 'Stylezone Online Platform' (Browzwear, 2021)**.**

Vidya is a 3D fitting software that has been used in the textile and apparel industry for product design and development in computer games, animation films and Internet stores. This software system allows to generate personalized virtual avatar. Same as Browzwear and Clo, Vidya can visualize 3D garment design from 2D patterns and simulate fabric on a virtual avatar. And also, it can simulate button, buttonhole,

artwork, seam and shrink. It allows the users to add color and fabric texture what they want to use in their designed garments (Sayem, Kennon and Clarke, 2010).

Optitex is garment simulation system for 3D garment visualization, and it is based on 2D CAD pattern and, real garment features and fabric characteristics. This software as like other software systems (VStitcher, Clo, Vidya, etc.) offer to users, a range of parametric mannequins' properties with 65 changeable body measurements and posture positions (Sayem, Kennon and Clarke, 2010).

CLO provides a synchronization feature that allows users to draw clothing design directly on the virtual model and generate pattern pieces at the same time (CLO, 2019; Russell, 2019). Simulation might help designers to visualize products. The feature of virtual fitting could increase 30% efficiency of workflow (CLO, 2019; Figure 14). Collaboration between each sector in the global industry can be improved with the 3D features. According to CLO (2019), 50 per cent of international textile firms support sample clothes from sourcing agencies using 3D CLO. Also, Optitex (2019) claimed that their simulated fitting platform makes average output lead time 60 percent quicker than the typical workflow. Some CAD firms impose the benefits and importance of virtual fitting technologies (CLO, 2019; Gerber Technology, 2019; Lectra, 2019; OptiTex, 2019; Russell, 2019). However, the perspective of user candidates in the fashion and textile industry is not clear yet. In Figure 14, the comparison is seen between 3D and real sample process (Sayem, Kennon and Clarke, 2010).

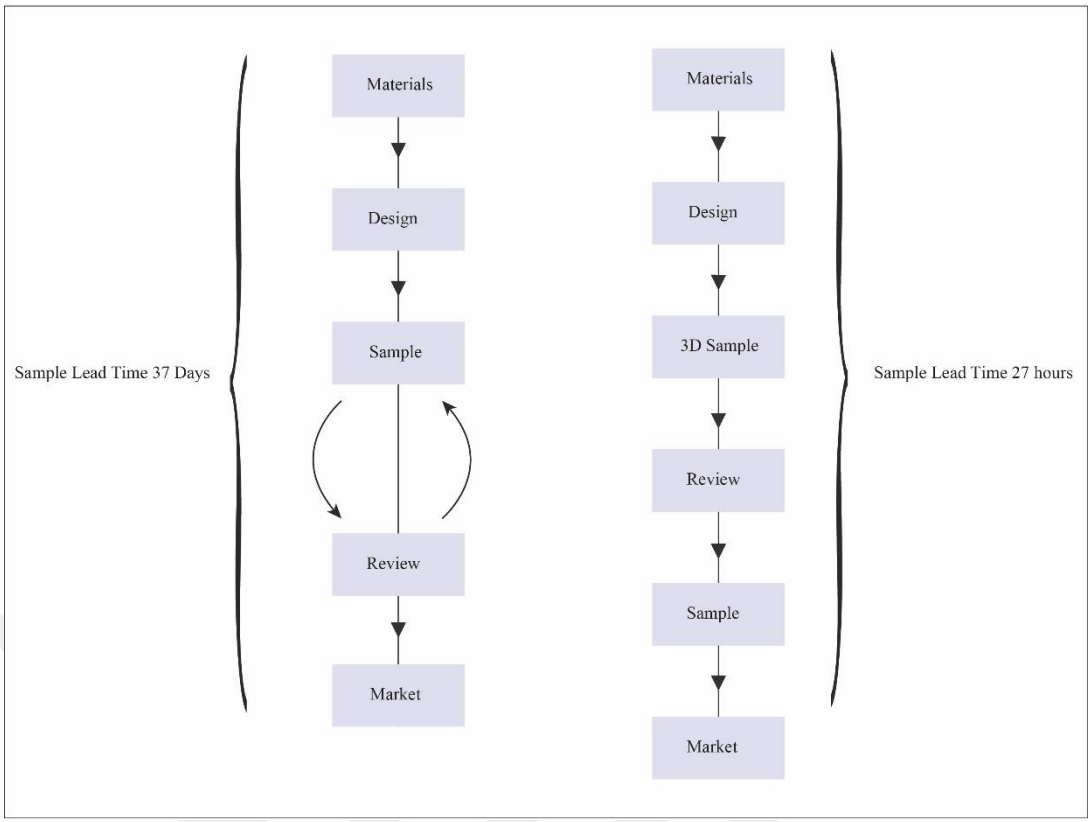

Figure 14. Before Use 3D vs. After use 3D (Source: Clo 3D, 2021)

The study in the Sayem, Kennon and Clarke (2010) article are research on the importance of 3D fit technologies by local suppliers and sourcing agents. In this report, the survey consisted of a total of 25 questions relating to the existing clothing fitting process in the apparel industry, the use of 3D virtual technology in the industry, and the opinion of the industry on the value of the potential use of 3D virtual technology. This study was applied in South Korea on randomly selected technical designers, manufacturing textile companies and apparel companies who are interested in 3D virtual sample systems. Those who answered this questionnaire were employees with over 8 years of industry experience, technical designers, merchandisers, fashion designers, cut-sewing operators, and pattern makers. While suppliers' own pattern makers and technical designers were responsible for the traditional sample control process, the system changed, and sourcing agents became responsible for the sample products evaluated by their technical designers. Sourcing agents stated that they mostly used photo interviews and web conferencing, 3D Virtual fitting system and at least face-to-face meetings while managing their business relationships. However, local suppliers stated that they prefer face-to-face meetings rather than web conferencing and 3D fit technologies as a technical package. In this case, compared to local suppliers

and sourcing agents, it has turned out that sourcing agents rely more on the technological structure. It shows that between agents and local manufacturers, 3D virtual technologies can be a more effective method of evaluating apparel application (Shin and Lee, 2020).

2.5 3D Virtual garment systems' effects on relations between vendors, designers and customers

3D virtual garment systems may be a useful tool for improving coordination between designers, merchandisers, retailers, vendors, and clients across the supply chain (Hwang and Hahn, 2017). 3D virtual systems can be used as a common language with everyone, including the marketing department, technical designers, fashion designers, suppliers, pattern makers, for all units in the apparel industry involved in this process (Lectra, 2021). More fashion companies are using 3D virtual garment systems, i.e. Under Armour, Theory have been using the 3D solution Optitex, Tommy Hilfiger, Calvin Klein, Banana Republic, Ralph Lauren have been using V-stitcher, and LC Waikiki and Only have been using Clo 3D CAD system.

In today's textile and fashion industry, with the increasing use of global outsourcing, long distance communication is expected to be made faster and easier. In order to connect, textile companies and sourcing agents normally focus on a tech pack, a set of documents which includes all the specification of the design of the textile, including garment prototypes, images or illustrations, patterns, designs, descriptions, sizes and body measurements. While companies and sourcing agencies have tried to comply with the manufacturing procedure laid out in the tech pack, they also have problems in achieving precise measurements in the garment fitting process. Recently, innovative 3D Virtual Fit programs of the apparel industry can be seen as a solution to these problems. There are available exist software systems such as: AccuMark 3D, Vsticher (Browzwear, 2021), CLO (Clo 3D, 2021), Modaris® V8R2, and OptiTex (Optitex, 2021). The use of this kind of technology has changed the use of the global supply chain and the speed of service flows from overseas. In the apparel industry in the USA and Europe, some intermediary offices, suppliers, and manufacturers have started to use 3D technologies to make fit faster and easier. But the most important and big question in the minds of companies that do not use 3D CAD is, is it right to use 3D CAD systems now or is it better to buy when the system is developed in the future? If

a 3D Virtual CAD program is to be used, which one should it be? Are 3D Virtual CAD programs reliable for the international fashion and textile industry? (Shin and Lee, 2020).

As a result of a study of Shin and Lee (2020), the most of local manufacturers stated that they either did not hear or use 3D systems, while sourcing agents stated that they use 3D virtual systems or know 3D technology. Sourcing agents stated their software system preferences as Clo (Clo 3D, 2021), Optitex (Optitex, 2021), Browzwear (Browzwear, 2021) from the most preferred to the least. Sourcing agents using 3D technologies for the longest time have been using 3D technologies for 3 years, while other sourcing agents participating in the research have been using 3D technologies for less than 1 year, which is a minority group. As a result of the same research, the ideas of sourcing agents and local manufacturers about 3D technologies are completely different. Sourcing agents emphasized the importance of 3D virtual fitting technologies for the current fashion and textile industry, while local manufacturers stated that these technologies were not a priority and importance for them. However, the only thing that local manufacturers and sourcing agents think in common is that the importance of 3D virtual fit technologies will be very important in the future. The stage where the participants of the research plan to use 3D fit technologies in the future will be in the fit sample, preproduction sample, design development and general product evaluation (Shin and Lee, 2020).

