ABSTRACT

WOOD, MEREDITH. Exploring Textile and Apparel Students' Experiences with 3D CAD: A Qualitative Study (Under the direction of Dr. Anne Porterfield).

3D CAD programs offer opportunities for sustainable development and innovation in the textile and apparel industry. As interest in 3D CAD programs for textiles and apparel increases, there are heightened expectations that students entering the industry workforce will possess knowledge and skills pertaining to 3D CAD software. However, there is a lack of research on the use of 3D CAD software in academic contexts. Consequently, there is a lack of information on how to effectively support instructors and curriculum designers in teaching 3D CAD technologies. It is necessary to investigate academia's role in shaping textile and apparel students' awareness, attitudes, acceptance of, and proficiency with 3D CAD to inform pedagogical practices to support training and industry readiness. The purpose of this study was to explore textile and apparel students' awareness of 3D CAD technologies in the industry, the nature of their acceptance of the technology, and their views on motivating and demotivating factors related to their learning of the programs.

A qualitative approach was selected to address this emerging area of study. In-depth interviews were carried out with ten textile and apparel students enrolled at a university in the Southeastern United States. Both Social Cognitive Theory (SCT) (Bandura, 1986) and the extended Technology Acceptance Model (TAM2) (Venkatesh & Davis, 2000) were used to develop the interview guide. Interview questions designed to elicit responses about students' experiences with learning and use of software were informed by SCT, while questions relating to students' prior experiences with software, their views on industry expectations, software user-friendliness and use advantages were based on TAM2. Responses were analyzed for categories

to define students’ experiences with 3D CAD for textiles and apparel in academic contexts and those categories were organized into themes to suggest how academia might better support student success through curriculum design.

Categories emerging from the data pointed largely to individual differences between students. These differences were noted in how participant responses varied within the categories of instructional context, project specifications, instructional modes and resources, personal career goals, general comfort with 3D CAD, individual learning differences, level of experience within academic program, and industry awareness when discussing their attitudes toward 3D CAD. Despite these differences, common themes shed light on areas where students struggle and how those could be addressed. Responses pointed to the importance of understanding how students practice software in and out of the classroom, as well as how they view software systems in terms of user-friendliness and industry expectations. The study indicates that academic institutions should intensify efforts to understand students’ individual experiences, attitudes, and acceptance of 3D CAD programs to enable the development and implementation of organizational support measures to enhance students' learning, as well as their awareness, perceptions, and acceptance of 3D CAD for textiles and apparel.

Exploring Textile and Apparel Students' Experiences with 3D CAD: A Qualitative Study

by

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A thesis submitted to the Graduate Faculty of
North Carolina State University
in Partial fulfillment of the
requirements for the degree of
Master of Science

Textiles

Raleigh, North Carolina
2024

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DEDICATION

To my Opa, who exemplified ingenuity and honesty, thank you for teaching me to be resourceful and compassionate.

BIOGRAPHY

Meredith Wood is a M.S. Textiles student at the Wilson College of Textiles through North Carolina State University, where she previously earned a Bachelor of Science in Fashion and Textile Management. Her research interests focus on 3D CAD and STEM education. Meredith has prior work experiences in apparel product development and design, including leading the development of a private apparel label for an athletic brand. Additionally, she has held research and teaching assistantships, where she gained experience as a lab technician and facilitated student learning with 3D CAD.

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Chapter One: Introduction

Background of the Study

The rise of networked personal computers in the early 1980s provided creative engineers with the necessary computer power and digital connectivity to utilize graphics and computer-aided design (CAD) programs, contributing to the digitalization of numerous industries (Horváth & Vroom, 2015). As computer technology advanced, CAD software became instrumental in aiding design, creation, modification, analysis, and optimization across industries, holding strategic importance for businesses and contributing to their commercial success (García et al., 2007; Horváth & Vroom, 2015). The need for collaborative design methods led to the development of online CAD systems, which enabled designers to instantly share data and rapidly communicate (Choi, 2022; Horváth & Vroom, 2015). The numerous benefits of CAD programs led to their increased adoption and implementation in high-tech industries, including the textile and apparel industry (Choi, 2022; Horváth & Vroom, 2015).

Over the past few decades, the apparel industry has undergone a significant transformation, shifting from a traditional labor-intensive sector to a highly automated and computer-aided one, driven by the increased adoption of CAD (Istook, 2000; Papahristou & Bilalis, 2017). In the apparel industry, CAD technologies can be implemented in planning, design, product development, and manufacturing processes and offer significant benefits, including increased productivity, interoperation, standardization, cost reductions, shorter lead times, and improved product quality (Dal Forno et al., 2023; García et al., 2007; Horváth & Vroom, 2015; Istook, 2000; Papachristou et al., 2019). The cost-saving benefits of CAD technologies have become essential for the apparel industry to secure a competitive advantage (Papachristou et al., 2019). Furthermore, the utilization of CAD has accelerated the speed and accuracy of new apparel product development while decreasing the manpower required to complete product development processes (Istook, 2000). By using CAD, designers can create and adjust designs rapidly in real-time, without restricting creativity, while facilitating improved communication and integration between product development systems (Papachristou et al., 2019).

Three-dimensional (3D) CAD technologies have brought advancements to various industries such as automotive, aerospace, architecture, and industrial design, and are now providing new opportunities for apparel designers (Dal Forno et al., 2023; Papahristou & Bilalis, 2016b). Initially, commercial CAD software in the textile and apparel industry focused on digitally replicating 2D physical design processes, such as pattern making, with less focus on the development of simulation technologies (Istook, 2000; Papahristou & Bilalis, 2017). However, the need for technological advancement in 3D simulation led to the development of updated CAD algorithms for 3D, enabling innovative use methods for apparel development and design systems (Dal Forno et al., 2023; Istook, 2000; Papahristou & Bilalis, 2017). In the apparel industry, the use of virtual technology, CAD programs, and 3D modeling has a multitude of potential benefits, such as reduced product development time and costs, as well as improved fit evaluation. Specifically, the implementation of 3D CAD programs in the textile and apparel industry offers additional benefits including enhanced product visualization, decision making, and communication, digital prototyping and fit evaluation through simulation, process and supply chain optimization, and reductions in waste, time, and costs (De Silva, Rupasinghe, & Apeagyei, 2019; Hodges et al., 2020; Papahristou & Bilalis, 2016a; Papahristou & Bilalis, 2016b; Papahristou & Bilalis, 2017; Rosca et al., 2023). An overview of 3D CAD software in the textile and apparel industry is included within the literature review for additional context.

The integration of 3D CAD technologies is increasing and is transforming the apparel product development and design process; however, 3D CAD software is not as widely used in the textile and apparel industry as traditional CAD programs (Dal Forno et al., 2023; Istook, 2000; Papahristou & Bilalis, 2017; Papahristou & Bilalis, 2016b; Segonds et al., 2014). Although 3D CAD programs for textile and apparel development have become valued in industry and academia due to their advantages, the apparel industry has been slow to adopt and integrate 3D visualization tools into its processes (Dal Forno et al., 2023; Hodges et al., 2020; Papahristou & Bilalis, 2017).

There are a variety of compounding factors that have been attributed to the slow adoption and implementation of 3D CAD programs in the textile and apparel industry. Researchers have reported a limited understanding of digital technologies among industry professionals (Tepe & Koohnavard, 2023). Despite increasing adoption of advanced technologies in the apparel industry and academia, there is a deficiency in computer literacy among working textile technologists and a lack of enthusiasm to learn emerging computer technologies (Garde, 2003; Tepe & Koohnavard, 2023). This reluctance may be attributed to factors such as time constraints, limited access to computer technology, and inadequate training support (Garde, 2003).

Learning 3D CAD software for textile and apparel development is not easy, and its complexity is exaggerated by the need for a wide range of skills and techniques, including computer skills, mental capacity, spatial visualization skills, physical coordination, and substantial effort (García et al., 2007; Segonds et al., 2014). 3D apparel CAD heavily relies on 2D patterns, which are assembled to create 3D garments. Even in 3D environments, accurate 2D patterns and appropriate grading are necessary, and designs are dictated by constraints and the experience of the pattern maker (Papahristou & Bilalis, 2017; Segonds et al., 2014). As a result, individuals learning new CAD programs can experience feelings of stress, frustration, and real panic, especially when learning unfamiliar programs (García et al., 2007; Hodges et al., 2020). Additionally, the design of the CAD software itself has a direct impact on teaching and learning processes. Training in CAD software, including those that facilitate 3D simulations, is further complicated by the fact that the technology advances continually (Papachristou et al., 2019). There is a need for continuous training on CAD and 3D technologies due to the rapid obsolescence of acquired knowledge, resulting in users experiencing stress (García et al., 2007).

Statement of the Problem

Despite the textile and apparel industry's reluctance to change and slow implementation of 3D CAD programs, apparel companies prioritize industry-relevant technology knowledge, skills, and experience in their hiring and promotion decisions, making 3D and virtual technologies, especially those that support virtual prototyping, indispensable to workers in the field (Hodges et al., 2020). As interest in 3D apparel CAD increases, there are heightened expectations that students entering the industry workforce will possess knowledge and skills related to 3D CAD software, as well as the capability to consistently learn and integrate new technologies (Hodges et al., 2020). Graduates with apparel design degrees are anticipated to have a comprehensive understanding of various functions related to 3D apparel CAD, including spatial visualization, rapid prototyping, and fitting (Hodges et al., 2020). Universities have adopted 3D CAD software to keep students current with the industry, where CAD skills and expertise are essential, and to meet demands for digitization (Papachristou et al., 2019; Tepe & Koohnavard, 2023). Textile and apparel educators aim to teach digital design and prototyping skills using 3D CAD software (Tepe & Koohnavard, 2023). Furthermore, academic institutions strive to improve and support apparel development processes with rapid prototyping, sustainable ideologies, design innovation, and communication between designers, as well as to effectively prepare students to participate in industry jobs by incorporating 3D CAD software for textiles and apparel into their curricula (Hodges et al., 2020; Kushwaha et al., 2018; Nayak & Padhy, 2015; Papachristou et al., 2019; Rosca et al., 2023; Tepe & Koohnavard, 2023). Students benefit from learning 3D software in terms of career readiness and professional development (Hodges et al., 2020). Overall, there is a need to further understand textile and apparel students' experiences with 3D CAD software in academic contexts, as well as their acceptance of these technologies, to enhance educational approaches and better equip future workers with the necessary skills and knowledge to integrate technology seamlessly into their workflows.

Statement of Purpose

The purpose of this study was to examine textile and apparel students' awareness of 3D CAD technologies in the industry, the nature of their acceptance of the technology, and their views on motivating and demotivating factors related to their learning of the programs. A qualitative methodology was selected to explore this emerging area of research.

Research Questions

The following research questions were defined to guide the research:

RQ.1 What is the extent of students' awareness of 3D Computer-Aided Design (CAD) technologies in the textile and apparel industry, and what are their perceptions of the industry's expectations regarding their proficiency in 3D CAD skills?

RQ.2 What is the nature of students' acceptance of 3D CAD technologies used in the apparel industry?

RQ.3 What do students feel motivates or demotivates them to learn or use 3D CAD technologies relevant to the textile and apparel industry?

Chapter Two: Literature Review

The purpose of this study was to examine textile and apparel students' awareness of 3D CAD technologies in the industry, the nature of their acceptance of the technology, and their views on motivating and demotivating factors related to their learning of the programs. A literature review was conducted, covering fundamental and critical publications, current research, and other relevant findings to assess research practices related to technology for textile and apparel development and to gain an understanding of the characteristics and processes associated with learning 3D CAD and the pedagogical practices employed.

The following review of the literature focuses on three areas. The first section provides an overview of 3D CAD software in the textile and apparel industry to introduce and contextualize the technology for the purpose of this study. The second section explores 3D CAD in education, examining valuable research studies related to its teaching and learning within academic settings. The final section introduces theories related to understanding learning and attitudes toward technology, which have influenced the development of this study.

Overview of 3D CAD

The following section of the literature review explores apparel product development challenges, and how 3D apparel CAD can address those challenges, highlighting its advancements and benefits within the industry. It also reviews relevant research on the current state of 3D apparel CAD adoption and implementation, emphasizing its barriers, and identifying gaps and opportunities for academic research. This section aims to contextualize the significance of 3D apparel CAD as an emerging technology and the need for focused research on 3D apparel CAD education.

Challenges and Opportunities, Apparel Product Development

3D apparel CAD programs can significantly aid and enhance the complex apparel product development and design process, addressing unique challenges within the industry. The need for skilled labor and the iterative optimization trial and error processes in product development amplify the industry's complexity (Brocker, 2023; Nayak & Padhy, 2015; Papachristou et al., 2019). Apparel product development and design involve numerous stages, requiring extensive personnel, time, and financial resources, and result in substantial waste and pollution (Brocker, 2023; Istook, 2000; Nayak & Padhy, 2015; Papahristou & Bilalis, 2016a; Papahristou & Bilalis, 2016b; Papachristou et al., 2019; Segonds et al., 2014). During apparel development and design processes, numerous iterations refine garment prototypes through collaboration between manufacturers and product development teams (Nayak & Padhy, 2015; Papachristou et al., 2019).

Effective cross-communication is crucial throughout the apparel product development process, but the higher the number of individuals involved, the more challenging it is to maintain a continuous and efficient flow of communication (Hodges et al., 2020; Papahristou & Bilalis, 2016a; Papahristou & Bilalis, 2016b) Product development is iterative and costly, with many designs discarded before production, and the textile and apparel industry is increasingly challenged to reduce production costs and increase sustainability measures (Brocker, 2023; Istook, 2000; Nayak & Padhy, 2015; Papahristou & Bilalis, 2016a; Papahristou & Bilalis, 2016b). Apparel product development teams face pressure to communicate online faster and readdress their approach to prototyping, sizing, and fitting (Papahristou & Bilalis, 2016a; Papahristou & Bilalis, 2016b). Furthermore, apparel producers feel that traditional product development methods are too demanding and time-consuming, making it difficult to respond to consumers' needs in a timely manner (Istook, 2000; Papahristou & Bilalis, 2016a; Papahristou & Bilalis, 2016b). Product development teams have begun adopting more collaborative and virtualized approaches as part of the apparel industry's digital transformation, and the use and implementation of innovative technologies within the industry continue to increase (Segonds et al., 2014; Tepe & Koohnavard, 2023). The implementation of 3D technologies in apparel design and product development can help to optimize and automate production processes, reduce waste, promote sustainability, transparency, and social responsibility, create efficient channels of communication, support mass customization, and reduce time to market (Avadanei et al., 2022; Brocker, 2023; Gazzola et al., 2020; Horváth & Vroom, 2015; Istook, 2000; Papahristou & Bilalis, 2017; Rosca et al., 2023).

Advancements and Benefits of 3D Apparel CAD

With technological advancements becoming increasingly integrated into the apparel industry, apparel product development teams are now working more collaboratively and virtually, leading to the prevalence of digital prototyping in design and product development processes (Papahristou & Bilalis, 2017; Papachristou et al., 2019; Segonds et al., 2014). The adoption and integration of 3D CAD software in apparel design and development processes offers numerous advantages to the industry. 3D CAD tools enable designers to create full-scale 3D garment models, which can be automatically converted to two-dimensions (2D) for manufacturing purposes (Hodges et al., 2020; Nayak & Padhy, 2015; Papahristou & Bilalis, 2017). Virtual prototyping allows for instant assessment of pattern modifications in 3D, leading to reduced product development time and increased cost savings (Hodges et al., 2020). In 3D apparel prototyping and virtual fitting, digital product simulation with accurate fiber and fabric characteristics enables efficient virtual communication and data monitoring throughout the product development process, reducing the need for physical fabric or garment samples (Hodges et al., 2020; Nayak & Padhy, 2015; Papahristou & Bilalis, 2017; Papahristou & Bilalis, 2016b). 3D simulation software, such as Lotta and CLO3D, allows users to directly model 3D garments on virtual avatars, enabling rapid design changes without the need for numerous fit sessions on human models or repetitive manual processes (Papahristou & Bilalis, 2017). Additionally, 3D body-scanning technology can generate digital models onto which garments can be draped and fitted within 3D CAD programs, providing qualitative information and revealing potential fit issues (Nayak & Padhy, 2015; Papahristou & Bilalis, 2017). This process is often referred to as virtual fitting.

3D CAD technology, in tandem with 3D body-scanning technology, allows for precise adjustments tailored to individuals who may not conform to standard target group sizes and shapes, enhancing the potential of customization in apparel design (Papahristou & Bilalis, 2017). Consequently, virtual prototyping has become a valuable tool for verifying designs and streamlining product development processes and timelines (Segonds et al., 2014; Papahristou & Bilalis, 2016b). 3D CAD programs offer designers opportunities to create fashion experiences that exclusively exist in digital environments, independent of physical end products (Tepe & Koohnavard, 2023). These technological advancements have revolutionized the apparel industry, providing designers with innovative tools to enhance design processes and create compelling virtual fashion experiences. Moreover, digital assets created with 3D CAD technology find applications in apparel merchandising and marketing (Papahristou & Bilalis, 2016b).

3D Apparel CAD Research Gaps and Opportunities

This section of the literature review discusses relevant research on understanding 3D apparel CAD within the industry, its adoption and implementation, benefits, and the need and opportunity for additional research on the technology. Research conducted by Dal Forno et al. (2023), Rosca et al. (2023), and Hoque et al. (2021) focused on understanding technology adoption and implementation within the textile and apparel industry. These studies revealed an increasing interest in 3D CAD software, slow rates of 3D CAD adoption and implementation, a lack of industry- and academic-specific research pertaining to 3D CAD training, adoption, and implementation, and a need for further research on 3D CAD training and adoption within academia. The findings highlight the necessity for additional research on the adoption and implementation of 3D CAD software in the textile and apparel industry, making it crucial to conduct studies that explore students' acceptance, attitudes, and learning of 3D CAD within academic settings to gain a comprehensive understanding of its adoption and implementation in the industry.

Hoque et al.'s (2021) findings suggest that there is a need for research on technology adoption in the textile and apparel industry to identify its determinants and related trends and established the need for exploration on technology adoption in relation to textile and apparel education. Hoque et al. (2021) conducted a bibliometric literature review with a focus on technology adoption in the apparel or fashion industry. They discovered that literature on industry-specific technology adoption is scarce, and the authors suggested that an apparel industry-specific review is necessary to identify determinants and research trends (Hoque et al., 2021). The researchers also found that research on the determinants of technology adoption from an organizational and industry-specific perspective is lacking (Hoque et al., 2021). Moreover, Hoque et al. (2021) identified that research on the determinants of technology adoption within the textile and apparel industry from organizational perspectives is sparse, suggesting a need for research exploring textile technology adoption in academic organizations.

Through a systematic literature review, Dal Forno et al. (2023) identified 3D CAD software as an emerging technology within the textile and apparel industry. The results of their review suggested there is a need for research on 3D apparel CAD in academic contexts, as well as in relation to students' experiences, to understand how those factors impact the technology's adoption and implementation in the industry. It was found that simulation technologies, such as those that support virtual prototyping and 3D modeling, have been utilized in product development, manufacturing, and retailing in the apparel industry and that their use is beneficial to processes and products, but implementation is still in its early stages (Dal Forno et al., 2023). Despite growing interest in 3D CAD technologies, the textile and apparel industry was found to have a slow adoption rate of innovative technologies in comparison to other industries despite the significant advantages of 3D CAD (Dal Forno et al., 2023). Dal Forno et al. (2023) found that studies are needed in the textile and apparel industry to address its reluctance to change and slow technology adoption rate. Furthermore, Dal Forno et al. (2023) identified virtual prototyping and simulation technologies, which encompass 3D CAD programs for apparel development, among the least commonly implemented innovative technologies in the textile and apparel industry. Dal Forno et al.'s (2023) findings indicated that research is needed specifically regarding the adoption and implementation of virtual prototyping, simulation, and 3D CAD technologies within the textile and apparel industry. Furthermore, the results of the study suggested that research should be conducted on how academic institutions play a role in the adoption of 3D CAD technologies through student development, and whether students' experiences with 3D CAD in educational organizations impact their adopting of the technologies.

Rosca et al. (2023) examined the use of 3D CAD software in apparel development and design practices and found that implementation was lacking because of limited 3D CAD training and learning infrastructure, further pointing to the need for research on students' acceptance, attitudes, and learning of 3D CAD within academic settings. The researchers also identified 3D CAD software in the textile and apparel industry as an emerging innovative technology that would support digitization of the textile and apparel industry, enhance design production and design processes, and enable sustainable and socially responsible industry practice (Rosca et al., 2023). A process and model were developed for garment production sheet creation with the use of CAD software with 3D visualization capabilities and conclusions were made (Rosca et al., 2023). The process model was created with consideration for the method of creating a production sheet, which included the garment pattern, and the steps required to complete those steps with the use of Gemini CAD, a Lectra Company. Rosca et al. (2023) stated that the purpose of digital technologies is to assist the apparel industry in overcoming real challenges through its influence on industry practices. However, the process of a full digital transformation within the apparel industry is a multistage process that must start with the development of strong infrastructure (Rosca et al., 2023).

Their findings suggested that it is necessary to carry out further research regarding how academia can support the development of the infrastructure required for the textile and apparel industry to continue its digital transformation through informing and educating the future workforce about digital technologies. Rosca et al. (2023) posited that it is crucial to develop foundations for 3D design implementation and train a “digitally skilled workforce”, and only then could an effective framework for digital product development be carried out (p. 104). The findings indicate that it is necessary for employees in the apparel industry to be proficient in using digital technologies and that 3D CAD for apparel is fundamental to the success of furthering the digital revolution and advancement of the apparel industry (Rosca et al., 2023, p. 104). Subsequently, there is a need to understand the pedagogical practices for 3D CAD currently utilized within academia and the learning experiences of students with those technologies so that enhanced educational methods can be carried out to aid in the adoption and implementation of 3D CAD within industry contexts.

Researching 3D CAD in Education

This section of the literature review discusses research that provides valuable insight to the 3D apparel CAD education, as well as those that exemplify the need for additional research on the technology in academic contexts and relevant methodologies that have supported the development of the current study.

Understanding Academia's Role in Adoption and Implementation

Although Papahristou and Bilalis's study was conducted in 2017, the findings provide valuable insight to understanding academic perspectives on the adoption and implementation of 3D CAD software for textile and apparel development and design and underscores the need for research on 3D CAD software education, students' experiences, and their attitudes toward learning and using the technologies. The findings emphasized the importance of 3D CAD proficiency in the textile and apparel industry and indicated that 3D CAD skill is required to obtain the full benefits associated with its implementation. The researchers investigated the extent of 3D CAD implementation among adopters and the challenges, opportunities, and obstacles that must be addressed for digital prototyping to enhance business processes in an integrated manner (Papahristou & Bilalis, 2017). It was found that the textile and apparel industry must focus on the development of 3D CAD training, proficiency, and skill to harness the benefits provided by the technology.

Papahristou and Bilalis (2017) identified individuals who would be affected by the implementation of 3D prototyping technology and grouped them by their position within the textile and apparel industry, resulting in the following 4 groups: (1) Technology providers-vendors; (2) Managers-executives-professional users; (3) Entrepreneurs-independent user; (4) Academics. These groups were utilized to recruit a purposive sample and the researchers selected 100 experts for participation in their study (Papahristou & Bilalis, 2017). A total of 43 relatively unstructured interviews were conducted with experts from four different backgrounds in the textile and apparel industry (Papahristou & Bilalis, 2017). The results from the first-hand interviews were presented alongside secondary data (Papahristou & Bilalis, 2017). The researchers identified numerous perceived advantages, disadvantages, and barriers associated with the implementation and use of 3D and virtual prototyping technologies in the apparel industry (Papahristou & Bilalis, 2017).

The benefits of implementing 3D apparel programs were found to include the need for fewer samples, faster prototyping, the ability to achieve higher quality apparel prototypes more quickly, and enhanced decision making, collaboration, and technical understanding (Papahristou & Bilalis, 2017). Other notable advantages included collision detection, such as that offered by CLO3D, realism, and high-quality fabric and precise cut simulation when parameters are adjusted appropriately (Papahristou & Bilalis, 2017). Although aspects of 3D CAD fabric and cut simulations were identified by the researchers as an advantage of using 3D CAD software for textiles and apparel, the findings indicate that users must have enough skill and knowledge to achieve high-quality simulations. This finding highlighted the importance of 3D CAD proficiency within the textile and apparel industry and indicates 3D CAD skill is necessary to receive the full benefits associated with implementation.

Papahristou and Bilalis (2017) discovered that participant groups identified different advantages associated with the use and implementation of 3D CAD programs for apparel. This finding suggested that individual differences, such as job relevancy or personal goals, impacted the formation of individual perceptions and attitudes toward 3D CAD technologies in the apparel industry. However, it was found that each participant category believed 3D CAD was advantageous to textile and apparel product development and design processes due to its ability to increase the speed at which those processes are navigated and completed (Papahristou & Bilalis, 2017).

Participants were asked to further discuss the advantages of 3D CAD in terms of process speed and the findings illustrated that the proficient use of 3D CAD programs for apparel requires technical design skills (Papahristou& Bilalis, 2017). Papahristou and Bilalis, (2017) found that the amount of time required to complete apparel customization tasks with 3D CAD programs was dependent on the product complexity, meaning less time is required to make garment alterations that result in simple apparel items in comparison to more complex apparel items. It was discussed that the process of design alterations can be achieved quickly with 3D CAD if users are provided with basic block patterns and the appropriately sized 3D avatar (Papahristou & Bilalis, 2017). This finding and discussion suggested that users are capable of quickly completing simple apparel design alterations with 3D CAD software but may require more time to complete complex garment alterations due to limited understandings of and skill with technical apparel design techniques. Moreover, it should be considered that 3D CAD may be easier to learn and use for individuals who have technical apparel design skills.

Similarly, it was found that the time required to produce a variation of an apparel design with 3D CAD software was dependent on the design complexity and users' proficiency with the program and technical apparel design skill (Papahristou & Bilalis, 2017). Participants discussed that design variations could be produced quickly with the use of 3D CAD software but the production of design variations through pattern alterations required more time to complete (Papahristou & Bilalis, 2017). This finding similarly points to a need for understanding skills acquisition in the context of 3D apparel CAD.

In additional findings, some 3D professional users mentioned that experienced users would be able to adjust designs more quickly than non-experienced designers (Papahristou & Bilalis, 2017). This finding indicates the importance of prior experience in relation to how easy 3D CAD programs are to use and further suggests that there is a need to understand how 3D CAD users acquire technical apparel design skills.

Papahristou and Bilalis (2017) also asked participants to discuss the disadvantages of 3D prototyping technologies for apparel. Vendors of 3D technologies believed the biggest disadvantage of 3D virtual prototyping programs had to do with the difficulty of implementation and adoption, which they felt was unrelated to the software itself and, instead, had to do with the type of individual who chooses to use them and dedicate their time and effort to the adoption process (Papahristou & Bilalis, 2017). Papahristou and Bilalis (2017) cited the CEO of Browzwear, who asserted that implementing 3D virtual prototyping technology requires persistence and perseverance (p. 5). Papahristou and Bilalis's (2017) findings and discussion indicate that one of the difficulties of adopting and implementing 3D CAD for textiles and apparel has to do with whether individuals will showcase perseverance and effort to gain knowledge and competencies surrounding the adoption process.

Independent users of digital prototyping technologies reported that the solutions' accuracy levels are not at the level needed for industry and attributed this disadvantage to the lack of adoption and implementation (Papahristou & Bilalis, 2017). Expert users of 3D prototyping technologies in academia stated that the implementation of 3D and virtual prototyping technologies is obstructed by the lack of 3D CAD users who have technical apparel design knowledge and skill (Papahristou & Bilalis, 2017). These findings suggest that 3D CAD training must support the development of program proficiency alongside traditional apparel design techniques and skills. It was also found that those in academia were concerned with the amount of time required to learn digital prototyping technologies and the insufficiency of the tools when used by individuals with amateur skillsets (Papahristou & Bilalis, 2017). Participants in academia noted that the needed skills to effectively and efficiently use the technology were often ignored in higher education courses run by non-technologists, and unsuccessfully taught by educators who lacked experience and were fearful of change (Papahristou & Bilalis, 2017). Academic users' perceptions of learning 3D CAD for textiles and apparel and their thoughts on the pedagogical approaches to teaching them indicate a need for the development and improvement of educational support and teaching of 3D CAD. The disadvantages reported by expert users of digital prototyping technologies in academia suggest that more research should be done to identify the skills necessary to the use digital prototyping tools, and to assess the instructional methods and practices used in teaching them.

The researchers' findings provided an understanding of industry proficiency expectations and academia's role in supporting 3D apparel CAD adoption and implementation, demonstrating the need for future research on the technologies in academic contexts. The methodology chosen by the researchers also proved to be an effective means of gaining comprehensive insights into professional attitudes and beliefs related to 3D apparel CAD through interviews. Papahristou and Bilalis' (2017) study exemplified that interview methods can be used to effectively assess participant attitudes and beliefs.

Academic Limitations in Educating 3D Apparel CAD

Papachristou et al. (2019) acknowledged increasing digital prototyping processes within the textile and apparel industry because of digitalization and the need to ameliorate traditional product development processes. However, additional skills and tools are required to integrate innovative technologies in the textile and apparel industry (Papachristou et al., 2019). The researchers stated that CAD technologies have become instrumental to the success and advancement of the textile and apparel industry, and academic institutions have incorporated CAD programs for pattern making and 3D software into their curricula in response to the need for high-skilled designers and engineers (Papachristou et al., 2019). 3D CAD implementation in academic institutions for textiles and apparel was found to be limited though, especially in comparison to universities for engineering and industrial design, and despite its proven educational benefits (Papachristou et al., 2019).

Papachristou et al. (2019) discussed that CAD implementation within academia is hindered by the high costs associated with licensed software and the rapid obsolescence of technologies (Papachristou et al., 2019). Considering this, the researchers suggested that academic institutions investigate the capabilities, complexities, and learning processes of open-source software (OSS) for textiles and apparel (Papachristou et al., 2019). The purpose of their study was to compare the usability of four OSS that could support digital garment prototyping and examine whether the programs supported learning processes associated with textile and apparel development and design in comparison to two licensed CAD programs (Papachristou et al., 2019).

The study was conducted in an academic context, where fourth-year students were introduced to the four OSSs and two licensed CAD programs and were selected for participation based on their ability to efficiently use each program (Papachristou et al., 2019). Participants were required to develop ten different style variations from the same block pattern with each of the selected programs (Papachristou et al., 2019). The usability of the programs was determined by comparing the development times for each style and program (Papachristou et al., 2019).

Papachristou et al. (2019) found that OSS for textile and apparel development and design was not yet sufficient to perform as effectively as licensed CAD programs or to fully support student learning. The researchers stated that academic institutions should further their efforts in preparing students for the industry workforce by implementing experiential learning opportunities based in industry contexts (Papachristou et al., 2019). Although this study did not find evidence in support of OSS for textile and apparel education, a similar study that evaluated and compared 2D CAD and 3D CAD programs could prove to be beneficial in enhancing digital apparel design education. Additionally, further research on 3D CAD programs and effective pedagogical approaches could encourage academic adoption and support student development as needed for future employment.

Innovations in 3D Apparel CAD Education

In a 2023 study conducted by Tepe and Koohnavard, it was determined that increasing industry digitalization requires the development of innovative practices for digital fashion design and distribution. Tepe and Koohnavard (2023) found that 3D CAD programs are primarily implemented and taught in academia as a digital design tool utilized to produce a physical product, and heavily connected to developing physical skillsets and practices. When employed in that way, 3D CAD programs can improve apparel development processes through rapid prototyping, supporting sustainability, and enhancing communication (Tepe & Koohnavard, 2023). However, Tepe and Koohnavard (2023) suggested that it could be advantageous for academia to approach the use of digital tools as means of creating digital end products and experiences and expose students to opportunities outside of creating physical garments through digital means. Specifically, they discussed the opportunity to create digital fashions that do not rely on commodification, functionality, and wearability (Tepe & Koohnavard, 2023). The minority of academic fashion institutions utilize approaches that instruct and encourage the use of CAD tools for the purpose of achieving an entirely digital outcome (Tepe & Koohnavard, 2023). Tepe and Koohnavard (2023) stated that, amongst the textile and apparel industry's digitalization, there is a need for research on the implementation of digital design tools and the development of related use methods. They also suggested that understanding the limitations of how academia employs the use of digital technologies within digital contexts might inform fashion design strategies that are contemporary and more considerate of a variety of design disciplines (Tepe & Koohnavard, 2023). Tepe and Koohnavard (2023) analyzed digital fashion design through an interdisciplinary lens and specifically inspected the digital game design industry as a possible contributor of methodology, practices, and skillsets. They conducted in-depth interviews to determine the strategies used in the fashion industry to approach digital tools and environments, and to suggest how fashion design education can adapt in response to fashion and digital game design industry expert's perspectives. Participants consisted of nine industry experts from the fashion and digital game design industries and they were asked to share their experiences, motives, and opinions (Tepe & Koohnavard, 2023). Participant responses were used to conduct a thematic analysis and identify patterns and meanings within the data (Tepe & Koohnavard, 2023). Interviews lasted approximately forty minutes and a total of eight questions were asked (Tepe & Koohnavard, 2023).

Tepe and Koohnavard (2023) found that each participant believed there is a need for designers who can “mediate” between fashion and digital game design, which was discussed in relation to the increasing design collaboration between the two industries (Tepe & Koohnavard, 2023, p. 41). It was also discovered that fashion designers and those who participated in fashion and game design perceived that individuals in leading fashion design positions lack understanding of digital technologies, resulting in the apparel industry’s limited participation in hybrid design practice and engagement with digital technologies (Tepe & Koohnavard, 2023, p. 38 & 41). All participant groups thought smaller companies in fashion and game design industries could participate in hybrid design practices or collaborations but lacked the financial capacity to do so, while larger companies had the necessary financial means but were inhibited by set structures and roles (Tepe & Koohnavard, 2023).