CHAPTER 3: USER PROFILES FOR 3D CAD SYSTEMS

As Li and Lu (2014) stated, since the 1980s the working method of 3D clothing simulation systems has been developed as 3D-2D-3D schemes. In other words, to explain the steps in detail, the process starts with pattern design tools in the designer's mind (3D - 2D phase). These 2D patterns are then sewn together to create the garment on a 3D human model (2D - 3D stage). In such a process, creating a 2D pattern requires expertise. It is known that it takes years for a person to become an expert pattern maker. Even the creation of basic clothing, such as t-shirts and skirts, requires the skill of a professional pattern maker. Making pattern in the textile and fashion industry is not handled by fashion designers, because making the pattern of the model while designing clothes restricts the designer's freedom to design. Considering the user base of these 3D programs, it is expected that only fashion designers or pattern makers will be using it. This severely restricts the user base. In order for a fashion designer to be able to complete and design a model in 3D in a 3D CAD program, designer must know professional pattern making, and a pattern maker should know how to design.

Li and Lu (2014) developed a 3D simulation system, which is based on allowing the user to easily produce new models by showing the edges that are suitable to be stitched together in the pattern parts of the ready-made garments (such as the sleeve and the armhole) with different curves or shapes, just like the puzzle logic. According to them, it is necessary to be able to use these systems without requiring much technical knowledge in order to meet customer expectations quickly according to the needs of the changing world or to personalize products from various occupational groups. The most important of this technical knowledge is the pattern experience. Therefore, they argue that it is possible to design a program with a 3D-3D scheme (Li and Lu, 2014). For the ‘Modeling Module of the Garment’ in their article, three fashion designers from the textile industry and many university students with no garment design experience were asked to use their method. In this project, students were also asked to use their proposed CAD system as a discussion portal to make their design requirements aware to designers, and designers were asked to develop the student's design from their professional point of view. After a quick demo, both designers and students can use the software fluently. Student feedback shows that their framework is beneficial for them to discover and show what kind of clothing they really want.

Feedback from the designers suggests that one challenge at the early stage of design is how to inspire the design. And also, their prior work LookStailorX has been successfully used in a variety of apparel businesses. The review from consumers indicates that their work makes the pattern simpler than the traditional methods (Li and Lu, 2014).

3D virtual systems are not only used by designers. At the same time, pattern maker uses 3D virtual sampling systems to control the fit of the garment's pattern with the body and the proportions of the pattern in very detailed and especially panel patterns. This method gives them the opportunity to double check themselves before the last sample is sewn (Spahiu, Shehi and Piperi**,** 2014). According to another study, people who prepared the patterns of the products were trained in 3D CAD software (Shin, 2015). Throughout the study, their interactions with 3D systems were observed. The topics explored during the research are some of the challenges arising from the format differences between 2D and 3D software systems, the efficiency of the integration of 3D virtual prototypes in companies, and feedback on the process of adapting technical users to 3D software (Shin, 2015). These feedbacks are listed as follows:

1- The study of the 3D product creation time has been calculated. It has been observed that every 3D process takes several hours. While the fitting period of a 3D-created product and the order confirmation of the product takes 4 weeks, this period can be extended up to 8 weeks with real sample fitting works performed with traditional methods. A serious decrease in costs is observed in manufacturers whose cost ratio is directly proportional to time, as the sample processes decrease (Shin, 2015).

2- In this study, 3D software users were professionally trained in pattern preparation and 3D Optitex program training. 3D systems have been found to be useful in creating 2D patterns and 3D apparel. At the same time, another comment of the users stated that it is easier to use 3D systems compared to 2D systems. Although it varies from user to user, it took about two and half months for all users to get used to the 3D system and users had some difficulties in this process. Many users have also faced the difficulty of using the 3D CAD system while trying to focus specifically on pattern-related fit issues. Those who experience difficulties in either case is those who have less experience with 2D patterns. They had a hard time trying to understand 2D and 3D interfaces (Shin, 2015).

Li and Lu (2014) stated that this intuitive working model can be experienced quickly and easily for users who do not have technical knowledge about pattern making.
With this new 3D modeling approach proposed by the researchers, it can be easily used by people who do not have any design and pattern skills by using the existing clothing patterns and mixing them together to create new designs.

3.1 Fashion designers as a user profile of 3D virtual technology

While 3D virtual systems are frequently used in industrial design, architecture and various engineering departments, which are other areas of design education, the use of 3D virtual systems is new in Fashion and Textile design departments (Baytar, 2017). Digitalization in the fashion industry is slower than other industries. The garment prototype process is time wasting, costly, due to designer's skills, knowledge, and experience (Papachristou and Bilalis, 2015). However, today's fashion designers have transformed the apparel industry significantly by combining their design processes with 3D virtual sample systems (Hwang and Hahn, 2017). For instance, today's young fashion designers may plan their collections in 3D virtual CAD systems, display their designs through a virtual environment or social media, and then produce a collection on demand (Hwang and Hahn, 2017).
In the apparel industry, the design process of the product depends on the skill and experience of the designer. The first step in creating the garment is the design process. Traditionally, 2D CAD systems are used for this process. This traditional way of working has always caused misunderstandings between the pattern maker and the designer. Either the pattern maker does not read enough or there is a discrepancy between the model and the desired result due to the designer's lack of technical knowledge. According to Hwang and Hahn (2017), it was concluded that designers had to improve their technical knowledge of creating patterns and clothing in order to use 3D virtual CAD systems. It has also been determined that the designers make a more understandable relationship with the pattern maker and other production employees with the 3D virtual sample image they create.

According to Taylor, Unver and Worth (2010), the findings of evaluating the 3D software tools show that in order for fashion designers to successfully learn to design, create, and then simulate fabric and clothing correctly, precise textile details and ‘intelligence'

must be written into plug-ins or used in the 3D modeling software applications. Plug-ins are seen as important artistic tools for developers, designers and animators. The plugins provide the soft dynamics of the fabric surfaces, the form deformations, the simulation properties of the 3D clothing product and the association of the clothing with 3D objects (Spahiu, Shehi and Piperi, 2014).

In order to identify the qualifications of a fashion designer as a user for 3D CAD systems, all stages for creating a 3D product are summarized with the steps of the sample product in VStitcher software.

First of all, the designer must know the garment pattern and know how to apply the style designer wants to design on the pattern. In addition to all this information, the ability to apply pattern on the computer and understand the real scale of measurements is also very important at this stage. The possibility of vectorial operation in 2D pattern CAD systems is available in a simpler way on the 2D screen of 3D CAD systems (Figure 15).

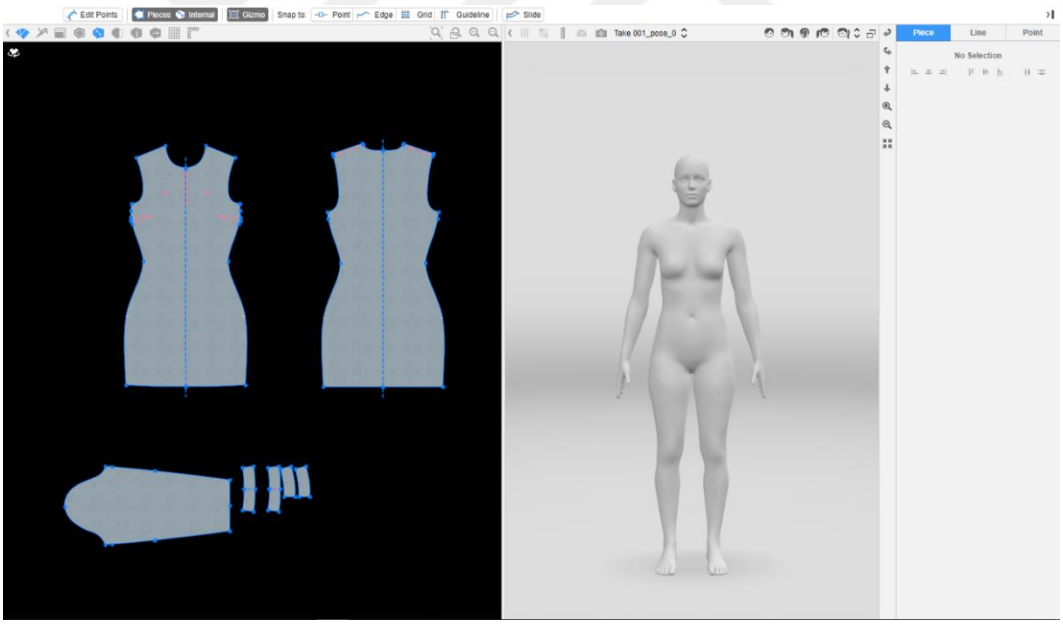

Figure 15. Step 1: Vectorial Operation (Source: Browzwear, 2021)

In the second stage, the 3D designer must make the adjustment on the body in the 3D system according to the pattern knowledge. At this stage, the designer actually guides the software on which pattern part should be when it is worn on the body. While doing this, designer must actively master the ability to place parts on the screen with Gizmo, which is the basis of 3D systems because of Gizmo tool is not usually found in 2D

systems, this tool is available in 3D CAD systems (Figure 16).

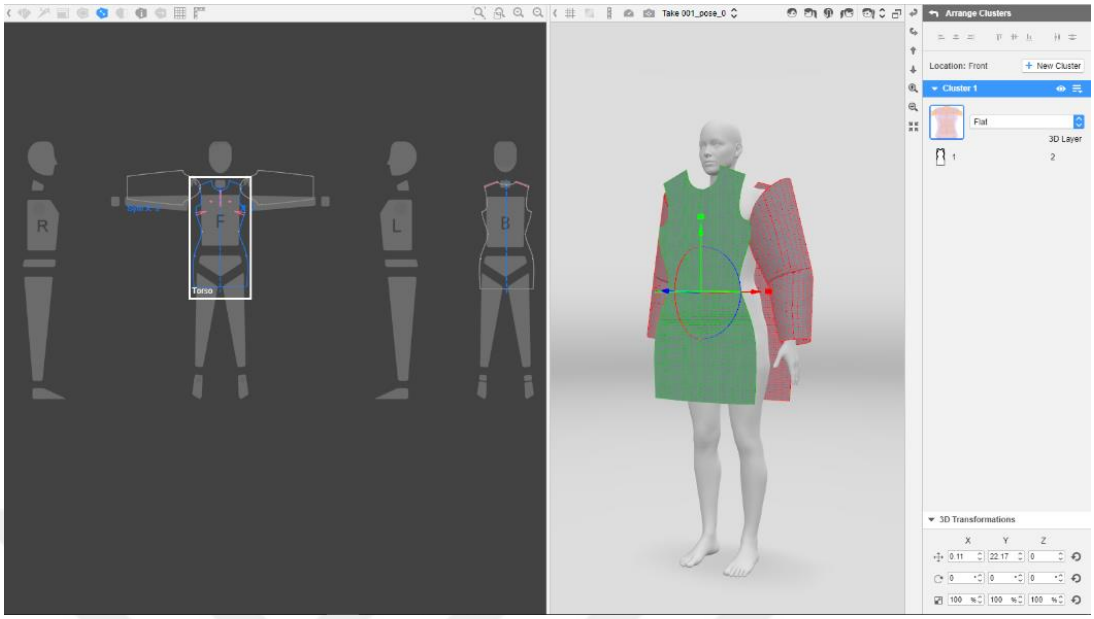

Figure 16. Step 2: Pattern adjustment (Source: Browzwear, 2021)

In the third stage, the designer must have knowledge of sewing as well as pattern knowledge. The designer has to show the system with the help of tools which piece will be sewn where (Figure 17).

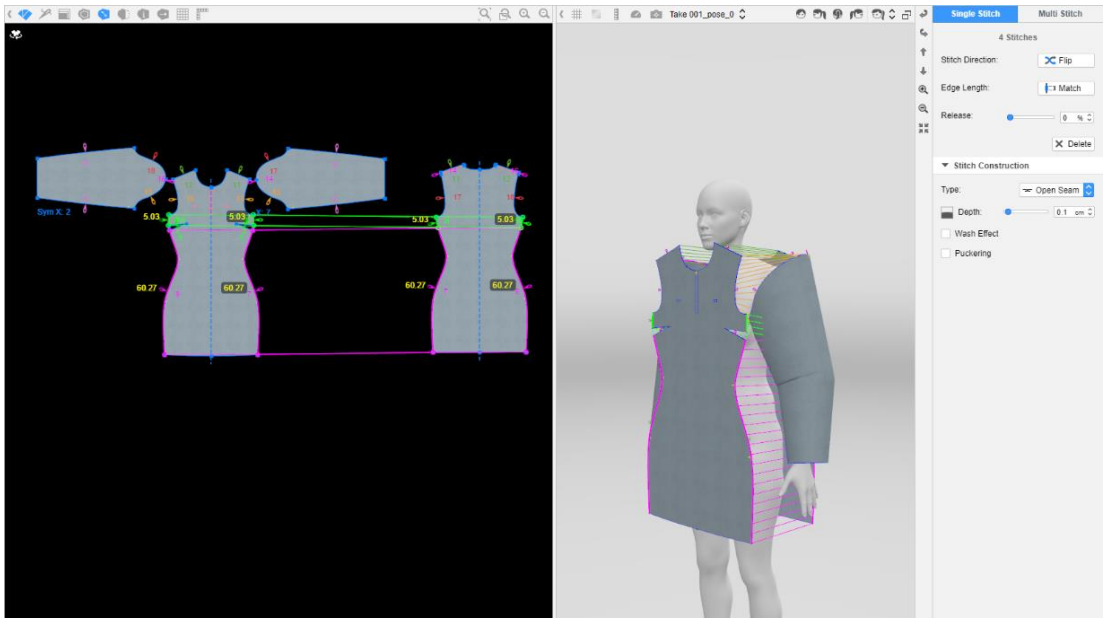

Figure 17. Step 3: Sewing application (Source: Browzwear, 2021)

At fourth stage, the designer chooses the fabrics he/she wants to use and makes sure

that they are in harmony with the model. Designer can choose from a library that is in the 3D system itself and divided according to fabric composition and types. In order for the designer to make these choices, it is expected that they also know technical textile information such as fabric and accessories, rather than focusing on visual design (Figure 18). After making the design phase of the product and the accessory choices, it finishes the simulation on the 3D screen and performs the pinch operations on the model.

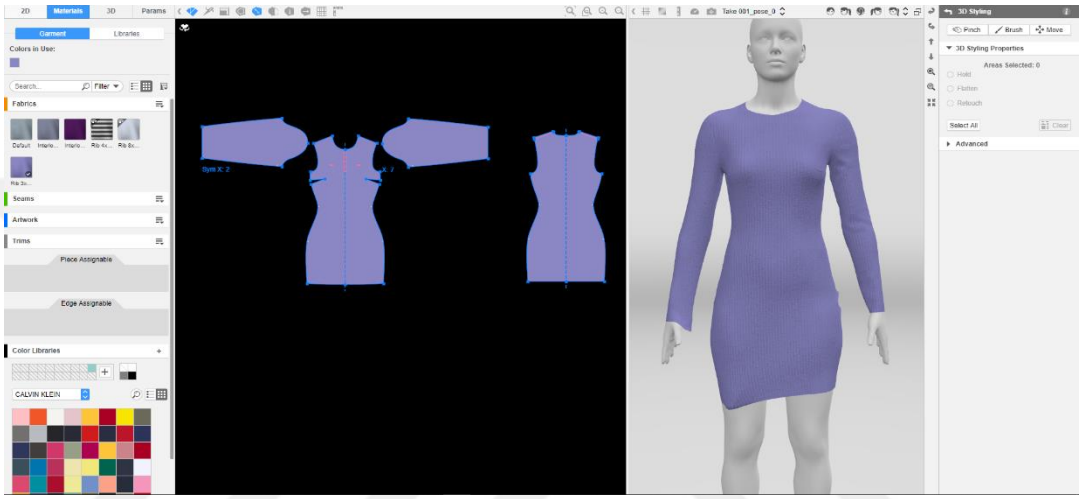

Figure 18. Step 4: Pinch operations (Source: Browzwear, 2021)

The 5th stage, the styling and fit processes, is important to obtain the most aesthetic and correct fit appearance on the body of the designed product. In order to evaluate the correct fit of the product, the compatibility of the dummy with the pattern and the compatibility of the fabric with the pattern and the model should be taken into consideration. It is expected that the designer perceives these evaluations visually after program experience. In order for the designer to gain a fit experience on the digital screen, the model that the designer is working with in the 3D CAD system should actually dress the real product in the same dummy in the 3D system and make a visual comparison of the sewn samples with the virtual samples. 3D CAD systems have some features such as tension map or pressure map to make it easier for users to interpret the correct fit. These features provide the user with the necessary guiding information to make a fit interpretation (Figure 19).