Tepe and Koohnavard (2023) found that, for the fashion industry to support emerging hybrid designers, higher education for fashion must adapt to a variety of digital technologies and practices that involve nontraditional outcomes and functions of garment design. To do so, Tepe and Koohnavard (2023) stated that textile and apparel academia needs trained educators who have experience with hybrid design practices and numerous digital technologies along with those that support fashion design. Tepe and Koohnavard (2023) suggested that fashion educators with such experience would establish greater compatibility between technologies and file formats as well as encourage design that is not limited to specific end-uses or disciplines. It was mentioned that students could benefit from learning general tools and applications of digital technologies, such that it would help students adjust to changing digital technology implementations as the fashion industry continues to become more digitalized (Tepe & Koohnavard, 2023).

Tepe and Koohnavard's (2023) research suggested that fashion education must increase students' knowledge of digital tools and aspects of co-creation for future designers to participate in hybrid design practices and be able to adapt to the changing digital environment of the fashion industry. It was suggested that establishing hybrid design practices in fashion education would increase students' knowledge of digital technologies, improve their skillsets, encourage collaborative workflows, and ultimately provide future fashion designers with greater opportunities across design fields and disciplines (Tepe & Koohnavard, 2023). The methodology adopted by Tepe and Koohnavard (2023) demonstrated a comprehensive exploration of industry professionals perceptions of fashion design education, ensuring that their research population was accurately represented. The researchers were able to gain a deeper understanding of industry professionals opinions on design education and made valuable implications for academic enhancement, however it is important to understand students perspectives and experiences to advance and implement effective education in fashion design. Considering the emerging nature of 3D apparel CAD it is crucial to investigate students experiences and perceptions of the technology.

Understanding 3D Apparel CAD Teaching and Learning

A study conducted by Hodges et al. (2020) provided valuable insight to the teaching and learning of 3D CAD technologies in the textile and apparel industry. The need for their study was identified through evaluating research literature on the textile and apparel industry and in academia which showed that 3D CAD technologies were becoming increasingly attractive within the apparel industry and that students in apparel programs will be required to be skilled in using them upon graduation, especially for virtual prototyping processes (Hodges et al., 2020). Simultaneously, there is a need to understand the teaching and learning of 3D CAD programs (Hodges et al., 2020). The study aimed develop a method for teaching 3D CAD that focuses on industry relevancy. The researchers examined the training results to understand the needs of students as learners of the technology (Hodges et al., 2020). Hodges et al. (2020) emphasized that proper educational practices for 3D CAD have not been identified or thoroughly assessed within the literature and that their study aimed to address that gap.

Conceptual Framework. The researchers conducted a study to assess students' attitudes toward 3D CAD programs and to determine which skills were important for learning the software (Hodges et al., 2020). The study was developed using Kirkpatrick's Training Evaluation model to understand students' learning outcomes and evaluate teaching methods (Kirkpatrick, 1994, as cited in Hodges et al., 2020, p. 121). Assessments were made based on the model's depiction of the Training Evaluation process, which includes the following:

> (1*) reaction*, or the response to the training event (e.g. satisfaction, engagement); (2) *learning*, or the degree to which objectives for training were met (e.g. knowledge, skills, abilities); (3) *behaviour*, which refers to the extent to which knowledge and skills are applied; and (4) *results* of the training for achieving broader organisational or training goals (Kirkpatrick, 1994, as cited in Hodges et al., 2020, p. 121).

The researchers acknowledged that the Training Evaluation model was developed to assess and evaluate teaching methods quantitatively; however, they argued that individuals' unique experiences must be considered when examining learning due to its highly subjective nature (Hodges et al., 2020). As such, the researchers chose to explore the third and fourth level of the Training Evaluation model, behavior and results, qualitatively (Hodges et al., 2020). The researchers examined reaction and learning, the first and second levels of the Training Evaluation model, with comparisons of pre- and post-test scores, which were also used to measure and compare attitude toward the technology, skill development, and to assess spatial visualization skill (Hodges et al., 2020). Pre- and post-test development, scales, and qualitative assessment procedures are discussed further in the following section.

Methodology. A three-phased mixed methods approach was utilized to assess students' attitudes toward 3D CAD and the skills important in learning them (Hodges et al., 2020). The sample population consisted of students who were enrolled in a freshman and sophomore level apparel course at a large university in the Southeastern US (Hodges et al., 2020).

During the first phase of the study, the students were introduced to a popular 3D CAD software by industry professionals during their course period. The second phase of the study involved a two-week training period where the students were taught how to use the same 3D CAD program. Due to the nature of the course, students had limited experience with 3D apparel CAD or apparel prototyping (Hodges et al., 2020). One week prior to students' introduction to the 3D CAD software and training, a pre-test was distributed to measure attitude toward the technology, skill development, and to assess spatial visualization skill (Hodges et al., 2020). Attitude and skill were measured with the use of a seven-point Likert scale and spatial visualization skill was evaluated with a paper-folding test (Hodges et al., 2020). In addition to the typical paper-test assessment, participants were asked to match images of 2D garment patterns to a 3D depiction of the completed garment, both of which were used to quantitatively assess and compare spatial visualization skill (Hodges et al., 2020).

Following the two-week training period, a post-test was distributed that consisted of the same measures as the pre-test and an additional seven open-ended questions that prompted students to reflect on their learning experience and evaluate the teaching approach (Hodges et al., 2020). The third phase of the study involved in-depth interviews for the purpose of gaining a broader understanding of students' experiences (Hodges et al., 2020). Of the participant group, forty completed the pre- and post-tests and the responses were analyzed to form the results of the study. In total, fifteen in-depth interviews were conducted with participants who had also completed the pre- and post-tests and the interview data was analyzed and interpreted (Hodges et al., 2020).

Findings. Hodges et al. (2020) found that students' reported attitudes toward virtual technology improved positively, and skill increased significantly from the pre-test to post-test. Additionally, the researchers found that students spatial visualization skills increased significantly when pre- and post-test scores were compared (Hodges et al., 2020). These findings suggest that students' attitudes toward 3D CAD should increase as knowledge increases, indicating that students with more knowledge of 3D CAD should have higher levels of acceptance toward the technologies.

Three themes were identified from the qualitative data which were related to and included the following: "achieving personal learning goals", "understanding professional expectations", and "relating to future career goals" (Hodges et al., 2020, p. 125). The theme of achieving personal learning goals included responses that were related to beliefs that the software could enhance and improve individuals learning processes with textile and apparel development and design and included aspects of the challenges faced by students during the learning process (Hodges et al., 2020). Although responses did indicate that there were some feelings of frustration and difficulties that came along with the software learning, the responses indicated that students believed this to be a normal part of learning something new (Hodges et al., 2020). Moreover, responses indicated that students were able to overcome the barriers associated with learning 3D CAD due to their interests and motivations, and that students who felt positively about their learning experience became more confident in their learning capabilities with programs for textiles and apparel (Hodges et al., 2020). Further research should be conducted to evaluate pedagogical practice for 3D CAD software in the textile and apparel industry in relation to SCT and self-efficacy theories to further understand the nature of their attitudes and learning experiences with the technologies.

Students' understandings of professional expectations were related to the framing of the software introduction, which was presented as an industry related learning opportunity (Hodges et al., 2020). The software was introduced to students by an industry professional who discussed the software's applications and advantages within their company and the overall industry, which highlighted the importance of virtual prototyping proficiency for students' future careers. Due to the industry framing, students found the 3D CAD software and subsequent training to be valuable and important and they related the knowledge to real-world settings (Hodges et al., 2020). These findings point to the value of framing learning from practical and industry perspectives (Hodges et al., 2020). The results suggested that students' awareness of industry expectations, trends, and use applications of 3D apparel CAD is an important source of and influence on their attitudes and interests toward the programs, and their motivations to learn them. Many students from both merchandising and design related majors related the learning of the software to their overall future career goals (Hodges et al., 2020). Students' responses indicated that they believed learning the software would enhance their performance in jobs such as fashion design and buying (Hodges et al., 2020). Other responses indicated that students with non-design specific career goals felt that learning the 3D CAD software would enhance their ability to understand the design process and the limitations faced by designers (Hodges et al., 2020).

Conclusions and Implications. Hodges et al. (2020) concluded that their findings indicated challenges and benefits associated with learning 3D CAD software in the textile and apparel industry. One of the most commonly reported challenges associated with learning 3D CAD software was the time required to learn the full capabilities of the program (Hodges et al., 2020). It was found that students felt time to explore the program was limited (Hodges et al., 2020). Practice with the 3D CAD program was found to be the most important aspect of the learning process that students reported (Hodges et al., 2020). In the context of this study, practice was understood as the enactment of behaviors that result in skill development (Hodges et al., 2020). It was also found that students appreciated the learning processes being closely related to industry practice, which enhanced their overall learning experiences (Hodges et al., 2020). The researchers believed that having the programs be introduced by industry partners allowed students to more closely associate the use of the programs with their future career goals (Hodges et al., 2020). Another important finding was that students' motivations to learn the programs were related to the personal career goals in the textile and apparel industry (Hodges et al., 2020). Using in-depth interviews, the researchers were able to acquire an understanding of students experiences with 3D CAD, and assess behavior and results, demonstrating the effectiveness of this approach. Additional research is needed to understand students' learning experiences and attitudes toward 3D apparel CAD technology to thoroughly interpret and address their academic needs.

Spatial Visualization Enhanced with 3D Apparel CAD

Park et al.'s (2011) study involved the use of 3D CAD software as an instructional method for the successful development of apparel design students' spatial visualization skills and as means of understanding the technologies effectiveness in academic settings. The researchers found that 3D CAD programs can be used as an effective instruction tool in the development of students' spatial visualization skill but its potential within pedagogical practice was hindered by technological limitations (Park et al., 2011). The study provided valuable insight into the use and implementation of 3D CAD software in textile and apparel design education and serves as a guide for the development and execution of future research on 3D CAD use in textile and apparel pedagogy (Park et al., 2011).

The use of 3D CAD in the effective development of apparel students' spatial visualization skill was of particular interest because those skills are required in understanding how 2D patternmaking translates into 3D garments and for students to successfully participate in the evolving landscape of the textile and apparel industry workforce (Park et al., 2011). The methodology consisted of three instruction methods delivered sequentially to 23 apparel design students over one day (Park et al., 2011). The sample population was comprised of apparel design students enrolled in an introductory level patternmaking course to reduce prior training effects on the results of the study, which was carried out during the eighth week of semester to prepare students with basic foundations in patternmaking (Park et al., 2011). 3D CAD instruction was provided to students as the second phase of instruction because the researchers' aim was to assess the effectiveness of 3D CAD instruction as a supplemental learning tool and not to assess it as a means to replace traditional educational practice in textile and apparel academia (Park et al., 2011).

Lecture was the first stage of instruction, which lasted one hour, and a lecturer taught patternmaking techniques (Park et al., 2011). Following the lecture, students were shown instructional videos that consisted of 3D CAD simulation animations of 2D apparel pattern, their arrangement onto a 3D avatar, the creation of digital stitch relationships, and final simulations of the garment (Park et al., 2011). Three 3D apparel simulation videos were shown for two different sleeve variations, a petal and bishop sleeve, and a godet skirt (Park et al., 2011). These designs were selected to as demonstration and exercise marital for students participating in the study because they were previously identified as challenging to visualize by students who had taken the same introduction patternmaking course within years prior (Park et al., 2011). The third and final instruction method was studio practice of paper patternmaking (Park et al., 2011).

Students' visualization skills were assessed after each instruction method with the use of notch-matching tests on the same apparel designs involved in the instruction methods (Park et al., 2011). The notch-matching tests were used as tool to evaluate students' spatial visualization skill (Park et al., 2011). Students' perceptions of 3D CAD software implementation as an educational tool were assessed following the second phase of instruction and their evaluation of each teaching method was collected upon the completion of the third instruction phase, both of which were measured with a seven-point Likert scale (Park et al., 2011).

Apart from one notch-matching question related to the godet skirt, it was found that the percentage of correct responses increased across each instruction method and proved that 3D CAD software, specifically in the form of animated instruction videos, was an effective means to develop students' spatial visualization skills (Park et al., 2011). Park et al. (2011) argued that the sandwiching of 3D CAD instruction between lecture and patternmaking practice "boosted the students' learning curves positively" (p. 514). It was also found through the analysis of students' evaluations of 3D CAD software as an instructional method that students felt more positively about the benefits provided by 3D CAD software use than they did about their use and performance with using the programs (Park et al., 2011). Overall, students reported positive perceptions of all three instruction methods, but 3D CAD software instruction methods were perceived to be the least efficient in the development of their spatial visualization skills (Park et al., 2011). These findings indicate that 3D CAD instruction methods can be operationalized within academic settings to improve students' spatial visualization skills and students expressed optimism toward the use of 3D CAD in education, however they also indicate that students do not feel as positively regarding their level of learning with the use of 3D CAD software (Park et al., 2011).

Park et al.'s (2011) findings and study limitations support the need for further research on students' experiences with learning and perceptions of 3D CAD software in the textile and apparel industry. The finding that students were not satisfied with their level of learning with 3D CAD software provides support the need of research that evaluates the current pedagogical implementations of 3D CAD software in the textile and apparel education, as well as to examine students' perceptions and attitudes toward their training and learning with the technologies (Park et al., 2011). The study suggests that additional research on students' experiences and attitudes related to 3D apparel CAD education is required to develop and implement teaching practices that are not only effective, but satisfactory to students to support their overall and continued learning.

Creativity Enhanced with 3D Apparel CAD

In a 2014 study, Chang (2014) found that 3D CAD education can significantly benefit students' creative thinking and design abilities and proved that 3D CAD implementation within academia can enhance the design skills of students in creative fields. Chang (2014) posited that 3D CAD software can be used to improve spatial visualization skill, as demonstrated by Park et al. (2011), and the communication of creative ideas, but that research was necessary to determine the impact of 3D CAD on students' creativity in academic settings. To address this need, the researcher conducted a study to examine the correlation between students' spatial visualization skill and creativity, the impact of 3D CAD software of students' creativity, and the impact of 3D CAD software on students' creativity in relation to their existing spatial visualization skill levels (Chang, 2014). The participants of this study consisted of 349 high school students from Taiwan, who were randomly assigned to the experimental or control groups (Chang, 2014). Students in the experimental group were instructed with 3D CAD and the students in the control group received traditional design education without the use of 3D CAD (Chang, 2014). Both methods of instruction guided students toward the same end goal, which was to develop "a single chair from a personal creative design" (Chang, 2014, p. 401).

The study adopted previously developed and supported measurement scales for spatial visualization skill and creative performance (Kang, 2006, as cited in Chang, 2014). The scale used by the researcher to assess spatial visualization skill consisted of "spatial orientation, plane-rotation spatial ability, graphic-to-spatial visualization ability, and spatial perception" sub-scales (Chang, 2014, p. 400). Creative performance was measured in terms of "novelty, resolution, and functionality" (Chang, 2014, p. 400). The research design included the use of pre- and post-tests, which were given before and after design instruction to both the experimental and control groups (Chang, 2014). The pre-test was used to measure students' spatial visualization skill and creative performance to understand the various abilities of students in terms of spatial visualization skill and creativity prior to design instruction (Chang, 2014). Following the design instruction, the resulting designs of students were assessed in terms of creative performance with the same measurement scale used in the pre-test and were considered the post-test scores (Chang, 2014). Spatial visualization skill was not measured for comparison across pre- and post-tests because it has been found and supported within literature that 3D CAD education improves students' spatial visualization skill, and the researcher's aim was to assess the impact of 3D CAD education on students' creativity, to evaluate the impact across spatial visualization skill, and to understand differences in creative performance in relation to existing spatial visualization skill (Chang, 2014).

It was found that students' spatial visualization skill and creative performance were moderately and positively correlated (Chang, 2014). Chang (2014) argued that individuals with higher spatial visualization skill can think more creatively. It was also found that 3D CAD education improved students' overall creative ability, with significant impacts on design aesthetics (Chang, 2014). Due to this, it was posited that 3D CAD implementation in academic settings can positively improve students' design visualization and aesthetics in terms of creativity, as well as positively influence creative thinking overall (Chang, 2014). Another notable finding from this research study was that students' with higher spatial visualization skill levels had higher creative performance scores when taught 3D CAD in comparison to students' with lower spatial visualization skill levels who were taught 3D CAD (Chang, 2014). However, the results of this study indicate that 3D CAD education can enhance creative performance regardless of students' existing spatial visualization skill (Chang, 2014). The overall findings of the study suggest that 3D CAD education significantly influences students' creative thinking and creative design outcomes (Chang, 2014). A similar research design could be employed in the context of textile and apparel education to assess the impact of 3D CAD learning on students' creativity and design outcomes.