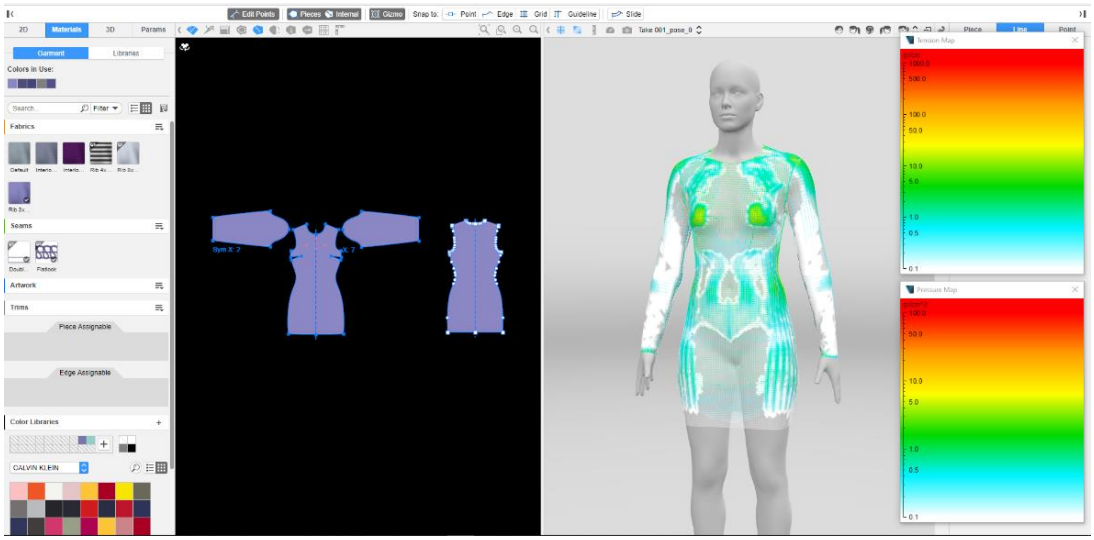

Figure 19. Step 5: The styling and fit processes (Source: Browzwear, 2021)

In the sixth stage, the designer must render the garment after completing the garment and the necessary corrections regarding the fit (Figure 20). This processed image provides a more realistic view of the garment's fabric, accessories and sewing details of the model. At this stage, the fashion designer must know the technical details and features on the render screen, which is a feature of 3D programs (Figure 20,21).

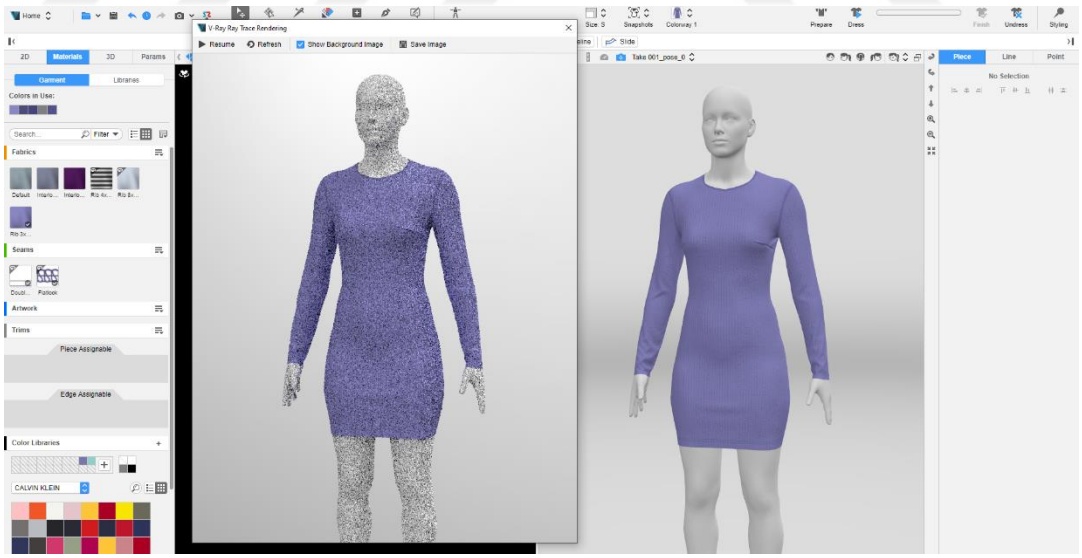

Figure 20. Step 6: Render process (Source: Browzwear, 2021)

Figure 21. Final rendered look (Source: Browzwear, 2021)

3.2 Integrating 3D CAD systems into universities' fashion design curriculum

Designers enter a highly competitive environment after graduation. There is a demand from the textile and fashion industry for students from design-based disciplines to learn and train more about computational design and simulation-based CAD programs (Baytar, 2017). Firms in the sector expect designers who graduate from the fashion design department of universities to be better equipped and able to adapt to the sector quickly (Ryan, 2020). However, the use of 3D modeling as an educational purpose in fashion design lessons has evolved more slowly than in most other areas. Furthermore, few researchers have examined the diverse implications of technology-integrated methods including 3D virtual modeling in student-centered fashion education or 3D simulation as a medium for enhancing fashion design education. For this reason, considering the change created in the apparel industry with the acceleration of digital change, educators need to equip students with digital and technical skills, that is, to

learn 2D and 3D CAD programs in order to enable students to be process and design oriented (Hwang and Hahn, 2017). It can be used as an important tool in fashion classes to measure the fit, design principles, and aesthetics of a garment by encouraging students to digitally test them.

According to the Boorady and Hawley training of pattern preparation to designers will also require them to use 3D simulation systems (Stanley and McKinney, 2016). It will be useful for designers to evaluate the garments they designed with 3D systems on 3D avatars. In addition, creating 2D patterns using 3D systems is a quite new application. 3D CAD systems can bring many new qualifications to fashion design students. Apparel design is a process that takes place sequentially as a result of solving design problems, sample development and application of all these (Baytar, 2017). Samples may need to be prepared for each of these processes, which is costly. It has been observed that 3D virtual systems can reduce the production of 5 prototypes to 2 prototypes (Baytar, 2017).

3D virtual CAD systems continue to spread slowly in the apparel industry and using 3D virtual CAD systems is an investment that will benefit companies. However, the adoption of 3D systems by large textile companies has revealed a large user deficit. For this reason, universities that provide fashion design education must close this education gap in their students. Design students should be trained to use both 2D patterns and 3D simulation CAD tools in line with the industry's expectations.

According to Kolb's Experiential Learning Theory (1984) (Baytar, 2017), human beings learn by doing something. This learning becomes that person's experience. When fashion design students work in 3D virtual systems, they will learn faster and more actively as they receive feedback at every step related to the product (Schanze, 2009). With this learning method, students can be offered the opportunity to explore virtual objects and textile materials. This digital learning becomes a digital process that also improves students 'design skills (Lee and Park, 2016). There is limited research on the inclusion of 3D virtual systems in design education. There are doubts about whether textile materials are transferred to digital media in a completely reliable way (Siersema, 2015). However, 3D systems allow fashion design students to analyze their designs and apply the necessary changes (Baytar, 2017). If these CAD systems are used in prototype-trial samples made in order to see product design and fit problems in fashion design departments, real sample sewing will not be required. In this way, the student will be able to make a faster and more accurate model fit, while

at the same time technically speeding up, it will be able to design more products. To develop 3D virtual prototypes, the user must have a specific information infrastructure. In order to create a 3D virtual product, it is necessary to use 3D virtual apparel systems by using all the necessary data intelligently and systematically bringing them together. While working on this entire inventory, some problems arising from the shortcomings of 3D systems should be approached with a solution-oriented perspective. Unlike other CAD programs, 3D systems work with a different logic. It is necessary to know this separate language for 3D virtual systems. While making new discoveries in the ways of problem solving and going to solution due to some limitations of software, the student's ability to solve problems and approach problems also improves (Dalgarno, 2002). Problem solving ability is essential for learning. It has been determined that the interaction of students with simulation in 3D programs and virtual reality learning environments improve students' problem-solving skills and support them to make different discoveries. The fact that students can see the instant reactions of the garment in the 3D simulation of the pattern changes made on the 2D screen on the interface of the 3D virtual apparel systems, allowing them to intervene in the fit problems instantly. The first criterion is to work a product as realistically as possible in 3D virtual sample systems. It improves the realism perception of the product working in the 3D virtual apparel system by making comparisons with real products while the user works in the virtual system. The visible criteria of this perception of reality are usually when you dress a mannequin with the real product, the position of the fabric on the pattern and on the body. At this stage, a visual comparison is made by looking at the shedding of the fabric and where it causes wrinkles or abundance on the body. The perception of reality in 3D can be developed in students with this method (Lee and Park, 2016). According to Teo and Zhou (Teo and Zhou, 2014), when students discover that they can be more productive in a short time using 3D virtual garment systems, they will want to use this software.

In the research by Ryan (2020) data are obtained from graduates who have completed an Integrated Graduate Internship Program at the Arts University of Bournemouth. Data collection was carried out using a combination of internal knowledge and documents, semi-structured interviews, and an online questionnaire from graduate students in their present workplace or postgraduate studies. As a result of the research of a case study on the expectations of students and the industry, the following findings were determined that the designer should develop in the university before graduation:

- developing advanced digital fashion expertise and skills,
- the importance of interpersonal and communication skills,
- creative application development opportunity and learning experiences (Ryan, 2020).

The effects of 3D virtual sample systems on the product design process have been examined by many researchers. The traditional product creation process and the process of creating products on 3D systems were compared. Not only the processes, but also the comparisons between the resulting real design and the virtual product were experienced. Porterfield and Lamar (2016) stated that 3D virtual sample systems have a multidisciplinary working infrastructure. For this reason, what they especially want to measure while doing the research is the difference between real fitting and virtual fitting. The challenges they determined for the research are related to the modification of avatar proportions, avatar posture modifications, choice of simulated materials, and representation of garment layers. Interviews were conducted with designers and producers who use the 3D virtual sample system to evaluate these challenges, and they benefited from collecting research data through them. As a result of the research, it was concluded that 3D virtual sample systems are the future for designers, and they are suitable for use in verifying the real product. But most designers are still hesitant to trust the system 100 percent. They are more in favor of physically connecting with the real sample. On the other hand, manufacturers have stated that they feel that the trust in the software will increase with the continuous use of 3D virtual sampling systems. It has been concluded that software-induced simulation problems in the 3D simulation process can be solved as long as having experience on 3D systems (Porterfield and Lamar, 2016).

In another study by Baytar (2017), it was examined how much the use of 3D virtual apparel systems in 3 different school projects affects students' skills. Skills specifically measured in research. Students' interactions with 3D systems, to what extent 3D systems develop students' imaginations, and students' problem-solving abilities were examined. In addition, students' tendencies to use 3D systems for evaluating 3D simulation systems and for 2D patterns work were also measured. Students worked on 3 different designs as both real and virtual samples. They used the data of the fabrics they will use and the measurements of the dummies and mannequins that they made fit in the 3D virtual apparel system.

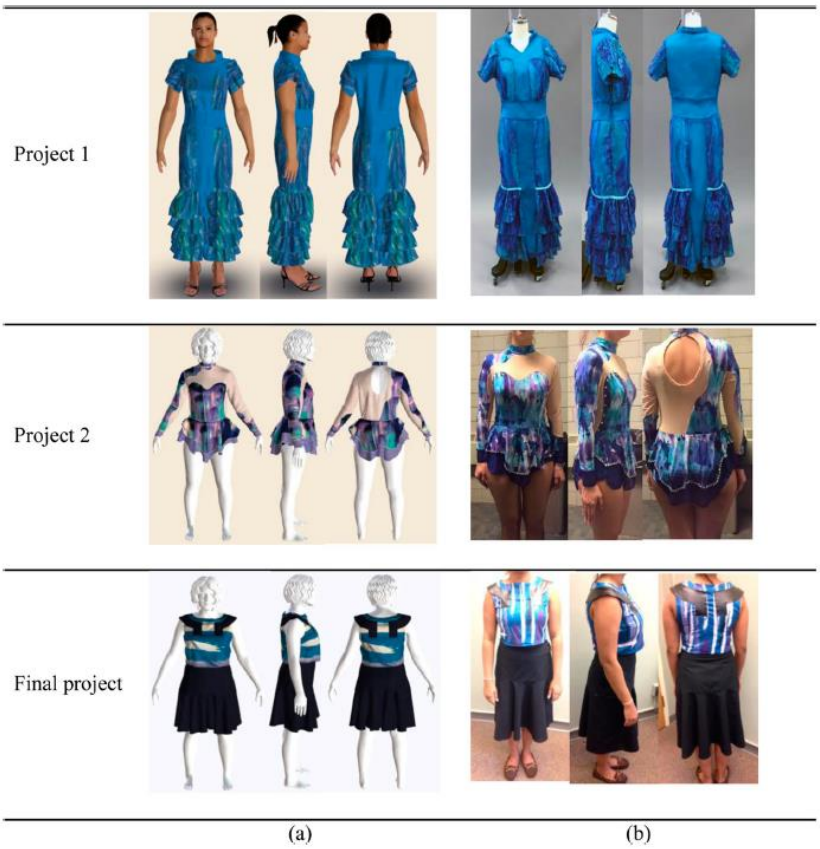

Figure 22. Examples from three projects completed by students. Comparisons between 3D virtual prototypes and actual garments (Source: Baytar, 2017)

As a result of the study (Figure 22), it was observed that as the skills of the students improved, they interacted with 3D virtual systems more easily. By looking at the difference between the first project and the last project, it has been observed that students have an increase in their ability to complete virtual prototypes in a realistic way. Students benefited from the 3D virtual system while working on 2D patterns according to the dimensions of the mannequin, and it was observed that there was an increase in problem solving skills (Baytar, 2017).

CHAPTER 4: THE EFFECT OF THE USE OF 3D VIRTUAL TECHNOLOGY ON APPAREL INDUSTRY AND FASHION DESIGNERS: SURVEY ANALYSIS WITH 3D FASHION DESIGNERS

In this research, an interview is designed in order to evaluate the effect of the use of 3D virtual technology on apparel industry and fashion designers. The interview aims to investigate designers' experiences on the following topics and their thoughts on the effects of 3D virtual systems:

- The opinions of the interview participants about 3D systems were investigated by asking general and sub-questions about their suggestions were also asked to improve 3D virtual sample systems and make their integration into the industry more effective.
- The participants were asked about their ability to use the 3D CAD system and their thoughts on the general user infrastructure.
- Effective use of 3D systems in Turkey and the perspective of the apparel industry in Turkey were questioned. In addition, it is aimed to get information about the effect of 3D systems all over the world.

The interview participants consist of 10 people, 8 females and 2 males, between the ages of 24-48. The most important factors in determining the participants are that they graduated from the fashion design department of universities and can use 3D virtual garment system.

Interview questions are divided into 4 sections and each section have the sub-questions.

- Section 1: An overall background of participants was explored in the first section.
- Section 2: In the second section, the opinions of the participants concerning 3D virtual systems were examined by asking general and sub-questions.
- Section 3: In the third section, the participants were asked about their abilities to use the 3D virtual CAD system and their opinions on the overall user experience were experienced.
- Section 4: In section four, participants were asked about the efficient use of 3D systems in Turkey. Participants were asked for feedback about how to develop

3D simulated sample technologies and improve their adoption into the industry. During the interview, data on the impact of COVID-19 pandemic on the use of 3D virtual systems were also collected.

4.1. Section 1: Demographic information of the interview participants

The interview study was conducted with 10 participants. These participants are between the ages of 24 and 48, 8 females and 2 males, and their experience as a 3D fashion designer in the textile industry varies between 2.5 months and 10 years. The variety of 3D CAD system used by the participants is summarized in Table 2.

Table 2. Software used by the participants

	Browzwear	**Clo**	**Optitex**	**Vidya**
Person 1		✕		
Person 2	✕			
Person 3	✕			
Person 4	✕			
Person 5	✕			
Person 6	✕	✕	✕	✕
Person 7	✕			
Person 8		✕		
Person 9	✕			
Person 10	✕	✕		

4.2. Section 2: Evaluations of 3D virtual sample systems by fashion designers

During the interview, the designers were asked about the problems they experienced while using the 3D CAD system. 3D fashion designers have considered this question from a technical point of view. Clo 3D users explained their problems with the 3D CAD system as the use of the tool is not practical enough in case of instant changes to the design in the CAD system, thus causing a little time wastage while working on a

product. They also stated that computer performance can cause problems in using 3D CAD system. Browzwear and other CAD system users mentioned the problems they experienced while using the CAD system as follows:

- Software-related bugs,
- Limitations in avatar and object development,
- Insufficient online material libraries belonging to the software,
- Being able to capture reality in 3D and understanding fit in 3D CAD systems,
- After completing the 3D garment the styling process of the virtual product, that is, dressing the product properly on the dummy and correcting it takes a long time due to the slowness of the simulation.