Patternmaking Education with 3D Apparel CAD

Baytar (2018) conducted a study to assess students' skill development with a proposed approach to teaching patternmaking with 3D CAD software, as well as to investigate their perceptions of 3D CAD. This study offered significant perspective in understanding textile and apparel education with 3D CAD software and its impact on students' skill and attitudes toward 3D CAD technology (Baytar, 2018). The researcher identified increasing industry demand for education that involves patternmaking training with the use of 3D CAD software and highlighted the need for research on the technologies' use and usefulness within academic settings and its ability to support student learning (Baytar, 2018). It was argued that 3D CAD adoption and implementation in the textile and apparel industry was dependent on educating designers to be proficient in 2D and 3D apparel design techniques, and that effective skill development with 3D CAD would positively influence users' perceptions of software performance over time (Baytar, 2018). For their study, Baytar (2018) specifically examined the development of students' skills in relation to interaction, imagination, and problem solving and assessed how apparel design students' perceptions of the software's performance and their intentions to use the software evolved through education on patternmaking with 3D CAD software over the course of a 16-week long semester.

The proposed method for teaching patternmaking with 3D CAD was employed during an upper-level patternmaking course for students who had previously learned patternmaking foundations in a prerequisite course (Baytar, 2018). The sample population consisted of 32 apparel design students who were enrolled at a large Midwestern University. Data was collected from 16 students each from two semesters and analyzed to address the research questions (Baytar, 2018). The course structure involved four weeks of instruction that covered basic tools and skills for 2D patternmaking and three weeks of 3D related instruction (Baytar, 2018). Over the course of seven weeks, students were required to complete six assignments and six quizzes, followed by three large projects (Baytar, 2018). The projects were designed to methodically improve student skills methodically and required students to create virtual and physical garment samples (Baytar, 2018). During the first project, students designed dresses, completed virtual and physical fit testing, and created digital fabric assets that closely matched their physical fabrics (Baytar, 2018). Students made themselves active wear garments for the second project with the use body-scanning technology to create avatar files (Baytar, 2018). The final project required students to work in pairs to create a garment that fit a hypothetical client's preferences and body shape, which was also provided to them as an avatar file within the 3D CAD software using 3D body-scanning technology (Baytar, 2018).

A mixed-methods research design was utilized to examine students' skill development in 3D CAD, their perceptions of the software performance, and their 3D CAD use intentions (Baytar, 2018). Prior to their software use, students completed a pre-test which was then readministered as post-tests following each project (Baytar, 2018). The tests included 17 measurement items to evaluate students' interaction, imagining (visualization), and problem-solving skills with 3D CAD software, perceptions of the software performance, and intention to use, as well as two open-ended questions that collected students' thoughts on what they believed they knew about 3D prototyping and how they thought 3D prototyping would help their patternmaking skills (Baytar, 2018). The 17 measurements items used a seven-point Likert scale with 1 being strongly disagree and 7 being strongly agree.

Baytar's (2018) study found that the development and utilization of 3D CAD related apparel design projects can be used to guide and improve student learning, skill development, 3D CAD software perceptions, and their intention to use. Through their analysis of the quantitative data, the researcher found that students' interactions with 3D CAD software became more effortless as their skills developed (Baytar, 2018). There was a significant increase in 3D CAD interaction skill from the first project to the final project (Baytar, 2018). Additionally, student responses to the open-ended questions revealed valuable insight to their experience interacting with 3D CAD software for apparel design, most of which were initially optimistic (Baytar, 2018). However, one student reported that learning and using 3D CAD software became more difficult than they had previously expected, and two students believed that 3D CAD software was initially 'overwhelming and scary' (Baytar, 2018, p.192). Other student responses indicated that they became more comfortable interacting with 3D CAD software for apparel design as they gained more use experience and skill (Baytar, 2018).

Students' visualization skills significantly increased from project one to the final project, and there was significant improvement in students' problem-solving skills from project two to the final project (Baytar, 2018). Baytar (2018) suggested that the significant improvement of students' problem-solving skills from project two to the final project could be the result of the collaboration between students. These findings indicate that 3D CAD programs can be used effectively in pedagogical practices for improving textile and apparel design students' skill sets, proving to be a valuable teaching tool in preparing students for the industry workforce. Students' responses to the open-ended questions also provided insight to their perceptions of the impact of 3D CAD software on their visualization and problem-solving skills (Baytar, 2018). It was found that students perceived 3D CAD software to positively impact their visualization skill and their beliefs that the technology helped them understand aspects of apparel construction and fit (Baytar, 2018). It was noted that one student expressed that it was difficult to use 3D CAD software to accurately visualize their design idea but that they enjoyed when they were able to see the final garment come together (Baytar, 2018).

Students' perceptions of 3D CAD software performance also improved as their skills increased (Baytar, 2018). Notably, students believed 3D CAD software was useful in providing visual information and providing realistic representations of garment and body interactions, but they did not perceive 3D CAD visualization to be accurate enough for apparel fit testing and evaluation (Baytar, 2018). The researcher considered that this finding could be due to students lacking knowledge and skill in garment fitting (Baytar, 2018). It was also noted that most students who participated in the study and course did not challenge their capabilities and design skills beyond what they had previously exhibited during their prerequisite patternmaking course, which was attributed to students' perceptions that creating complex 3D garments would be too time consuming (Baytar, 2018). Students' intentions to use 3D CAD for apparel design was found to be high and to increase over the completion of the projects (Baytar, 2018). The researcher stated that there is a need for the development of similar studies that evaluate technology adoption determinants, such as the impact of students' perceived usefulness, perceived ease of use, and perceived enjoyment on their learning (Baytar, 2018). This study demonstrated the effectiveness of student-focused research but there is still a need for additional studies in this area.

Theories of Learning and Education

The following section of the literature review discusses theories that informed the present study, including Social Cognitive Theory (SCT) (Bandura, 1986b) and its related theories of self-efficacy, the Technology Acceptance Model (TAM) (Davis, 1989), and the extended Technology Acceptance Model (TAM2) (Venkatesh & Davis, 2000) respectively. In parallel, relevant research literature was examined to understand how these theories have been used in the development of existing studies, as well as to acknowledge how the theories' constructs have been assessed and measured.

Social Cognitive Theory (SCT) and Self-Efficacy

Introducing SCT and Self-Efficacy. Bandura's (1986b) work, *Social Foundations of Thought and Action: A Social Cognitive Theory*, contributed a comprehensive framework for understanding human behavior through the lens of Social Cognitive Theory (SCT), which highlighted the interactions between personal and environmental factors, and behavior. SCT is an extensive account of human behavior and its determinants and has been instrumental in elucidating the facets of learning and behavioral change, making significant contributions to fields such as psychology, education, and organizational behavior (Bandura, 1986b). The following summary of SCT will be framed to provide understanding of self-efficacy theories in the contexts of behavioral change, learning and motivational processes, and student performance.

As argued by Bandura (1986b), constructs of self-efficacy are especially influential and central to human behavior. The concept of self-efficacy is introduced as a critical determinant of behavior, behavioral change, and intent, and has significant influence over cognitive, motivational, affective, and selective processes (Bandura, 1977, 1982, 1986a, 1997). Self-efficacy is defined as the "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments." (Bandura, 1997, p. 3). Typically, self-efficacy is measured by presenting individuals with a list of tasks that vary in difficulty and collecting self-reported beliefs on the strength of their abilities to complete those tasks (Bandura, 1997).

Bandura (1982, 1997) emphasized that self-efficacy scales do not always accurately portray individuals' actual capabilities and are more importantly a gauge of self-efficacy beliefs which successfully predict behavior as specified by SCT (Bandura, 1986b).

Self-Efficacy in Qualitative Research. Self-efficacy theories have been assessed, tested, and examined within research literature across multiple industries and contexts. Although self-efficacy is often measured quantitatively, qualitative research procedures and mixed-method designs have also been used to effectively assess and support self-efficacy theories. Research conducted by Web-Williams (2018) and Gravill and Compeau (2008) serve as valuable guides to exploring the self-efficacy beliefs in the context of learning with the use of interviews. Gale et al. (2021) conducted interviews to assess and explore self-efficacy beliefs and sources in relation to experience. Although the focus of Gale et al.'s (2021) study was related to instructor self-efficacy, the interviews provided valuable insight into the nature of the participants self-efficacy and has therefore been considered relevant in the development of this study.

Interview Insights of Self-Efficacy Beliefs and Sources. Web-Williams (2018) conducted a mixed-methods research study to assess and explore students' self-efficacy beliefs and sources of self-efficacy in relation to science and student attitudes to understand how science education can increase student, interest, engagement, and participation. The methodology of the study proved to be an effective means of assessing and understanding students' self-efficacy beliefs, as well as self-efficacy sources within academic contexts, and students' attitudes toward learning within specific domains.

The researchers chose to evaluate self-efficacy due to its influence on academic performance, course selection, and career goals (Bandura, 1997, as cited in Web-Williams, 2018). Web-Williams' (2018) based their study, on the assumption that that students with low perceptions of self-efficacy in relation to science may be less inclined to participate in or feel more negatively about science education or science related careers.

Web-Williams (2018) also sought to understand students' sources of self-efficacy in relation to science education, which they argued was necessary to develop academic practices that incite positive self-efficacy change. They highlighted that self-efficacy is a determinant of thoughts, feelings, motivations, and behaviors, which makes self-efficacy beliefs essential to individual's goals and decisions (Bandura, 1997, as cited in Web-Williams, 2018). As identified by Bandura (1997, as cited in Web-Williams, 2018), there are four sources of self-efficacy: enactive mastery experience, vicarious experience, verbal persuasion, and physiological and affective states. The influence of enactive mastery experiences on self-efficacy are based on behaviors and their outcomes, such as failures and successes (Bandura, 1997, as cited in Web-Williams, 2018). The researcher argued that past accomplishments lead to future success (Web-Williams, 2018). Vicarious experience is another source of self-efficacy that is obtained through observations of others' behaviors and the resulting attainments (Bandura, 1997, as cited in Web-Williams, 2018). Web-Williams (2018) considered that people will often rely on others in self-evaluations of their performance. Self-efficacy is also influenced and formed through verbal persuasions, which include related social influences (Bandura, 1997, as cited in Web-Williams, 2018). Web-Williams (2018) did assess verbal persuasion as a source of students' self-efficacy but referred to the construct as social persuasion. The final source of self-efficacy outlined by Bandura (1997, as cited in Web-Williams, 2018) are physiological and emotional states, which is discussed regarding concepts of emotional arousal. Web-Williams (2018) found that the sources of self-efficacy were under researched and understanding them in the context of science students' learning could provide insight to student engagement, motivation, and enhance science teaching practices.

Web-Williams (2018) chose a mixed-methods design to evaluate students' self-efficacy beliefs and sources of self-efficacy in relation to science education. The sample population consisted of 182 students between the ages of 10 and 12 who attended one of two large public schools in the UK where classes taught science with aid from science specialists (Web-Williams, 2018). Quantitative measures were obtained on academic performance on science related topics, and self-efficacy was assessed with the use of a questionnaire (Web-Williams, 2018). Three self-efficacy measures were included at the end of the questionnaire and were scaled using a seven-point Likert scale (Web-Williams, 2018). Qualitative data was then collected one to two weeks after the questionnaire was distributed and completed (Web-Williams, 2018). Six focus group sessions with six students each and sixteen individual interviews with students were conducted to obtain qualitative insight (Web-Williams, 2018). Fifty-two students participated in either a focus group or interview session with the researcher (Web-Williams, 2018). The researcher advocated for the need for qualitative assessments of self-efficacy, stating that quantitative self-efficacy scales do not contribute information regarding the meanings of a student's self-efficacy, its contextual influences, how students perceive or interpret the sources of their self-efficacy beliefs, and does not provide an understanding of students' academic needs (Web-Williams, 2018).

The focus group and interview sessions were semi-structured and allowed for free discussion (Web-Williams, 2018). Students were fist asked to discuss their "confidence level in science" to assess their self-efficacy beliefs (Web-Williams, 2018, p. 948). Self-efficacy beliefs were also qualitatively assessed during the interviews in relation to the completed academic performance test and students were asked "Thinking about the science test you just did, what do you predict your scores to be?" (Web-Williams, 2018, p. 948). Other important questions were asked during the interviews to understand students' sources of self-efficacy and included the following: "What makes you feel this confident?", "What do you think about doing science at school?", "What things influence the way you think about yourself in science lessons?", and "What things influence the way you think about your school work and confidence in science lessons?" (Web-Williams, 2018, p. 948). Web-Williams (2018) analyzed and coded the qualitative results using deductive and inductive reasoning in reference to SCT (Bandura, 1986b, as cited in Web-Williams, 2018), which inspired a similar approach to thematic coding for this research study.

Through the use of interviews, the researcher was able to gain a deep understanding of students' self-efficacy beliefs and the sources of self-efficacy in academic contexts (Web-Williams, 2018). The interview results indicated that all four sources of self-efficacy formed students' self-efficacy beliefs and revealed the details of students' experiences that were related to their self-efficacy beliefs (Web-Williams, 2018). From students' responses, Web-Williams (2018) identified another source of self-efficacy, which was self-regulation. The researcher was able to draw conclusions about students' learning, engagement, and motivations in academic contexts that had significant implications for pedagogical practice (Web-Williams, 2018).

Interview Insights of Self-Efficacy in Software Training. A research study conducted by Gravill and Compeau (2008) assessed software learning methods through mixed-methods and was able to provide insight into the role of self-efficacy in software training. The aim of the study was to examine the success of self-regulated software learning in relation to learning outcomes, such as self-efficacy (Gravill & Compeau, 2008). Self-efficacy was chosen as a construct of interest because of its affiliation with positive performance (Gravill & Compeau, 2008). The first phase of the study involved 27 semi-structured interviews with professionals across a variety of industries who had participated in solo software training programs within the past year (Gravill & Compeau, 2008). Interview questions were designed to capture participants' experiences with learning software skills, the difficulties they experienced while learning software, how participants navigated the challenges they experienced, and how they managed their self-regulated software learning (Gravill & Compeau, 2008). During the second phase of the study, eighty-five individuals participated in self-regulated software training, and completed a questionnaire and two knowledge tests (Gravill & Compeau, 2008). The questionnaire was used to quantitatively measure self-efficacy with 10 items on a seven-point Likert scale (Gravill & Compeau, 2008). It was found that self-efficacy had a strong and positive relationship with learning outcomes (Gravill & Compeau, 2008). The interview results supported this finding, as participants responses indicated that confidence, or self-efficacy, was an important part in their software leaning process (Gravill & Compeau, 2008). Notably, it was found that self-efficacy impacted learning through its influences on motivation and perseverance (Gravill & Compeau, 2008). Gravill and Compeau (2008) argued that the results of their study could be used in the development of software education and suggested that self-efficacy support measures were crucial to enhance individuals' learning processes and learning outcomes. This study provides support for the effective assessment of self-efficacy through qualitative means, in addition to highlighting the importance of self-efficacy in software leaning (Gravill & Compeau, 2008).

Interview Effectiveness in Exploring Self-Efficacy. Gale et al.'s. (2021) study also quantitatively and qualitatively assessed instructor's self-efficacy and self-efficacy sources in relation to experience and the researchers were able to draw successful conclusions from the results. The qualitative approach utilized in this study serves as an example for the development of research and interview guides in other contexts that seek to qualitatively assess self-efficacy. The research approach consisted of two phases, the first being the distribution of a survey to teachers that included self-efficacy measurement scales for quantitative data collection and two open-ended questions to gain qualitative insight to the sources of teachers' self-efficacy (Gale et al., 2021). In the year following, ten semi-structured interviews were conducted to assess teachers' self-efficacy and self-efficacy sources (Gale et al., 2021). Interview questions were designed to elicit responses on teachers' intent to continue as an educator and why, their feelings and emotions, confidence, and experiences, all of which were framed to garner a deeper understanding of their self-efficacy beliefs, sources self-efficacy, and influences on self-efficacy (Gale et al., 2021). Interview results were analyzed, and it was found that the four sources of self-efficacy as outlined by Bandura (1997) were influential to teachers' self-efficacy beliefs (Gale et al., 2021). Another notable finding was that various aspects of teacher experience influenced their self-efficacy (Gale et al., 2021). Gale et al.'s. (2021) is an example of study that used qualitative assessments of self-efficacy to gain valuable insights to human behavior and experiences.

Self-Efficacy in Quantitative Research. Social Cognitive Theory (SCT) and self-efficacy theories have also been, and most commonly, used in the development and assessments of quantitative research studies in the contexts of software training. A 2013 study conducted by Ineson et al. assessed a variety of influences on students' self-efficacy in the context of software training and the researchers' findings had significant implications for the development of future research and pedagogical practice. Yi and Davis's (2003) research revealed that shaping students' self-efficacy through software training was fundamental in the development of students' skill and task performance. Both studies suggest that research on students' self-efficacy is necessary to enhance software pedagogy and have implications for the development of studies that explore students' experiences, attitudes, and learning processes in the contexts of 3D apparel CAD.