The most satisfying feature about 3D virtual sample systems is that designers using Clo 3D can design not only apparel textile products but also different clothing products (shoes, socks, bags, etc.) as a whole look in 3D virtual systems. Designers see as an overall product development in Clo 3D. Fashion designers using Browzwear and other 3D CAD systems mostly gave a common answer for the most satisfying feature of 3D CAD systems, as Browzwear's rendering quality is the closest visual to reality and that it offers the product in maximum reality so that you can make the right fit assessment as a result of pattern fabric compatibility. Participant 3 claimed that the exact same fit and look from a real garment can be achieved in the 3D CAD system by using the fit patterns that have been used for 15 years in the company he works for. In addition, Participants 6, 7 and 10 commented on the accuracy due to the Fabric Analyzer (FAB) (Browzwear, 2021) machine, which is the fabric digital scanning device of 'Browzwear'. This gives more accurate results than the fabric scanning devices of other 3D CAD systems. Participant 5 said about Browzwear that, *'the 3D CAD system I use has a very user-friendly interface'*.

Fashion designers were asked whether they could use the 3D virtual sample system effectively enough. If not, the factors that prevented them from using the software effectively were investigated. 5 out of 10 designers (Participants 2, 3, 7, 9, 10) stated that they could not use the 3D virtual sample system effectively. 3 out of 5 participants (Participants 9, 10, 2) have problems using effectively because the 3D CAD system does not work enough product variety, 1 person (Participant 2) has just started using 3D, another user (Participant 7) stated that she had difficulty in following the current developments in 3D software. Others can use 3D virtual CAD systems effectively (Participant 1, 4, 5, 6, 8). Expectations from the 3D virtual sample system were asked to designers. The satisfaction

level of these expectations was also investigated. Many designers have answered this question differently:

- *'It is among my primary expectations to produce works that are as close to reality as possible, that there is no difference between the 3D and real product when I look at the final product. Because when there is a difference, I question whether I can use the program effectively. Considering that 3D CAD systems depend on many parameters, the current 3D CAD systems meet eighty percent of my expectations.'* (Participant 1)
- *'We have a symmetry feature that exists in the 3D area, I would prefer it to be in the styling stage as well. In addition, the automatic sewing feature in the program during the sewing process of the model could speed up the working process while working on the system. But, of course, there are some points that I think should be improved.'* (Participant 2)
- *'If you apply all the technical details as they should be while working on the product in the system, you will get a realistic result. However, as a suggestion, it is possible to use shortcuts or tools to save time. The method of implementation of the technical specifications can be further shortened.'* (Participant 3)
- *'First of all, there are atmospheric factors such as light, shadow and the environment that affect the result you see when you dress a real sample on a dummy. When you compare the real sample with the sample you created in the virtual environment, the biggest factor is atmosphere and light. These are the biggest factors for your 3D product rendering to be the same as reality with a sample photo image taken in real environment. Therefore, in order to achieve more realistic results, my expectations from the 3D CAD system are improvements in light, shadow and realism in the background, as well as holistic improvements that include the product.'* (Participant 4)
- *'The purpose of using the '3D virtual sample system is to reach the samples as quickly as possible and to use it for saving in sample garment making. My biggest expectation in this direction will be to reflect realism. If you follow the steps correctly while developing a 3D product, you will get realistic results. Existing 3D systems meet 90% of my expectations.'* (Participant 5)
- *'Of course, there are problems that need to be developed in the 3D CAD system, but I do not want to talk about them because they are very technical to mention.*

Therefore, if we need to evaluate it from a different perspective, my expectation is that 3D virtual sample systems will be integrated with automation. It is my biggest expectation that the 3D software will be integrated into the computerized machine and the real fully automated sewing of the products will be realized. With the rapid change in the industry, I think these expectations will come true quickly. My other minimization expectation is that the program will work more practically during the sewing process while designing. To give an example, it would be to apply the pieces to be sewn on each other with a 'drag-and-drop' method with a single tool. There are existing systems, but they are not yet technically sufficient.' (Participant 6)

- *'I think it's mostly a problem with avatars of all 3D virtual sample systems. Perhaps more improvements can be made in this regard. Especially when I am working on product development on underwear, I have problems with fit because the avatars do not reflect the correct proportions or realism. My expectation is that this issue will be resolved.'* (Participant 7)
- *'I don't have any expectations. I can do too many things in 3D CAD.'* (Participant 8)
- *'3D virtual sample systems should include simple design options without the need for Photoshop for visual presentation. There should be more flexible presentation techniques. Existing 3D systems meet some of these expectations. However, you may still need to work in integration with different CAD systems.'* (Participant 9)
- *'I would expect the 3D virtual system to be able to offer a wide range of patterns, fabrics, accessories, sewing techniques that a designer might want to use while in the design phase. At the same time, in the 3D CAD system, the sewing phase could have been in a more automatic system. Current 3D systems do not fully meet these expectations.'* (Participant 10)

The 3D fashion designers who participated in the interview were asked about their most utopian expectations from 3D CAD systems. In response to this question, the designers gave different answers as follows:

- *'It would be very utopian for me if 3D systems could perceive the technical illustration made in 2D and reflect what is in the image as a 3D virtual sample, such as all the colors, sewing details, etc. in the 2D drawing.'* (Participant 1)
- *'It would be a very utopian feature for me if the 3D program would detect the*

vectorial 2D technical drawing and present it to us as a template in the 3D system. Thanks to this feature, we would not need a pattern technician. It would also make our job much easier if the program offered possible standard product arrangement suggestions according to the product type.' (Participant 2)

- *'It would be utopian for me to have the product appear as a hologram on the avatar with a button. In this way, we would have the opportunity to examine the product more closely.'* (Participant 3)
- *'To be able to present a product as a package with maximum reality accessory quality, avatar and maximum reality environmental design.'* (Participant 4)
- *'I have been working as a 3D fashion designer for a very short time and my experience may not be enough to imagine something very utopian. Over time, everything in the program seems utopian. But most of all, I would like to be working in the 3D virtual system with human-look mannequin.'* (Participant 5)
- *'There are 2 important features for me that I think everyone might be interested in. The first of these is the fashion show of the product I created in the 3D system with the support of holograms. Another is that I would like to do digital draping with hologram or VR glasses. I would be excited to be able to go beyond 3D, perhaps feeling the fabric when I touch the product.'* (Participant 6)
- *'I don't have a utopian expectation to be honest, but the thing I hear most from my customers is 'I wish we could scan the photo in a 3D system, and it would be nice if a 3D virtual sample appeared together with the 2D pattern.'* (Participant 7)
- *'I have more utopian expectations during the virtual fashion show stage. The first feature that comes to my mind is Clo 3D integration with Google Maps. Thus, a fashion show can be made at the desired location in 3D.'* (Participant 8)
- *'In "Business to Customer" stores, using holograms or 3D glasses, the model chosen by the customer appears as a hologram with an avatar and presented to the customer in 3D. At this stage, the avatar verbally transfers the fit values that are outside the normal on the body with the 'tension map' feature of the program. With this feature, 3D virtual sample systems appeal to different senses, and it becomes easier to perceive the product.'* (Participant 9)

- *'As a designer, the most exciting feature of the program for me is the virtual fashion show. I think that a more detailed and easy-to-use improvement can be made on the virtual fashion show. I would love to be able to design the virtual fashion show using a single 3D virtual system instead of working integrated with other CAD systems. Depending on the theme of the collection you want to present, it would be very useful for the software to advise me on the walk of the mannequin, the design of the fashion show set and the details of the mannequin selection.'* (Participant 10)

4.3. Section 3: Evaluations regarding the use of 3D CAD system user infrastructure

In this section, when designers were asked who should use this program, 3 out of 10 participants (Participants 2, 4, 9) thought that 3D CAD systems were designed more in line with the ability of designers to use, and if the designers used the 3D program, the 3D system could serve its purpose more. 6 participants (Participants 1, 3, 5, 10, 8, 7) stated that the program can be used by both pattern makers and designers with pattern technical knowledge by separating the features of reflecting pattern fit correctly and designing. The other 1 designer who participated in the interview stated that a new profession group called 3D designer has emerged and this profession requires being both a designer and a pattern maker.

Another question in this section is whether fashion designers' knowledge on how to use the 3D virtual sample system provides them with an advantage over other designers who do not use these systems in the industry. In general, 3D fashion designers answered *'yes'* to this question. In addition, they also made some statements. According to Participant 1, *'A designer has to think about multiple parameters at the same time while using 3D, and with this multi-thinking ability, the designer's ability to design improves'* According to Participant 6, *'When a designer uses the 3D virtual sample system to manage the entire product development process, the designer can stand out by combining his/her fashion design education with his/her practical experience about technical pattern making.'*

In the second part, designers were asked whether there is any area that they feel is missing while using 3D systems. In the continuation of the question, main reasons for these deficiencies were questioned in relation to the fashion design education they have completed at the university. In response to these questions, the designers gave common

answers about their shortcomings. The points that the designers felt were missing are as follows:

- Lack of a broad 2D pattern development knowhow on a variety of products,
- Lack of in-depth fabric and accessory knowledge,
- Lack of experience on Adobe Photoshop and Illustrator programs,
- Lack of knowledge on apparel production process,
- Lack of experience on the 3D virtual sample systems,
- Lack of experience on the use of other 3D programs that support the use of 3D virtual sample system, such as 3Ds Max, Blender etc.