Self-Efficacy Influences in Software Training. Ineson et al.'s 2013 study examined the influences of prior subject knowledge, ability, and work experience on self-efficacy in the context of learning a business simulation software in the hospitality industry and was part of larger study that examined the impact of the previously listed constructs on experiential learning. The researchers posited that the results of their study could be used in the development of enhanced education that supports student learning and self-efficacy, suggesting that similar research in other learning contexts could prove to be just as valuable within academia. The researchers discussed self-efficacy theory in the development of their study and suggested that prior academic ability and knowledge were strong predictors of self-efficacy and, because strong-self efficacy beliefs support positive performance attainments, academic institutions should focus on developing student capabilities and self-efficacy (Ineson et al., 2013). It was hypothesized that prior knowledge and prior ability would have direct positive influences on self-efficacy (Ineson et al., 2013). Ineson et al. (2023) posited that work experience can positively influence self-efficacy through the development of knowledge and ability within specific contexts, task domains, and industries. It was hypothesized that work experience would be a significant moderating variable between prior knowledge and prior ability on self-efficacy (Ineson et al., 2013).

For their study, Ineson et al. (2023) chose to a research population of hospitality students who used the same business simulation software in their programs. Data was collected through the online distribution of surveys (Ineson et al., 2013). Students' general self-efficacy was measured with the eight-item new general self-efficacy scale (NGSE) (Chen et al., 2001 as cited in Ineson et al., 2013), which was scored with a five-point Likert scale (Ineson et al., 2013). Additionally, the survey recorded students prior work experiences in terms of length of time, job type (full-time or part-time), and field, as well as their knowledge and ability on specific skill sets for the business simulation software with twenty-three questions measured with a ten-point semantic scale (Ineson et al., 2013). It was discovered that there were significant relationships between the defined skill sets of prior knowledge and prior ability and self-efficacy, except for prior financial knowledge and ability (Ineson et al., 2013). Ineson et al. (2013) found no significant relationship between prior financial knowledge and prior financial ability on self-efficacy, and they suggested that these findings indicate that students lacked confidence regarding those specific skills. Due to this finding, it should be considered that evaluating prior subject knowledge and ability in relation to self-efficacy can help educators determine how instruction can be designed to improve student self-efficacy, in addition to understanding which skills students need further training on.

The researchers also discovered that work experience had no significant moderating effect between prior knowledge and ability and self-efficacy (Ineson et al., 2013). Ineson et al. (2013) stated that this finding could suggest that work experience may act as a moderating variable between prior knowledge and ability and self-efficacy in instances where the experience was of great importance, otherwise experience acts as an independent variable with a positive influence on self-efficacy as previous research had shown. The findings of this study could propose the need for further research on the relationships between prior knowledge, ability, experience, and self-efficacy in relation to student experience and learning. Additionally, the development of similar studies could provide insight to the skills students feel they need further training on and aid academic institutions in establishing enhanced curricula that supports student learning and self-efficacy.

Observational Learning, Self-Efficacy in Software Education. Yi and Davis (2003) proposed an educational model of observational learning for software training and examined the influence of self-efficacy on task performance. The findings demonstrated that software education, and students' learning and skill development can be improved with instruction methods that successfully develop students' self-efficacy (Yi & Davis, 2003). Considering the results of the study, the need to assess students' self-efficacy beliefs, and sources of learning motivations, is emphasized as crucial to the development of effective educational practice for 3D apparel CAD education. The findings of the study also indicated that understanding students' self-efficacy in relation to their current experiences with 3D apparel CAD learning could increase understandings of students' educational needs, such that it would provide insight to whether students currently feel self-efficacious due to their experiences.

Study Development and Observational Learning. The researchers developed an educational model of observational learning for software training based on SCT (Bandura, 1986b), which outlines the observational learning process. Bandura (1986b) asserted that human behavior is learned most through observation. Through observations of modeled behavior, individuals can learn the rules of behavior which can then serve as a guide for future action (Bandura, 1986b). Observational learning can additionally serve as a means for increasing knowledge and skill and has been considered a significant mechanism in the formation of values and attitudes (Bandura, 1986b). One of the main functions of observational learning is its influence over behavior inhibitions (Bandura, 1986b).

Observational learning through modeled behavior has been found to have strengthening and weakening influences over behavioral inhibitions (Bandura, 1986b). The impact of observational learning on behavioral restraint is dependent on observers' beliefs regarding their capabilities to perform the modeled behavior (self-efficacy) and presumed outcomes or consequences pertaining to the modeled behavior (Bandura, 1986b). Bandura (1986b) indicated that observational learning is regulated through attentional, retention, production, and motivational processes. Yi and Davis's (2003) proposed training intervention specifically aimed to enhance the mechanism of retention in observational learning processes, which Bandura (1986b) advanced has to do with the information that observers commit to memory through symbolic representations and acts as a guide for future performance.

Procedure. Two different teaching conditions were carried out by the researchers on a control and experimental group of participants learning Microsoft Excel (Yi & Davis, 2003). The experimental condition was conducted with the proposed method of observational learning, which was designed to enhanced retention (Yi & Davis, 2003). The pre- and post-training questionnaires were completed to measure and compare task performance and declarative knowledge, software self-efficacy, and observational learning processes (Yi & Davis, 2003). The pre-training questionnaire also assessed participants pretraining motivation to learn (Yi & Davis, 2003). As there were no previously developed or validated scales for measuring observational learning processes, Yi and Davis (2003) developed an original measurement scale following standard procedures.

Findings. The researchers' findings related to self-efficacy are discussed presently. The researchers found that self-efficacy was significantly influential to task performance (Yi & Davis, 2003). The results of the study indicated that software education, students' learning, and their resulting skills can be improved through successful self-efficacy development. Moreover, the researchers found that self-efficacy played a moderating role on the influence of training interventions and task performance (Yi & Davis, 2003). This finding indicated that higher levels of self-efficacy enhance learning processes, resulting in increased levels of positive performance (Yi & Davis, 2003).

Yi and Davis's (2003) study provided valuable insight into the nature of student learning processes and observational learning processes, and the impacts of self-efficacy. Based on their findings, there is a need to assess aspects of students' self-efficacy in relation to their learning of 3D apparel CAD to understand their needs in the development impactful and beneficial educational approaches to teaching the technology.

Technology Acceptance Models

The Technology Acceptance Model (TAM). The Technology Acceptance Model (TAM) was proposed by Davis in 1989 to predict and explain system use of information technologies in the context of user acceptance. The TAM employs the constructs of perceived usefulness and perceived ease of use as determinants of future system use intent and actual system use. Perceived usefulness refers to "'the degree to which a person believes that using a particular system would enhance his or her job performance.'" and perceived ease of use is defined as "'the degree to which a person believes that using a particular system would be free of effort.'" (Davis, 1989, p. 320). Davis (1989) developed TAM with several theoretical foundations including self-efficacy theory (Bandura, 1986b, 1982).

Scale Development. A multi-item scale was developed to measure the constructs of perceived usefulness and ease of use with the use of preexisting literature and refined through several pretests and studies (Davis, 1989). The resulting multi-item scale consisted of six items for each construct in the form of statements that participants rated based on how likely or unlikely they believed them to be (Davis, 1989). The researcher found that the scale had strong psychometric properties and could measure empirical relationships between perceived usefulness, perceived ease of use, and self-reported system usage, and a greater understanding of perceived usefulness and ease of use as acceptance determinants was gained (Davis, 1989).

Results. The study's results revealed that perceived usefulness and ease of use were significantly related to self-reported predictions of system use, which was previously determined as the best indicator of actual future system use (Davis, 1989). It was found that perceived ease of use and usefulness were correlated with both predicted system use and actual future use (Davis, 1989). Notably, the relationship between perceived usefulness and system use was found to be stronger in comparison to the relationship found between perceived ease of use and usage (Davis, 1989). Davis (1989) considered that the findings on the strength relationships between perceived ease of use, perceived usefulness and system use were rational because users are motivated to adopt systems based on the functions the systems can perform and then on how easy they are able to perform those functions with the system, such that users can often withstand some level of difficulty in using a system if it is critically needed to perform certain tasks (David, 1989). Additionally, the researcher discussed that although the difficulty associated with system use can dissuade its adoption "no amount of ease of use can compensate for a system that does not perform a useful function." (Davis, 1989, p. 334). This finding emphasizes the importance of understanding 3D CAD users' perceptions of the program's advantages in the exploration of their acceptance toward the technologies. Another significant finding was that ease of use influenced system users' perceptions of a system's usefulness (Davis, 1989). Davis (1989) explained that the influence of ease of use on usefulness was understandable because tasks can be completed more quickly with systems that are easier to use, resulting in positive job performance outcomes, and it is argued that beneficial outcomes of system use are dependent on how easy a system is to use.

The Extended Technology Acceptance Model (TAM2). A study conducted by Venkatesh and Davis (2000) proposed the extended Technology Acceptance Model (TAM2) to further assess the relationships between additional determinants and perceived usefulness and use intentions, as well as to understand how those relationships change over time with increasing user experience. Perceived ease of use, perceived usefulness, intention to use, and usage behavior were retained from the original TAM (Davis, 1989) and incorporated to TAM2 (Venkatesh & Davis, 2000) alongside additional constructs. In the development of TAM2, Venkatesh and Davis (2000) incorporated constructs related to social influence processes and cognitive instrumental processes.

Subjective norm, voluntariness, and image were identified as social influences that impact an individual's technology adoption. Subjective norm refers to an individual's intent to perform or not perform a particular behavior based on their perceptions of the expectations of significant individuals around them regardless of their personal beliefs surrounding that behavior (Venkatesh & Davis, 2000, p. 187). Subjective norm was posited to have direct influence on image, perceived usefulness, and intention to use. Voluntariness has to do with an individual's belief that an adoption decision is mandatory or non-mandatory (Venkatesh & Davis, 2000, p. 188). Voluntariness was hypothesized to have a moderating effect on the relationship between subjective norm and intention to use. The researchers chose to incorporate image based on the argument that individuals will choose to perform behaviors that elevate their standing within a particular social group (Venkatesh & Davis, 2000, p. 189). Image was proposed to have a direct effect on perceived usefulness. Experience was included as a moderating variable to the relationships between subjective norm and perceived usefulness, and subjective norm and intention to use. It was hypothesized that the positive direct effect of subjective norm on intention and the positive direct effect of subjective norm on perceived usefulness would weaken over time with increased user experience (Venkatesh & Davis, 2000, p. 189-190).

Job relevancy, output quality, and result demonstrability were included within TAM2 as constructs of cognitive instrumental processes and were hypothesized to have positive direct effects on perceived usefulness. The researchers integrated these cognitive instrumental processes based on the assumption that individuals' perceptions of a systems usefulness are formed in part by comparing their beliefs on a system's capabilities with goals (Venkatesh & Davis, 2000, p. 190). Job relevance pertains to an individual's belief that a technology is helpful to their job (Venkatesh & Davis, 2000, p. 191). Output quality refers to an individual's beliefs on how well a system can perform specific tasks to achieve their goals (Venkatesh & Davis, 2000, p. 191). Venkatesh and Davis (2000) differentiate job relevance from output quality, expressing that job relevancy has to with an individual's perception that a system can be utilized to achieve job related goals and output quality being ideals of how well a system can perform tasks to achieve job related goals. Result demonstrability was included based on the argument that individuals will have more positive perceptions regarding the use of a system if they are able to easily discern positive results, such as job performance improvements, from the use of a system (Venkatesh & Davis, 2000, p. 192). The researchers hypothesized that individuals would continue to rely on the constructs of cognitive instrumental processes over time and with increased experience, such that the impact of these constructs on perceived usefulness would not weaken over time.

Procedure. The extended Technology Acceptance Model (TAM2) was tested with the use of four longitudinal field studies at four different organizations where new systems were being introduced. Surveys were administered at multiple points in time to capture changes in user perceptions and usage behaviors as experience increased (Venkatesh & Davis, 2000, p. 191).

Results. Venkatesh and Davis's (2000) findings support the previously defined relationships between perceived usefulness, perceived ease of use, and intention to use from the original TAM (Davis, 1989). Consistent with the researcher's expectations, subjective norm had a direct effect on intention to use when system use was mandatory but was found to weaken over time. Subjective norm had no direct effect on intention to use when system use was not mandatory. Perceived usefulness and perceived ease of use were found to be significant determinants of intention to use over time (Venkatesh & Davis, 2000). Subjective norm was found to have a direct effect on perceived usefulness that weakens over time. Image had a consistent direct effect on perceived usefulness over time and subjective norm had a significant influence on image over time. Job relevancy, output quality, result demonstrability, and perceived ease of use all had significant effects on perceived usefulness over time (Venkatesh & Davis, 2000).

The results of the study indicated that subjective norm plays a significant role in the formation of individuals perceptions of perceived usefulness due to individuals incorporating social influences as part of their own beliefs, and through image (Venkatesh & Davis, 2000). Additionally, subjective norm was found to have a direct effect on intention to use when system use was mandatory but not when system use was voluntary (Venkatesh & Davis, 2000). This finding suggests that social influence does not have a significant influence on behavioral intent in voluntary contexts. It was also found that individuals relied less on social influences (subjective norm) in their perceptions of usefulness and intent to use over time and as experienced increased but continued to rely on image to form their perceptions of system usefulness (Venkatesh & Davis, 2000). This finding could indicate that users are able to form their own perceptions of a system based on personal experience rather than relying on others to form their opinions, such that social influence because less important over time.

Notably, it was discovered that job relevancy and output quality influenced individuals' perceptions of system usefulness, suggesting that users' perceptions of usefulness can be based on their specific job and goals, as well as on their perceptions of how well a system is able to achieve specific tasks related to their job or goals (Venkatesh & Davis, 2000). Output quality was found to have a greater influence on perceived usefulness than job relevancy (Venkatesh & Davis, 2000). These findings suggest that although a system may be capable of achieving a specific task related to an individual's job or goals, individuals believe it is more important that a system can perform those tasks competently. The influence of cognitive instrumental processes were consistent over time (Venkatesh & Davis, 2000). It may be valuable to consider whether this finding should remain true over extended periods of time. Venkatesh and Davis (2000) discussed the adoption decision in relation to cognitive instrumental processes, expressing that individuals' perceptions of systems job relevancy, output quality, and result demonstrability are formed through their comparison of a set of options of multiple systems. Consequently, there may be reason to believe that the impact of cognitive instrumental processes on perceived usefulness could change over time given that new information systems continue to be developed and existing systems are regularly updated, resulting in changes to the set of options by which individuals make their comparisons and form their judgements.

Technology Acceptance in Apparel Education. The acceptance of innovative technologies has been empirically tested and validated within research literature across a variety of contexts and industries. Many research studies that examine technology acceptance and its determinants with TAM and TAM2 utilize quantitative measures similar to and based on the previously discussed multi-item scales. TAM (Davis, 1989) served as the theoretical framework for Yu's (2018) study, which examined fashion merchandising students' perceptions of usefulness, ease of use, and enjoyment of a simulation software, and the influence of those beliefs on their attitudes toward the software. The research study referenced and modified Davis's (1989) established scales and measured students' perceived usefulness, perceived ease of use, and perceived enjoyment of a fashion merchandising simulation software (Yu, 2018). It was found that students believed the simulation software to be more useful than easy to use or enjoyable, and students' with higher perceptions of software usefulness, ease of use, and enjoyment had more positive attitudes toward the use of the software and believed software use had greater positive influence on their critical thinking skills (Yu, 2018). Remarkably, students with more positive attitudes toward the use of the software had more positive improvements in critical thinking skill (Yu, 2018). Moreover, the technology acceptance models have been adopted and extended with constructs of self-efficacy, quantitatively assessed, and provide evidence that self-efficacy constructs influence the perceptions, attitudes, and acceptance of technology (Alfadda & Mahdi, 2021; Cheung & Vogel, 2013; Hong et al., 2002; Igbaria & Iivari, 1995).

Summary of Literature Review

As shown in the above review of literature, 3D apparel CAD is an emerging technology that can be used to support and ameliorate textile and apparel design and development processes but industry adoption and implementation has been slow and difficult, which could be related to current practices in training and education on 3D apparel CAD (Avadanei et al., 2022; Brocker, 2023; Dal Forno et al., 2023; Gazzola et al., 2020; Hodges et al., 2020; Horváth & Vroom, 2015; Istook, 2000; Papahristou & Bilalis, 2017; Papahristou & Bilalis, 2016b; Rosca et al., 2023; Tepe & Koohnavard, 2023). Research on industry technology innovations, adoption, and implementation found that academic specific research on 3D apparel CAD training was limited and was considered a necessity for enhancing 3D apparel CAD education and supporting industry implementation (Dal Forno et al., 2023; Hoque et al., 2021; Rosca et al., 2023). Existing research on 3D apparel CAD education was conducted to gain insight from industry professionals on its adoption and implementation. Researchers found that 3D apparel skills were important to take advantage of 3D apparel CAD's full benefits (Papahristou & Bilalis, 2017). It was identified that research was needed to improve effective 3D apparel CAD education and further understand training from apparel students' perspectives to support industry implementation (Papahristou & Bilalis, 2017).

Research specifically related to 3D apparel CAD education was related to academic limitations, innovative design practice in education, assessing attitudes and skill development requirements, enhancing spatial visualization and creativity, and 3D apparel CAD as a patternmaking support measure (Tepe & Koohnavard, 2023; Hodges et al., 2020; Papachristou et al., 2019 Baytar, 2018; Chang, 2014; Park et al., 2011). Despite these various studies, a gap within the literature remains and educational practices for 3D apparel CAD need further evaluation, both of which can be addressed through additional research on students' learning experiences and attitudes of 3D apparel CAD in academic contexts. Potential approaches for additional research that could address the identified gap have emerged, including qualitative research studies that employ the use of interviews to gain thorough and rich understandings of students' learning experiences and attitudes of 3D apparel CAD within academia.

Research literature on theories surrounding learning and education were reviewed to provide a basis for developing and asking questions that would effectively glean narrative insights from students to understand their learning experiences and attitudes toward 3D apparel CAD. Social Cognitive Theory (SCT) (Bandura, 1986b) and self-efficacy theories have been extensively studied, including within software training scenarios, and their concepts have proven to be tied to students learning, motivations, performance, attitudes, and behaviors (Gale et al., 2021; Web-Williams, 2018; Ineson et al., 2013; Gravill & Compeau, 2008; Yi & Davis, 2003; Bandura, 1997, 1986a, 1982, 1977). The significance of self-efficacy in relation to students' learning, motivation, performance, attitudes, and behaviors suggests that qualitative research on 3D apparel CAD education would benefit by exploring SCT and self-efficacy in relation to students' learning experiences and attitudes with 3D apparel CAD.

The Technology Acceptance Model (TAM) (Davis, 1989) and extended Technology Acceptance Model (TAM2) (Venkatesh & Davis, 2000) have also been studied in relation to software training and 3D apparel CAD education and its constructs have been proven to be valuable in assessing students' beliefs and attitudes, as well as illustrating their overall acceptance, of the technology (Yu, 2018; Venkatesh & Davis, 2000). Notably, TAM (Davis, 1989) was developed with theoretical foundations including SCT (Bandura, 1986b) and self-efficacy theories (Bandura, 1982), which resulted in numerous extensions of the TAM with self-efficacy constructs and provide supporting evidence through their findings that self-efficacy constructs influence perceptions, attitudes, and acceptance of technology (Alfadda & Mahdi, 2021; Cheung & Vogel, 2013; Hong et al., 2002; Igbaria & Iivari, 1995). Based on these review findings, the TAM (Davis, 1989), and its extensions, were heavily considered and influenced the nature of the interview questions employed in this study.

The development of this study has been informed, guided, and influenced by the literature reviewed and discussed here. Existing literature review insights have pointed to the gap within research literature, the need for this study, and informed its methods. To fill the identified research gaps, the purpose of this study was to examine textile and apparel students' awareness of 3D CAD technologies in the industry, the nature of their acceptance of the technology, and their views on motivating and demotivating factors related to their learning of the programs.

Chapter Three: Methodology

To address the research aims stated above, the following research questions were developed:

RQ1. What is the extent of students' awareness of 3D Computer-Aided Design (CAD) technologies in the textile and apparel industry, and what are their perceptions of the industry's expectations regarding their proficiency in 3D CAD skills?

RQ2. What is the nature of students' acceptance of 3D CAD technologies used in the apparel industry?

RQ3. What do students feel motivates or demotivates them to learn or use 3D CAD technologies relevant to the textile and apparel industry?

Research Design

This qualitative study used in-depth interviews to gain an understanding of textile and apparel students' awareness and perceptions of 3D CAD technologies in the industry, the nature of their acceptance, and to determine motivating and demotivating factors related to their learning of the programs. The purpose of qualitative research is to gain an understanding of participants' experiences and perspectives, as well as to understand how participants interpret their experiences to form meaning (Merriam & Tisdell, 2015). Implementing a qualitative research approach allowed the researcher to explore students' experiences with learning emerging 3D apparel CAD technologies through informal in-depth interviews that were conversational in nature.

Setting

This study was conducted at a major university in the southeast region of the United States. To accommodate participant availability and preference, they were given the option to take part in an in-depth interview virtually through Zoom or in-person. Seven of the in-depth interviews were conducted virtually with Zoom and three in-depth interviews were held in-person in private conference rooms located at the university. The researcher recruited participants by distributing approved recruitment materials throughout the university faculty pool and faculty members distributed those materials directly to students. A total of ten participants were selected and interviewed.

Participants

Both convenience and purposive sampling methods were used for this study. Convenience sampling is used to select participants based on their easy accessibility to the researcher (Merriam & Tisdell, 2015, p. 97). For this study, the sample population consisted of students who attended the same university as the researcher, and this made participant recruitment and communication unchallenging. However, convenience-based sampling methods alone are not considered credible information sources (Merriam & Tisdell, 2015, p. 97). Purposive sampling methods are used by qualitative researchers to gain insight from groups of people that have unique experiences or expertise on a specific topic (Merriam & Tisdell, 2015, p. 96). In the case of this study, the researcher used purposive sampling methods in conjunction with convenience-based methods to gather credible information regarding the research topic. The sample population was purposive because participants were required to have some experience with 3D apparel CAD, in addition to having unique experience with using and learning 3D apparel CAD in academic settings.

Experience with 3D CAD programs for textiles and apparel was the key criterion for participant selection. To appropriately respond to the interview questions and share their perceptions of and attitudes toward 3D CAD, participants had to have prior experience with 3D

CAD programs for textiles and apparel to refer to. The group of recruited participants consisted of ten students at a major university located in the southeast region of the United States who had experience with 3D CAD programs for textiles and apparel. Students were a convenient sample due to their reachability, however they also represented an understudied demographic in research that has to do with 3D CAD acceptance and pedagogies, as exhibited previously in the review of the literature. Participation was restricted to individuals who were full-time undergraduate students in design or product development programs, or full-time master's students. To qualify for participation, students had to be eighteen years old or older and were required to have completed at least one semester at the selected university and have some experience with a 3D CAD program that is used in the textile and apparel industry.

Data Collection

Qualifying Survey

A survey was created with the use of the online platform Qualtrics and was used to verify participants' qualifications for participation, determine their year of study, assess the number of 3D CAD programs they had used, and collect participants' informed and broad consent forms. Six questions were included in the survey (Appendix A). The first few questions were used to verify students' age, enrollment status, and student standing in terms of semesters completed at their current university, and the last couple of questions assessed the extent of students' experiences with different 3D CAD programs and course participation. The first 10 qualifying students with experience with 3D CAD programs in the textile and apparel industry were selected for participation in the study.

In-Depth Interview Guide

An interview guide was designed to support the researcher during the in-depth interview process (Appendix B). The in-depth interview guide consisted of ten questions that were organized and developed based on prior research in 3D apparel CAD education, the experience of the researcher, the Social Cognitive Theory and self-efficacy theories, and the extended Technology Acceptance Model. Social Cognitive Theory (SCT) (Bandura, 1986), the Technology Acceptance Model (TAM) (Davis, 1986), and the extended Technology Acceptance Model (TAM2) (Venkatesh & Davis, 2000) were used as a guide in the development of this study. SCT (Bandura, 1986), TAM (Davis, 2000), and TAM2 (Venkatesh & Davis, 2000) were discussed in detail in pervious chapter but the major points of these theories will be summarized here. Social Cognitive Theory, which encompasses self-efficacy theories, and its related research topics within the literature provides valuable insight to the determinants of human behavior, including aspects related to learning, motivations, acceptance, and attitudes. The Technology Acceptance Model and extended Technology Acceptance model incorporate a variety of determinates that can be used to explain attitudes, intentions, and acceptance of innovate technologies, including perceived ease of use and perceived usefulness.

These constructs were used to develop the in-depth interview guide and establish suitable conversation topics. SCT, related self-efficacy theories, and the attitudinal determinates of the technology acceptance models informed questions to elicit participant responses on their experiences with and attitudes toward the use and learning of 3D CAD technologies for textiles and apparel to gain an understanding of their acceptance of the technology. Each question was open-ended and participants were encouraged to share their thoughts openly and candidly, as well as to expand upon their thoughts, feelings, and perspectives as desired. Additional prompts were listed under some of the interview questions for the researcher to easily reference when further elaboration or clarification was needed. Throughout the interview, questions such as “how's your experience been with 3D CAD programs, any thoughts on the user-friendliness and learning curve involved with using these programs?” and “looking ahead to your future career, do you think 3D CAD programs will play a role in your professional development?” were asked and the participants were given opportunities to speak openly and answer with complete volition. Participants were also asked questions that were related to their experiences with using 3D CAD software for textile and apparel development and design and the nature of their acceptance.

The organized categories of data were then analyzed to draw conclusions regarding textile and apparel students’ awareness and perceptions of 3D CAD technologies in the industry, the nature of their acceptance, and to determine motivating and demotivating factors related to their learning of the programs. The results are organized and discussed according to the established codes in the following chapters.

Data Analysis

Once the data collection process was complete, each interview was transcribed manually by the researcher in combination with Microsoft Word dictate and then reviewed word-for-word to correct any inaccuracies. The researcher reviewed each transcript from beginning to end two or more times, which involved listening to the audio recording of each in-depth interview alongside the corresponding transcription. The researcher corrected mistakes within the transcripts as they were reviewed. During transcription, participant information and responses that would allow them to be easily identified were removed from the data so that participants and individuals they discussed could not be reidentified. The data that was discarded included details about participant comparisons of 3D apparel CAD programs, their experiences within academic and industry contexts, specific projects and coursework, and specific interactions with peers, instructors, or industry professionals. These types of responses were removed from the data where participants could have been easily identified as a student within a specific class, year, or as being under the direction of specific instructors. Although these data were removed, the remaining data provided a rich picture of students' experiences with 3D apparel CAD. Following the transcription process, the content of each transcription was reviewed to identify important phrases, topics, and themes that arose during the in-depth interviews.

This study used a hybrid approach to thematic analysis to ensure that the codes be both grounded in the data and informed by existing theoretical insights. In qualitative research studies with interviews, it is critical to code data according to the research purpose and its informing theories (Merriam & Tisdell, 2015, p. 199). Moreover, suitable qualitative data analysis procedures must be established using both inductive and deductive reasoning (Merriam & Tisdell, 2015, p. 202). Inductive and deductive coding were used to contribute to the depth of the data set, such that the codes were developed from the naturally emerging themes of the data and refined with respect to SCT, TAM, and TAM2 to form a coherent narrative that reflects both the data and guiding literature.

As transcripts were reviewed, annotations were made to categorize the responses according to commonly discussed themes and in relation to the existing literature. The transcripts were reviewed numerous times, and the responses of each participant were organized according to the themes they presented. Once the initial categorization and annotations were made, subthemes were developed, and participant responses were further categorized. The categories that were identified during data analysis were then reviewed and analyzed to draw conclusions and understandings regarding the overall themes.

Limitations

Limitations of the present study include the size of the sample group. The sample group for this study consisted of only ten participants in total and data collection was restricted to those ten students. Further research studies should be conducted with a larger number of participants to increase the extent of data collection. Another limitation of this study was that all ten participants came from one university. Due to this, students' interview responses may have been similar because of the similar contexts and settings of their educational experiences. Similar research should be conducted to evaluate whether the results of the current study can be repeatedly observed at other textile and apparel universities.

As a result of the small sample size and because all participants attended the same university, detailed responses were removed from the data as needed to avoid reidentification. The removal of this data could be considered a limitation of this study because conclusions could not be made in consideration to all of the nuances of participant experiences. To overcome this limitation, a similar study should be conducted with a larger sample size across multiple universities so that specific and detailed responses can be retained without risking reidentification of participants or other individuals.

Chapter Four: Results

Ten in-depth interviews were conducted to examine textile and apparel students' awareness of 3D CAD technologies in the industry, the nature of their acceptance of the technology, and their views on motivating and demotivating factors related to their learning of the programs. The in-depth interviews were guided with a list of ten questions that were designed to capture student responses related to their experiences with learning and using 3D CAD software for textile and apparel development and design. The following chapter presents the results of the in-depth interviews and is organized by the major themes that emerged from students' responses. The organization of the results present students' experiences with 3D CAD and provides a narrative of their overall acceptance of and attitudes toward 3D CAD technologies in the textile and apparel industry. The major themes that have emerged include industry awareness, organizational support, social influence, system characteristics, prior experience, and individual differences. Responses are further organized into categories within those themes to provide clarity.

Industry Awareness

The following section presents the results reflecting students' awareness and impressions of 3D Computer-Aided Design (CAD) technologies and trends in the textile and apparel industry and their beliefs of the industry's expectations regarding their proficiency in 3D CAD skills. Within this section, results are organized further according to the reoccurring categories present within participants' responses regarding industry awareness. The theme of industry awareness includes the categories of initial awareness, initial impressions, awareness and impressions of 3D CAD in industry, and proficiency expectations. Responses illustrating participants' initial awareness reflect how and when students were first exposed to 3D apparel CAD. The following category, initial impressions, has to do with how students felt about 3D apparel CAD after they gained their awareness of them. The category of awareness and impressions of 3D CAD in industry included responses regarding impressed advantages and industry trend awareness and impressions. Participant responses under the category of proficiency expectations are related to how they believe 3D apparel CAD will play a role in their professional development and impressions of the 3D apparel CAD skills that will be expected of them in industry.

Initial Awareness

The following subsection provides insight into how students gained initial awareness of 3D CAD technologies in the textiles and apparel industry. All ten participants gained awareness of 3D apparel CAD through academic contexts, but the time at which students gained awareness varied. Four participants gained awareness of 3D apparel CAD prior to becoming enrolled at a college or university but through personal university related research or university hosted events. Participants B and J learned about 3D apparel CAD technologies while researching universities during high school, but their awareness and knowledge of the tools were limited to what they had learned at the time. Participants C and D also gained awareness of 3D apparel CAD while they were in high school but through university hosted events and programs and they both expressed they had never known about 3D apparel CAD before those experiences. None of those participants, B, J, C, and D, had opportunities to gain use experience with 3D apparel CAD prior to their university coursework.

Five of the ten participants gained awareness of 3D apparel CAD after becoming enrolled at a college or university but before being exposed to it in a class. Participants A and G believed that they had been told about 3D apparel CAD in other courses at their university, but that those classes did not involve 3D apparel CAD training. Participant F discussed having initial exposure to engineering 3D CAD programs through a course at their university and "I had heard of other softwares like CLO, Browzwear and like Optitex, and stuff…." Participant K, a first-year student, gained awareness of 3D apparel CAD before class exposure through their peers and word of mouth, which lead them to believe they would be using the programs a lot during their undergraduate program and would need to become "really, like, comfortable with" the software. Notably, participant K stated that they had no prior awareness of 3D apparel CAD because fashion design was not common or "normal" where they were from, resulting in them having limited knowledge. Participant K also reported that they did not research their university program or textile and apparel design before coming to college because they did not have enough time. Participant H, a graduate student, also become aware of 3D apparel CAD during their undergraduate program from peers and by participating in a research study. Although they had gained awareness during their undergraduate program, participant H stated that "because of my specific undergrad program at [my university] I didn't have [an] early experience using CAD or CAD software" and "never became familiarized with it until I started my master's program." Participant E was the only student who gained awareness of 3D CAD when they were exposed to it in a course at a college or university, and the only participant who was simultaneously given the opportunity to use the software with training support.

Nature of Initial Exposure

Participants further discussed the nature of their initial exposure and impressions of 3D CAD technologies in the textile and apparel industry. Responses and initial impressions varied by participant. Of the initial impressions students revealed, four were positive, four mixed, and two were negative. Participant responses have been further categorized by the nature of their responses.

Positive Initial Impressions. Four participants of ten had positive initial impressions of 3D apparel CAD. All four of those participants mentioned aspects of their initial exposure related to academic influences and educational opportunities. Participant B recalled that while researching college and university programs that those schools “kind of advertised the 3D software as, like, a big deal”, which lead them to feel 3D CAD was “something really interesting” and “I wanna learn more about this I wanna practice it” so they could use it in their own design processes. They further discussed their positive impressions regarding 3D CAD for textiles and apparel, stating that their initial exposure to their programs after becoming enrolled at a college or university was “super base level” but “we really wanted to get involved with [3D CAD] as soon as we were introduced to it.” Participant D discussed having positive impressions of 3D CAD after gaining initial awareness through a university lead program, stating that they “thought [3D CAD] sounded really cool and… very, like, cutting edge.” Participant H also had positive impressions of 3D apparel CAD after gaining initial awareness, stating that participating in the research study “definitely sparked my interest” in 3D apparel CAD and they thought “that was, like, really cool.” Participant J had positive initial impressions of 3D apparel CAD, which were enhanced through their first use experience in a college level class where they began to see the technologies potential and see how useful it was.