Participants who graduated from the fashion design department expressed that a comprehensive education at the university including material technical knowledge, detailed information on product sewing, as well as CAD training on 3D virtual sample systems and digital pattern application for the industry is of great importance.

4.4. Section 4: Effective use of 3D virtual sample systems in Turkey and in the world, the effects of 3D systems on the textile industry and the integration of these systems into the textile industry

3D fashion designers participating in the interview were asked about their perspectives on the use of 3D virtual systems in textile companies in Turkey. The designers were expected to answer this question based on their personal observations. As a result, the common view of the designers was that 3D systems were not sufficiently adopted when they first started to be used in Turkey. They stated that the major reason for this was the distrust of the 3D virtual sample system. 5 of the interview participants agree about the current situation. Their common view is that the textile industry still has hesitations in accepting and using 3D virtual systems. According to the general participants, Turkish textile companies using the 3D CAD system were generally obliged to use it due to the mandatory rules of the customers they work with. A designer participating in the interview summarized the approach of the Turkish textile industry to 3D virtual systems as follows:

- *'Some textile companies think that the use of the 3D system will never be possible, and these CAD systems cannot reflect the reality, and it is not possible to work in the 3D CAD system of every product type. When you work and present the product types they produce in a 3D system, companies that think*

this way don't find the 3D sample functional. They even argue that real sample garment will be more practical and short-lived. The other thought of the textile companies is that 3D virtual sample systems are the business of the future, but after acquiring the program, they aim to make profit with maximum benefit in a short term. However, technology needs long term investment. Some of textile companies, on the other hand believe that apparel industry will evolve into 3D systems. Some of companies had to buy the 3D system as a result of the pressure of the international customers. All of apparel companies aware of importance of purchasing the 3D CAD system and already started to invest.' (Participant 6)

As another question to the designers, when they consider Turkey as a production country, they were asked for what purpose this virtual sample system should be used the most in the apparel industry in Turkey. As a result of this evaluation, 7 out of 10 participants (Participants 1, 2, 4, 5, 6, 7, 10) commented that textile export companies in Turkey should use a 3D virtual sample system in order to prevent excessive sample consumption, save time, cost and perform accurate fit work. Participants commented that manufacturers working with high value-added product groups and fabrics should use the 3D virtual sample system. The other 3 participants argued that it would be more appropriate for all purposes of the program to make a two-way presentation to the customer for both design, collection presentation and sample fit work, especially in export companies. (Participants3, 8, 9)

Considering the features of 3D virtual sample systems, the interview participants were asked the question of who might need 3D systems more and get efficiency. In this question, the participants answered each phase of the textile industry in the supply chain (Table 3). As seen in the table below, the majority of participants claimed that the vendors and the designers use the 3D system the most.

Table 3. 3D Virtual User

	Customer	Vendor	Source Office	Supplier	Designer	Merchandiser
Person 1	✖				✖	
Person 2		✖				
Person 3					✖	✖
Person 4				✖		
Person 5	✖				✖	
Person 6		✖				
Person 7		✖				
Person 8		✖			✖	
Person 9	✖	✖				
Person 10		✖			✖	

Interview participants were asked whether they think there is enough investment in 3D virtual sample systems. The answer of the participants to this question was that the investment made for 3D virtual sample requests in Turkey is quite insufficient. When the participants evaluated globally the investment in 3D, they answered that more investment was made compared to Turkey, but still not enough.

When grouped, the 3D fashion designers participating in the interview three main ideas for the question as: *'What would you suggest doing to ensure the integration of 3D virtual sampling systems into the textile industry?'*. 4 of the participants believe that 3D CAD systems should be taught in the courses in fashion design departments of universities and that the easiest and fastest integration will be provided by CAD users who are ready for the sector (Participants 10, 7, 4, 6). According to the answers of the other 4 participants, in order to ensure the integration of 3D CAD systems into the textile industry, priority should be given to detailed and frequent information about the 3D virtual sample system within the textile companies and between different departments (Participants 3, 9, 2, 1). One of the participants answered this question from a different perspective as follows: *'We should consider that customer-oriented business model is carried out in export area, production and supply chain and that companies in the industry evolve according to customers. Because of that, easy integration can also occur if 3D CAD systems evolve according to the customer, that is, according to customer demands.'* (Participant 5) Another participant stated that 3D

integration with the textile industry can be realized with the easiest PLM-3D integration. In this way, 3D systems can also be a solution to manufacturing-related problems and these speeds up integration. (Participant 8)

The last question of the interview is How Covid 19 affects the use of 3D CAD systems. First of all, the general comments of all designers to this question are that Covid-19 pandemic has very positive effects on the use and spread of 3D CAD systems. In addition, the opinions of designers, after the sewing real garment processes of textile companies stopped due to the pandemic and the transition to home working office system, 3D CAD systems have started to be used efficiently. Apparel companies that integrated the 3D CAD system before Covid-19 pandemic, became more active in prototype production during the pandemic (Participant 9). Participant 1, on the other hand, added a different additional comment. When the interest in 3D CAD systems increased with Covid-19 pandemic, a new job definition emerged thanks to the lack of 3D CAD users.

CHAPTER 5: DISCUSSION

In this research, different information has been obtained about the purpose of using 3D virtual sample systems in the textile and fashion industry, the requirements for the integration of 3D CAD systems and what the user infrastructures of 3D CAD systems should include. In addition, in line with the information stated by the participants, clear comparisons of CAD systems were achieved.

Interview participants are generally users of Browzwear and Clo 3D software. For this reason, as a result of the user expectations of the questions and the evaluations about the software, differences between the two programs based on the interview participants' comments were evaluated. Here, Browzwear users stated that they preferred the software they used because they found the software more user-friendly compared to other software and the fit of the product is more realistic. On the other hand, Clo 3D can be considered as a more creative platform for designers with its simulation speed, advanced animation features, and the opportunity to design various products that it provides to designers.

The expectations of the users were also examined so that 3D CAD software systems can be developed. With the development of 3D CAD systems, the validity of these systems in the textile industry will increase. The extent of integration between 3D CAD and the textile industry will change.

From the answers given by the participants, the knowledge of the different technical features expected from the programs was obtained. Expectations about these technical features have generally arisen from the expectations that the 3D CAD program can compensate for these deficiencies due to the inadequacy of the pattern and sewing technical knowledge of the users. These expectations are features such as fast and automatic sewing or smart manipulation in the pattern. However, the common view of all 3D fashion designers is that 3D virtual sample systems make the product design process very easy.

Another reason for the lack of confidence that some of the interview participants felt about the 3D CAD system they used is due to the fact that the export companies they work with have a certain product range. In other words, textile export companies, and therefore, 3D fashion designers are working on a limited product range. This situation causes 3D users to use only certain features in the program and not be able to use some

features effectively.

As a result of the literature review, it is seen that in the majority of the research is made on who should be the 3D CAD users are. According to the interview study applied in this thesis, it's seen that, 3D CAD systems are appropriate to be used by fashion designers. However, participants also focused on the qualifications that the users should have, rather than a certain occupational group. These qualifications were technical textile materials, digital pattern creation knowledge, 2D and 3D CAD skills and product design knowledge. Interview participants who graduated from the fashion design department mentioned that digital pattern making, sewing and textile materials knowhow. Could be improved since knowledge of textile materials, good knowledge of 2D patterns and sewing makes a designer qualified.

It is suggested that universities that provide fashion design education in Turkey and all over the world should keep up with the era and technology, and in this direction, they should meet the expectations of the sector by keeping their course contents up to date. Interview participants also suggested that students should be encouraged to follow innovations, learn to be curious, and make an effort to learn. In the literature review, it was also stated that when students learn the 3D CAD system at the university, this could encourage students to learn more. The interview participants who also stated that the 3D CAD system should now be included in the education system, claimed that this can arouse curiosity, together with the 2D CAD systems. In this way, potential student groups who may be interested in this field can be discovered and these students expand the profession of '3D fashion designer' thanks to their personal interests. If a new profession group as '3D fashion designer' occurs in the future, an optional '3D fashion design' subdepartment (option/track) can be opened in the fashion design departments of universities.