Of the participants who had positive initial impressions of 3D apparel CAD, three discussed positive outcomes related to their initial learning and use of the programs in academic contexts. Participant B felt their initial introduction to 3D apparel CAD in class was positive and “helped get me a little bit more interested” and led them to believe the tools were “not too difficult to learn.” Participant J felt similarly in regard to their coursework with 3D apparel CAD, stating they were “very happy with how they turned out” and made them “want to mess around with [3D CAD] a lot more" and "really want to see, like, how outside of the box you can go with [3D CAD] and, like, how dramatic we can push the boundaries of what designing is." Participant H mentioned having a positive use experience with a 3D apparel CAD program in an academic context, which positively influenced their impressions overall and made them want to take classes on the program to learn more because they find it interesting.

Two of the four participants who had positive impressions of 3D CAD technologies in the textile and apparel industry discussed peer influence. Participant H had positive impressions of 3D CAD based on their initial exposure to the programs, which they had gained awareness of in part through their peers while they were an undergraduate student. Participant J also had positive impressions of 3D CAD technologies in the textile and apparel industry and discussed that they gained curiosity about the programs through "hearing about the experiences of upperclassmen", which "really kind of informed that it would be something that be very integrated into being a fashion designer."

Mixed Initial Impressions. Four participants had mixed feelings and impressions about 3D apparel CAD once they became initially aware or had their first use experience with them. Participant A felt that 3D apparel CAD programs were "kind of odd" because the graphics reminded them of old animations or video games, but they also felt the software was "really cool being able to, you know, sew something that quickly digitally." Despite having slightly negative impressions about 3D apparel CAD graphics, participant A realized they could "save a lot of time with [3D CAD]." Following their first use experience however, participant A thought "the whole process you have to go through before you actually start sewing is, like, kind of long and complicated and if you mess up one step then the whole thing will be ruined and you'll have to start over." Consequently, participant A shared that this made them "very anxious about the whole thing."

Participant E recalled having mixed impressions about 3D apparel CAD when they first gained awareness and had their first use experience, stating "honestly I remember being kind of frustrated with it" and "I was struggling a lot with, like, the 3D aspect." They thought their initial difficulties could have been due to the mode of instruction or project specifications, but overall, their initial exposure "was kind of strange" because the class worked with one 2D program to create patterns that were then transferred into a 3D apparel CAD software. Although participant E had a generally negative first experience with 3D apparel CAD, they stated that class "did really kind of show me like, 'Okay, this is an option, and this is pretty cool'…."

Participant F had initially mixed impressions regarding 3D apparel CAD as well. Due to a negative experience with 3D CAD for engineering, participant F initially had negative impressions of 3D CAD technologies for textiles and apparel. When participant F became aware of 3D apparel CAD they were "intrigued" but based on their negative experience with 3D CAD programs for engineering, felt hesitant to use 3D CAD programs again and did not believe they were "going to be very good" at using them. However, participant F stated they "became a lot more, like, intrigued" by 3D CAD for textiles and apparel after they got into technical design and "saw people using them more", which is when they began to believe it was "definitely something where the future is kind of going towards." Once participant F took a course for 3D apparel CAD they came to believe that 3D apparel CAD "were more user-friendly than they were in the engineering software" and that "all the tools and stuff were a lot more useful."

Participant G also had mixed impressions regarding 3D CAD programs in the textile and apparel industry when they first gained awareness and had their first use exposure. Participant G revealed that when they first became aware of 3D CAD for textiles and apparel at their university "it was emphasized that they were really challenging to use or that the focus of that class is more on the basics and really pattern making or introductions to the software so [classes wouldn't] really [branch] into the 3D aspects." However, participant G discussed their first use experience with 3D CAD for textiles and apparel when it was incorporated to an undergraduate class and recalled "I remember thinking it was just kind of magical" and "how incredible it was." They felt that their positive impressions of 3D CAD for textiles and apparel and their positive use experience "was just really encouraging and piqued my interest", stating that "that's really what inspired me to come back even for grad school was just how incredible this program was."

Negative Initial Impressions. Two of the ten participants had negative initial impressions of 3D apparel CAD. Participant C first gained awareness of 3D CAD for textiles and apparel when they attended a university hosted fashion show that featured 3D apparel, which they felt "it was kinda odd because it looked like a waste of time" and they didn't understand why there were no "actual garments on the runway." Participant C expressed that "It kinda felt pointless in a way cause it didn't have a physical achievement, it was just all online." Additionally, participant C discussed having prior experience with 3D CAD programs for interior design and despite having some awareness "that fashion was kinda included" within 3D CAD technologies they "never, like, really wanted to touch on it." Participant C also spoke about their initial use experiences with 3D CAD for textiles and apparel during their first semester enrolled their university, stating that "it was nice but it still felt like it was a little pointless" and that the projects they were working on with 3D CAD at the time of the interview "feels even more pointless." Participant K also had negative impressions regarding 3D CAD technologies in the textile and apparel industry when they first gained awareness and had their first use experience with the programs. Based on their use experience and what they had heard about 3D CAD technologies in the textile and apparel industry, participant K stated the programs are "intimidating at first" and that they "would never touch that by myself" if it "wasn't required to do it in the project" and "if I wasn't, like, completely guided on how to use the software."

Awareness and Impressions of 3D CAD in Industry

The following subsection presents results regarding students' awareness and impressions of the use and implementation of 3D CAD technologies within the textile and apparel industry, as well as their awareness and impressions of industry related trends. Participants discussed which 3D apparel CAD advantages they were aware of, their impressions of those advantages, whether 3D apparel CAD had enhanced their creativity or design processes, and apparel industry trends in relation to 3D CAD programs and the results are reported respectively below.

Participant-Reported Advantages. Participants discussed what they believed to be the advantages of using 3D CAD technologies in the textile and apparel industry, as well as their impressions on whether 3D CAD had enhanced their creative or design process. The advantages that participants associated with the use of 3D CAD in the textiles and apparel industry emerged included prototyping, visualization, time and cost savings, sustainability, communication and accessibility.

Prototyping and Visualization. All ten participants mentioned visualization as an advantage of utilizing 3D apparel CAD in the textile and apparel industry in relation to prototyping and design processes. Participant A believed that prototyping and designing apparel with 3D CAD is "supposed to be faster and help you to be able to really see things and how they move, versus making a real-life thing." Participant A discussed that 3D CAD for apparel prototyping was beneficial because users can visualize "how everything would look before you actually commit" and stated that "having the 3D software to be able to do that will help you visualize it and make sure that your design, you know, works the way that you want it to." Participant A felt that visualizing apparel designs with the use of 3D CAD was "better than just, like, you know, coming up with a drawing of it cause you can see a 3D version of it at all angles, and you can see how it will drape over a person." Participant A discussed additional aspects of prototyping and visualization with 3D CAD that were beneficial in making design alterations and enhancing the final product. Participant B felt that 3D CAD was advantageous to prototyping processes because they were able to "see everything" through software visualization capabilities. In response to being asked what they believed the advantages of 3D apparel CAD were, participant C recalled:

> I was talking to someone who works high up for an apparel company and they were basically telling me that the only real benefits of it is seeing a garment before production instead of having that sample physical product and just saying, 'here's what you need to change, can you change it' and it's just an email away instead of waiting you know 6 months other than that I really don't I'm not really aware of any other beneficial aspects other than you know production time.

Participant C did later discuss during their interview that visualizing garment prototypes with 3D CAD was beneficial in comparison to creating physical prototypes and "instead of wasting actual fabric." Participant D believed an advantage of 3D CAD for textiles and apparel was "visualization for sure" because it provides "better context" of the "connection between 2D and 3D, just in terms of, like, patterns and design and… you become more familiar with how things drape and fit in 3D from the 2D." They felt that visualization through 3D CAD programs, and "being able to see… the impact of what you're doing live in 3D modeling", "definitely helped me, like, bridge that gap more” between 2D pattern making and the resulting 3D garment. Participant F thought visualization was an advantage of using 3D CAD programs for textiles and apparel because it allowed them to easily compare design choices, such as fabric selections and colors, without the need to create multiple physical apparel prototypes or make assumptions in their mind about what the garment would look like based on those changes. Participant F believed that the visualization aspects of 3D CAD software were “invaluable.” Participant G believed visualization was an advantage of 3D CAD programs for textiles and apparel, stating that by “using 3D tools or 3D CAD programs you can effectively communicate what the design is going to look like on a 3D form” and “it’s interactive so you can really get a better visual” in comparison to a 2D sketch or hanging a garment prototype on a hanger. Similarly, participant J stated that 3D CAD for textiles and apparel was beneficial because it allowed them to visualize their design “on an actual person before you go and make it” which “is really helpful.” Participant K also believed 3D CAD in the textiles and apparel industry were advantageous for prototyping and design processes because of its visualization capabilities.

Time and Cost Saving. Eight of the ten participants discussed that 3D CAD programs for textiles and apparel were beneficial for saving time. Participant A stated that “[3D CAD] is definitely a lot faster than coming up with a real-life prototype.” Participant B believed 3D CAD for textile and apparel prototyping and design “saves a lot of time” because users can adjust designs “and not had to, like, make tiny little adjustments on paper patterns” and can achieve a garment that fits correctly on the “first or second try.” Based on a conversation with an industry professional, participant C believed that an advantage of 3D CAD was the ability to quickly adjust apparel prototypes and rapidly communicate sample changes through digital means, resulting in decreased production times. Participant D felt that 3D apparel CAD programs were “really helpful” because it allowed them to “[be] able to, like, make mistakes and tweaks” that if done through physical design processes could result in a “completely wrong” prototype, which would feel “like a waste of time and resources and materials.” Participant E also expressed that an advantage of 3D CAD for textiles and apparel was related to prototyping processes and time savings. They stated that 3D CAD “speeds up the process considerably” and “saves me so, so, so, so much time” because “it allows me to iterate at a much faster rate and… try a bunch of different things” without needing to create physical prototypes. Similarly, participant F felt that one of the advantages of 3D CAD for textiles and apparel was that they were “able to make edits instantaneously” and if needed “undo it really quickly” without needing to make as many physical apparel prototypes. Participant G felt the same, stating that once users “[understood] how to use the programs well… [3D CAD] can save a lot of time in the design process” because they could “quickly manipulate patterns and make those edits and see very much in real time how that's going to look.” Regarding their impressions of the advantages of 3D CAD for textiles and apparel, participant H believed “it would make sense to continue to utilize more 3D software because it cuts down on production time..”

Five participants believed cost savings were an advantage of using 3D CAD programs in the textile and apparel industry. Participant D felt that 3D CAD software was “a huge cost cutting measure” in the textile and apparel industry. Participant E stated that “you don't have to put as much money into the physical testing, prototyping, and things like that” with the use of 3D CAD programs in the textile and apparel industry. Participant K felt that “3D programs and, like, electronic things are the most, like, price efficient way to test out if something works.” They stated that “using the 3D software will, like, help with saving money especially with making like gowns, and stuff like that, because that'll be really expensive.”

Environmental Sustainability. Seven participants mentioned that 3D apparel CAD was beneficial for decreasing waste. Participant B emphasized that quickly achieving higher quality garment prototypes was a sustainable advantage, such that fewer samples would decrease the amount of waste produced from the prototyping and design process. As previously discussed, participant C felt that 3D CAD for textile and apparel development and design was advantageous because prototypes can be visualized without generating waste. Participant D revealed that "being able to kind of cut out a little bit of that… waste" by using 3D CAD programs for textiles and apparel "is really cool" and that "the sustainability features feel very important to me." Participant E discussed that the amount of waste generated by pattern making processes were reduced through the utilization of 3D apparel CAD. Participant F believed an advantage of 3D CAD in the textile and apparel industry was waste reduction. and specifically discussed that they did not have to be concerned with the amount of waste generated during the prototyping process when using 3D CAD. Participant G stated that 3D CAD in the textile and apparel industry had a lot of "sustainable possibilities" because "there's a lot of waste there through traditional methods" such as "paper waste and shipping samples from your overseas partners, you think about the fossil fuels used… and also the actual garment that's not going to be worn or used ever is also trash." Participant H believed using 3D CAD programs for textiles and apparel helps to reduce the number of resources required in product development and design processes, stating that the programs are "more sustainable overall." Participant J felt that 3D apparel software was "helpful" at "reducing the amount of waste that's produced whenever you're sewing a garment."

Communication and Collaboration. Aspects of communication and collaboration were mentioned by five participants as an advantage of 3D CAD technologies for textiles and apparel. Participant C discussed communication benefits from what they'd heard form an industry professional, which was quoted above. Participant F discussed that with the use of 3D CAD they could communicate design ideas with their coworkers and make quick design edits through collaborative effort. Participant F was a master's student who was working in the textile and apparel industry with 3D apparel CAD at the time of the interview. They also believed that 3D CAD for textiles and apparel could aid in the communication of design ideas to overseas manufacturers, coworkers, and individuals who do not work in the textile and apparel industry. Participant G stated that 3D CAD for textiles and apparel can be used for "communicating to different teams within a company" and can "[help] lesson the disconnect between those teams." Participant H mentioned that the use of digital libraries with 3D assets for textiles and apparel was an advantage because fabric samples can easily be communicated without the need to send physical samples. Participant J stated that an advantage of using 3D CAD in the textile and apparel industry was that design ideas can be communicated through software visualization "to give everyone an idea of what things look like."

Accessibility. Three participants discussed elements of accessibility as being an advantage of 3D CAD programs for textiles and apparel. Participant E felt that 3D CAD for textiles and apparel made designing more physically accessible, stating, "I have some physical issues so, like, having to stand for a long time when you're drafting can be really hard so it's, like, being able to just do it on the computer is really, really nice" and the technology makes it so "I don't have to be in the studio." Participant F believed that accessibility was an advantage of using 3D CAD in the textile and apparel industry because some of the software licenses are available for independent or individual designers. Participant H discussed that 3D apparel CAD increases accessibility in terms of viewing digital textile and apparel products using virtual libraries.

Creativity and Design Process. Participants also discussed whether they felt 3D CAD for textiles and apparel had enhanced their creative or design process. Participants responses varied but the majority felt that 3D apparel CAD programs had enhanced their creativity or design process. Other participants felt that 3D apparel CAD had indirectly enhanced their creativity or creative process, and one participant felt that 3D apparel CAD had negatively impacted their creativity and design processes. Seven out of ten participants believed 3D apparel CAD had enhanced their creativity or design process and they discussed diminished constraints and design freedoms, exploration and iterative design processes, and visualization, which have been categorized respectively below. Responses that revealed an indirect impact on creativity and design processes, and negative impact on creativity of design processes have also been categorized for clarity.

Design Freedoms. Participants D, F, G, and J believed that 3D apparel CAD has enhanced their creativity and design processes because of diminished constraints and increased design freedoms. Participant D stated, "it definitely allows more creativity" because they had freedom for "a little bit more risk taking" and could "design more carefreely and with fewer … barriers." They further discussed that 3D apparel CAD gave them the opportunity to design without cost limitations, stating "not having to consider costs in that, like, initial creative prototyping, like, brainstorm phase I think is very valuable." Participant F discussed that 3D CAD allowed them to design with more creativity because they could rapidly design "something that's, like, really complex" and determine later if the garment was "actually manufacturable", indicating that they did not feel restricted by manufacturing or real-life constraints. They also felt they could design more freely with 3D apparel CAD because they did not have to consider the waste of prototyping, which they felt had enhanced their creativity and design process.

Participant G stated 3D apparel CAD "really allows for you to play with your creativity" because "I'm not limited to the physics of the real world or the needs of a soft body." They expressed that designing without physical limitations of the real world allowed them to "expand this so that it can just be whatever I want it to be or it can be as exorbitant and fantastical as I can make it." Similarly, participant J expressed that 3D apparel CAD had enhanced their design or creative process because they were not limited to the physical constraints of designing in a real-world environment, stating that it "definitely helped me creatively think about different things because I knew I had a lot more flexibility than I would if I were physically having fabric." Participant J provided further detail and expressed that 3D apparel CAD was beneficial to their creativity and design processes because they could "mess around with the fabric in a very controlled space", whereas they believed physical fabrics were "a lot harder to control."

Exploration and Iterative Design Processes. Four participants mentioned that 3D CAD for textiles and apparel had enhanced their creative or design process because the programs allowed them to explore and design iteratively. Participant D felt their design or creative process was enhanced because 3D CAD allowed them great "trial and error as opposed to, like, methodical on the front end for some achieved result." Additionally, participant D stated, "having the ability to, like… make edits and changes and, like, you know, the undo feature is, like, super helpful." Participant F believed 3D CAD for textiles and apparel had enhanced their creative or design process because they could "experiment more with different materials and things of that nature" and "change things around." Participant J felt that 3D apparel CAD enhanced their creativity or design process because they could experiment with different design decisions, stating "I could redo this and then try it again with the same pieces." Participant K thought that 3D CAD had enhanced their design or creative process because they could explore designing for a variety of demographics and model sizes. With the use of 3D CAD for textiles and apparel, participant K "was able to, like, come up with, like, a line for a unique demographic" and expressed that "I would have never done [a] line for that demographic if I didn't have a software."