According to the interview participants, fashion designers who can use 3D CAD systems are more qualified as fashion designers than those who do not know how to use 3D CAD. Considering that the ease of designing and producing products in the world is facilitated by 3D simulations and various automation systems, fashion designers who can use 3D virtual sample systems in the textile industry can be considered more qualified than designers working with traditional methods. Especially with the Covid-19 pandemic, expectations, material supply methods, services offered, communication methods in the textile industry, as in all industries, have changed beyond the old normal. According to the results of the interview, the new work routine

and the process of working from home, pushed the employees to use the conveniences provided by technology. Covid-19 pandemic has been a very important reason for 3D CAD systems to be a part of the textile industry.

There are many production companies operating in Turkey that export to international brands, especially to Europe and to the U.S. These brands apply some enforcements and standards to export companies for a more sustainable world and producing ecological production. Textile technologies existed before Covid-19 pandemic, and 3D virtual sample systems have been studied for about 20 years, as is known from the literature. Considering all these, the current perspectives of the textile industry in Turkey and the world on the use of 3D virtual sample systems are summarized by the participants of this research as follows. The textile industry is divided into three as perception. Minority companies discovered 3D virtual sample systems before Covid-19 pandemic and thought it as an investment opportunity. Most of them discovered 3D virtual sample systems with Covid-19 pandemic and thought its' necessity than decided to invest. However, these companies expect quick results on short time investment. On the other hand, some companies generally acquired the 3D virtual sample system as a result of the demands of the customer group they work with. The third group is textile companies are those who discovered the 3D CAD system before or after Covid-19 pandemic and could not see the future in any way, and did not trust the software and technology, so they refused to use the 3D CAD system.

The common opinion of the interview participants is that the investment in 3D CAD systems is insufficient in Turkey. Companies investing for 3D virtual systems in Turkey were obliged to use the 3D virtual sample system as a result of the export companies and customer requirement. According to the survey participants, export companies are the ones that need to invest in every aspect. However, 3D CAD systems could not be sufficiently internalized in the textile industry in Turkey due to the feeling of obligation, not voluntariness in these companies. For this reason, unfortunately, it is not a topic that creates excitement in Turkey yet. However, manufacturers in Turkey are in need of being ahead of their customers in other countries, which creates motivation for the use of 3D technologies.

One of the most important questions asked to the participants in the interview study for this thesis is their views on how to integrate 3D virtual sample systems to the textile industry. The majority of the participants said that university education should include 3D CAD systems, and another part of the participants said that textile and apparel

companies that use the 3D CAD system for the real integration should impose this awareness on all their employees. According to one participant, this integration will emerge as a result of the growth of the greatest firms in collaboration with their consumers. However, in order for the integration of 3D virtual sample systems and the textile industry to be permanent and continuous, it should be considered that if all of these views are realized in parallel, a consciousness will be achieved. In the first stage, it is necessary to create a demand for use by the customer for the use of the 3D CAD system and then develop a common awareness and integration with the employees of the companies. By anticipating the demands on the 3D CAD system, user training should be carried out for 3D virtual sample systems in this field in universities or educational institutions. This integration is not a one-sided formation. Those in the textile industry should adapt and contribute to this transformation.

CHAPTER 6: CONCLUSION

With this thesis, the level of application of 3D virtual technology in the field of clothing, the vision of clothing production companies, the effects of 3D virtual sample systems on the apparel industry are examined using qualitative research method.

The integration of virtual sample systems into the textile industry depends on the application of a correct process development method by textile companies. As a result of the literature review, it is seen that overall research have focused more on new sample production process development systems. The most focused subject of research has been the expectation of correct fit and maximum closeness to reality of 3D virtual garment. Depending on the realization of this expectation, the advantages and disadvantages of 3D CAD systems have been determined. The advantages of the 3D CAD system are determined as easy, fast and qualified product design, reduction in sample production time, and reduction in sample production costs. Disadvantages are that 3D virtual sample systems have a suspicion of authenticity and users cannot give up their desire to really touch the textures of the product. In addition, the literature review refers to the differences between 3D software companies and which one is more suitable for designers. As a result, it is summarized that all CAD systems have similar characteristics as well as strengths and weaknesses.

Additionally, studies on the determination of 3D virtual sample systems user background were examined. As a result, users were determined to be mostly fashion designers and a minority of pattern makers.

It has also been concluded that the manufacturing companies do not want to use 3D CAD systems because of the high investment and 3D designer's education costs. Manufacturers are exposed to use 3D virtual systems as a result of the demands of the intermediary offices and customers. On the other hand, it has been determined that the designers are more in touch with the product and have the feeling of working with the real sample.

This study evolved from a desire to understand more about the use of 3D digital design tools in apparel industry. The interview study was applied to people who are exposed to following the latest information and who work as active 3D fashion designers in various fields of the textile industry.

Interviews were conducted with 10 fashion designers graduated from fashion design

related departments of various universities, who are users of the 3D virtual sample system. In-depth interviews allow us to learn the responsibilities of software companies, textile companies and the education system to ensure '3D – Textile industry' integration, to learn the qualifications that 3D CAD users should have, and the current expectations of them from the education system.

As a result of the interview, the factors that prevent the integration of 3D virtual sample systems with the textile industry, the technical problems experienced by the users and the limits regarding the user infrastructure were determined. According to the user suggestions for integration between 3D CAD systems and apparel industry, textile companies should develop a workflow that includes 3D virtual sample systems between their departments and with their customers. Technical problems and utopian expectations from 3D virtual CAD systems were asked to interview participants for 3D software companies to improve themselves. These technical problems are about speed of 3D CAD systems and prevent more realistic product look. As a result, feedbacks were obtained from 3D users for software companies. In addition, it has been concluded that 3D virtual sample systems should be used by people who are equipped with the knowledge of digital pattern making, product creation, sewing, design and textile materials.

Because of the nature of qualitative research, the participants' experiences, thoughts and suggestions were examined in depth with using their own perspectives. Most of the findings in the analysis support the findings in literature review. Participants of interview conveyed their experiences for the integration of 3D CAD and textile industry, and they mentioned about the infrastructure of the 3D CAD user. In addition, 3D virtual sample system users have given a different perspective to the thesis by expressing their technical and utopian expectations from the 3D CAD system.

This thesis highlights what qualifications 3D CAD users should have, what the user feedbacks and utopian expectations for 3D software companies are, and how to integrate 3D virtual sample systems with the textile industry. For future research, more extensive research can be done by focusing on developing textile technologies and the integration of these technologies to the industry not just 3D virtual sample systems but including other technological improvements.

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APPENDICES

Appendix A- Interview Questions

1. Part: An overall background was tried to be found in the first sections.

1.A. Gender?

1.B. What is your age?

1.C. Have you had previous experience working with 3D product development?

1.D. How many years have you been working as a 3D designer in the apparel industry?

1.E. Which 3D software providers do you work with?

2. Part: In the second part, the opinions of the participants about 3D systems were learned by asking general and sub-questions and also it was asked about their suggestions to improve 3D virtual sample systems and make their integration into the industry more effective.

2.A. What is the biggest problem you face while using this software?

2.B. What is the most satisfying feature of the software you use, and, in your opinion, what makes this software unique from other software?

2.C. Can you use the 3D virtual sample system effectively enough? If no, what are the factors that prevent you from using this software effectively?

2.D. What are your expectations from the 3D virtual sample system?

2.E. How much of these expectations do current 3D systems meet?

2.F. What is the most extraordinary feature you expect from 3D virtual system?

3. Part: In the third part, the participants were asked about their ability to use the 3D CAD system and their thoughts on the general user infrastructure.

3.A. Do you think this 3D virtual system should be used by a designer or someone with another background?

3.B. Does the fact that a designer can use the 3D virtual sample system effectively makes that user more qualified than 3D users with other backgrounds?

3.C. As a designer, is there any area you feel lacking while using the 3D system? If yes, what are these?

3.D. Do you think that the area you feel lacking while using the 3D virtual sample system is related to your education in fashion design at university?

4. Part: In section 4, effective use of 3D systems in Turkey and interview questions for the participants to learn the perspective of the apparel sector in Turkey were asked about these systems. In addition, it is aimed to get information about the effect of 3D systems all over the world.

4.A. What do you think about the approaches of textile companies in Turkey on the use of 3D virtual sample systems?

4.B. If you evaluate Turkey as a country of manufacturer, in the apparel industry in Turkey, most of you think it should be used for what purpose this virtual sample system?

4.C. In your opinion, which link of the chain in the apparel industry in the world may need this program more: vendor, source office, supplier, customer, designer?

4.D. Do you think there is enough investment in 3D virtual sample systems?

4.E. What would you suggest to do ensure the integration of 3D virtual sampling systems into the textile industry?

4.F. What impact do you think Covid 19 has had on the use of 3D virtual sampling systems?