Visualization. Four participants discussed how 3D CAD for textiles and apparel had enhanced their design or creative process through its visualization capabilities. Participant A stated that being able to visualize designs was "a really nice thing about it" because "you get to see how everything would look before you actually commit" to it, which was "very helpful." Participant D felt 3D had enhanced their creative or design process through visualization because they're a "visual learner", saying that having "experience of working in that way where, like, you're able to see things play out and carry it out and learn from that to me is very valuable." Participant H recalled a specific project they worked on where visualization aspects of 3D CAD had been useful in enhancing their design, such that they were able to modify the 2D garment pattern based on assessments they were able to make through examining the 3D simulation provided by the software. Participant K also felt that 3D CAD for textiles and apparel had enhanced their design because it allowed them to visualize "a few of my prints in, like, a different way" than they had originally intended.

Indirect Impact on Creativity and Design Process. Of the ten participants, two believed 3D apparel CAD had "kind of" enhanced their creative or design process. Participant B stated that 3D CAD programs for textiles and apparel had "kind of" enhanced their creative or design process but that the software "didn't directly, like, cause me to do anything." However, they did recall that "when we got the point of, like, um, staging kind of how the fabric fluffs up, or whatever, it kind of gave me ideas" (of how they could make permanent design choices to alter the garment silhouette). In response to whether they felt 3D CAD programs for textiles and apparel had enhanced their creative or design process, participant E also said, "kind of." They thought because 3D CAD "allows me to iterate at a really fast rate does really help with me design process" because they do not have "to make, like, a pattern for every single thing and making physical mockups out of it." Participant E felt that 3D apparel CAD had enhanced their creative or design process because they were less limited by time constraints and able to "do a lot more." Additionally, they felt the visualization capability of 3D CAD "is really helpful" because they receive "immediate feedback" without the need for a physical prototype.

Negative Impact on Creativity and Design Process. Participant C was the only participant who did not believe 3D CAD programs for textiles and apparel had enhanced their creative or design process in any way. Participant felt that 3D CAD had "been more of an obstacle and red tape to go to the final product." They stated, "I've actually found out that it's taking me more time to cut and sew a garment onto the body" within the programs "rather than just going down to the studio and draping it and just cutting and then making the pattern itself." Participant C also felt that 3D CAD had not enhanced their creative or design process because they did not believe the programs to be user-friendly or beneficial.

Industry Trend Awareness and Impressions. Participants were asked to discuss whether they felt their impressions and beliefs regarding 3D CAD programs in the textile and apparel industry were related to any trends they had awareness of. Eight participants felt strongly that trends were related to their impressions and beliefs about 3D apparel CAD. The industry trends discussed by those eight participants included sustainability, industry advancements and evolving expectations, digitalization and technology innovation, textile and apparel marketing, and the influence of the COVID-19 pandemic on trends. Two participants did not express confidence that industry trends were related to their impressions and beliefs about 3D apparel CAD. Within the following section, participant responses have been categorized by trend and the responses indicated participants were unsure or did not indicate industry trend influence are summarized at the end.

Sustainability. Three participants felt that industry trends or needs for sustainability were related to their impressions and beliefs about 3D apparel CAD. Both participants B and D felt that environmental sustainability was one of the reasons 3D apparel CAD was becoming popular within the industry. Participant B responded, “I know CAD is linked to sustainability a lot” and they felt it could be used to reduce waste. Participant D said, "I would definitely say, like, sustainability and, you know, companies that are becoming more aware of, like, their impact on the environment are probably more likely to explore 3D.” Participant G discussed industry trends and need for sustainability in relation to the environment, as well as supply chain flexibility. They felt there was needed change in the textile and apparel industry and greater consideration for sustainability efforts, stating:

> …what are some more sustainable ways of doing things and what are some not just in an environmental sense but also thinking about how are we setting ourselves up to be more flexible in the supply chain… but being more flexible and adept to, you know, being able to change on a dime.

Industry Advancement and Evolving Expectations. Three participants identified industry trends of advancement and evolving expectations, which they felt were related to their impressions and beliefs about 3D apparel CAD. Participant C felt “the expectations for [3D CAD] have changed as the industry is growing” and they revealed “the more down into the future the more I see 3D garment runways.” Participant F believed 3D CAD trends were “not even just limited to textiles” but were emerging across a variety of industries, which they felt emphasized “how important [3D CAD] is.” They felt that 3D apparel CAD was part of the textile and apparel industry’s advancement, stating it’s “the future of, like, how we can do design and stuff how we can visualize and, like, show and explain things to other people even in, like, the education realm as well” and that its “really, like, on the rise and I think it's… not slowing down anytime soon.” Additionally, participant F believed because of industry advancement with 3D apparel CAD there were existing and increasing industry expectations for people to know how to use those technologies. Participant H felt “trends are a big influence” in relation to 3D apparel CAD, stating they’ve seen “the industry evolve, like, significantly and fashion industry and also, like, the…performance textile industry is heading towards 3D simulations”, suggesting that industry expectations have increased for 3D CAD skill and knowledge.

Digitalization, Technology Innovation, and Usefulness. Five participants discussed industry trends specifically related to the evolution of technology and industry digitalization in relation to their impressions and beliefs about 3D apparel CAD. Participants A and B believed 3D apparel CAD technologies were becoming more popular because of industry digitalization and technology innovation. Participant B stated that 3D apparel CAD would “[inevitably]… carry over into the actual garment design” to “keep everything, like, technologically up to date.” Each of these participants also discussed 3D apparel CAD innovation in terms of usefulness. Participant A believed 3D apparel CAD was becoming popular and industry expectations were increasing because the software would “help with fashion” and “having the 3D software… will help visualize it and make sure that your design, you know, works the way that you want it to”, allowing users to assess and easily fix design errors. Similarly, participant B felt that 3D apparel

CAD was becoming important within the industry because of its significant benefits and usefulness within practice.

Participants C and E also felt digitalization and technology innovation were related to their impressions of 3D apparel CAD. Participant E stated, “there's definitely been a shift to digital stuff in general” in the industry, which they associated with the popularity of 3D apparel CAD. Participant C and E related 3D apparel CAD innovations and increasing popularity to its usefulness in reducing costs. Participant D didn’t specifically discuss industry digitalization, but they felt that 3D apparel CAD would increase in popularity because they are useful as “a huge cost cutting measure” and “in the very near future that companies will start to realize the impact” of 3D CAD technologies more. Participant D also felt that 3D apparel CAD would increase in popularity due to its benefits associated with time savings and waste reduction.

Participant G felt that 3D apparel CAD in the industry had “been here” and were not “a new idea” but there’s been “a lot of rapid development and advances in those programs”, resulting in increasing industry interest and changing expectations. Participant G further revealed that due to the advancement of 3D apparel CAD “there's a real interest and desire for these technologies to be used for ameliorating traditional processes and improving the way that we've been doing things” and they personally felt “there's just a lot of possibility there.” Participant F discussed that their impressions of industry trends and 3D CAD programs were related to the usefulness of the programs and that “being able to sort of interact with things in, like, the 3D space… is so helpful.”

Textile and Apparel Marketing. Two participants felt that textile and apparel marketing trends were related to their impressions and beliefs about 3D apparel CAD. Participant B believed that CAD software was “so prevalent in, like, marketing” which would lead to its increasing use throughout the entire textile and apparel development and design process. Participant H discussed that 3D apparel CAD programs were used at their job for the purpose of "[promoting their] products" and that "just goes to show we're going to continue to use [3D CAD] and it's going to become more popular."

COVID-19 Influence. Two participants felt that the COVID-19 pandemic had influenced the use of 3D CAD programs in the textile and apparel industry. As previously reported, participant C believed there to be increasing virtual runways featuring 3D garments and felt there were "a lot of those in 2020 because of the COVID pandemic." Participant G felt that "the pandemic really pushed our industry to reevaluate how we did things", which lead to increased 3D apparel CAD interest and implementation. Participant G also believed that the COVID-19 pandemic had influenced technology adoption of 3D apparel CAD, stating:

> …the pandemic and the isolating factors really push people of all ages not- not just young people, there's a lot of people of older- older generations have different needs with technology adoption but they are definitely, especially because of the pandemic, it pushed interest and, during the pandemic, need for adopting technology…basically just the pandemic caused a huge shift in the way that we not just looked at technology but how we treated it and that change has continued in how we are now looking at implementing these innovative tools or how quickly…

Industry Trends, Unaware or Unrelated. When asked if they believed there were trends related to their impressions and beliefs regarding 3D apparel CAD, one participant was unsure. Participant J, a first-year student, stated, "I'm not exactly sure to be honest because I'm not as versed with the industry standards at this time" but that "I feel like as things grow and as I'm more exposed to the industry I'll definitely have more of a reference of, like, this is what they expect for students to know." Despite expressing that they had limited knowledge on industry trends, they confidently stated "I know having the foundation and having knowledge about [3D CAD] is better to have than not because our society is continuing to grow and if we don't have this information at all then it could be detrimental to our careers in the future." Participant K, also a first-year student, did "not necessarily" believe that trends were related to their impressions and beliefs about 3D apparel CAD. However, participant K did discuss that they were aware 3D apparel CAD was being used in the industry and they felt it was important for them to learn to use the software. The specifics of participants K's awareness of industry use and proficiency expectations are further discussed in the following section.

Proficiency Expectations

3D CAD Role in Professional Development. The following section has to do with students' impressions on whether 3D apparel CAD would play a role in their professional development in relation to their beliefs about industry expectations for 3D apparel CAD proficiency. Participant responses reflected varying degrees of assuredness that 3D apparel CAD would play a role in their professional development.

Industry Observations. Participant responses highlighted the growing importance of 3D apparel CAD proficiency within the industry, which they discussed in relation to its relevancy to their future careers. Participants B, E, and H responded confidently that 3D apparel CAD would play a role in their professional development, which they attributed to what they have observed within the industry. Based on their industry experience working for a company that uses 3D apparel CAD, participant H shared, "using 3D software is going to become normal" and emphasized that having experience with such software is "expected." Participant E observed increasing demands for 3D apparel CAD proficiency while applying for jobs, expressing, "I've definitely seen a much bigger emphasis on CLO than any of the other 3D design programs." Participant B shared an anecdote about an industry professional sharing concerns about a new hire's lack of 3D apparel CAD proficiency, saying, "I was, like, oh man this is a big deal, like, I have to, I should probably know this."

Participants A and K also felt that 3D apparel CAD would play a role in their professional development due to observations of industry, but they responded less confidently overall than B, E, and H. Participant A recalled reading about the number of companies that use 3D apparel CAD, which made them feel like learning the software was an industry opportunity. Similarly to participant B, participant K shared an anecdote about someone in the industry who had to teach themselves 3D apparel CAD due to lack of proficiency. They found this "eye opening", stating it motivated them to "try my best to learn how to, like, master it now so I don't have to do that later because it's just going to progress."

Usefulness. Participants also shared beliefs that 3D apparel CAD would play a role in their professional development due to its usefulness and benefits. Participant E shared that they had already been using 3D apparel CAD for professional work and they confidently expressed 3D apparel CAD would continue to play a role in their professional development because it has been so useful. Participant F shared similar expectations.

Participant K considered 3D apparel CAD would play a role in their professional development because it "is a very useful skill." Participant K expressed that they felt 3D CAD would play a role in their professional development because they felt it will specifically help with cost savings because of its digital prototyping capabilities.

Adoption and Implementation Challenges. Three participants were hesitant that 3D CAD for textiles and apparel would play a role in their professional development and discussed that it would depend on industry implementation and challenges. These participants expressed that the industry is interested in 3D apparel CAD but implementation is not as rapid or extensive as they have been led to believe by academic and industry experts. Participant D reported their impression that industry professionals appreciate their experience and awareness with 3D apparel CAD while applying for jobs, but that those companies “don't use [3D CAD] yet but they really want to.” The same participant felt that their university had stressed that 3D apparel CAD was “cutting edge” technology and it “is what industry wants and needs”, however, they revealed now they felt overprepared.

Participant G felt similarly, stating, it “should be an easy yes” that 3D apparel CAD would play a role in their professional development but stated, “it’s more complicated than that” and “I don’t know that the transition is as rapid as some of the conversations have led me to believe.” Participant G also felt there was industry interest in 3D apparel CAD but, “I think the actual adoption and implementation of these 3D CAD tools…it's a little bit slower to come.” Participant D felt that 3D CAD programs are not being implemented at large apparel companies because they “have, like, so many systems and processes that would require overhaul”, which made them feel hesitant that 3D apparel CAD would play a role in their professional development. They shared they’d been hired by a large apparel company who was interested in 3D apparel CAD but “[didn’t] even have a PLM system”, which the participant felt was “a huge priority” for them before they could implement 3D technology. Similarly, participant G felt 3D CAD implementation was challenging for large apparel companies, especially because “you also have to convince those people that it's worth adopting and that's harder than it sounds.”

Participant J felt unsure whether 3D CAD would play a role in their professional development because they felt that the use of the technology can be “a very slow process” and because of this would not be as useful to a company who is mass producing apparel. However, two of those three participants considered that 3D CAD would be more beneficial or easier to implement on a smaller scale or individual basis.

Individual Goals. Many participants felt that 3D apparel CAD would play a part in their professional development because of their goals and individual differences. Participants who felt that 3D apparel CAD would play a role in their professional development expressed this thought was related to their desires to work in fashion design. These responses suggested that participants felt 3D apparel CAD was mostly applied in creatively-focused industry jobs. This belief is demonstrated Participant D, who felt they would not encounter 3D apparel CAD for their most recent job because it was an "analytical role" and not creatively-focused.

Only two participants thought 3D apparel CAD would play a role in their professional development or that they'd encounter it for jobs that were not in fashion design. Participant G shared that they had "specific interest in digital work" so 3D CAD would play a role in their personal professional development and, in the context of job availability, that there "is a pretty immediate availability for people interested in that or for me" because there is a growing interest in 3D CAD and need for "somebody who has that expertise and has the skills to talk with people and understand how to meet their needs well both from a technology and a design standpoint." Participant G did not specify whether they were interested in going into the technical design field, they only expressed their desire to work with 3D apparel CAD. Participant H felt that it would play a role in their professional development and they'd encounter as well because they were interested in product development. Both participants G and H were graduate students.

Only one of the ten participants did not feel that 3D CAD programs would play a role in their professional development. Participant C felt that 3D CAD programs would "absolutely not" play a role in their professional development due to their individual design preferences. Despite being a first-year student, participant C discussed having "years" of experience working as a designer in the industry and stated that "3D software is not in my point of view" and their designs "really are physical." Participant C said, "I don't expect people to know how to use [3D CAD]", although "it could be nice if they did…", and "I don't expect myself to be proficient at it."

Likely to Encounter 3D apparel CAD. Participants were asked to further discuss their impressions of industry expectations regarding 3D apparel CAD and to discuss whether they felt they would be likely to encounter 3D technologies on the job. Six of the ten participants felt that they would be likely to encounter 3D apparel CAD in an industry job, three participants were unsure, and one participant felt they would be likely to encounter 3D CAD on the job but that it would not be expected of them to know how to use them. Responses have been categorized according to whether participants expressed confidence or uncertainty about the likelihood of encountering 3D apparel CAD.

Confident they will Encounter. Of the six participants who felt they were likely to encounter 3D apparel CAD in an industry job, one participant felt that they would likely to encounter 3D CAD due to its perceived usefulness. Participant F felt they were "100 percent" likely to encounter 3D apparel CAD because the program "has really, like, honestly taken my ideas to the next level and made them even more a reality," in addition to their rapid prototyping and virtual sampling capabilities. Due to the usefulness they associated with 3D apparel CAD, participant F believed they would encounter the software and on the job and its use in industry would increase.

Two participants of the six who felt likely they would encounter 3D CAD programs during a job in the textile and apparel industry discussed that their beliefs were related to specific career goals and job positions. Participant B thought they “most likely” would encounter 3D apparel CAD “If I’m sticking to the path that I wanna go I would…”, indicating they believed specific jobs are more likely to encounter 3D apparel CAD than others. Participant E also felt they were likely to encounter 3D apparel CAD based on their experience applying for jobs. They believed most jobs “wanted you to have some kind of experience with, like, 3D programs” but they did feel it was related to specific job responsibilities, stating that “the only ones that didn’t really, like, have that” were for positions that were “not really, like, design-focused ones.”

Participant H felt that they were likely to encounter 3D apparel CAD on the job and discussed that this belief was a motivating factor in their continued learning of those programs because proficiency was expected in the industry. Participant H stated that “is why I’m, like, preparing myself for it” and “why I’m reaching out to take classes to learn that stuff so I can have, like, some, like, base level knowledge of… different types of CAD software.”

Only one participant of ten felt that they would be likely to encounter 3D CAD programs for a job in the textile and apparel industry but that it would not be expected of them to know how to use them. Participant C stated “Yeah, in way” they would be likely to encounter 3D apparel CAD on the job and that “with the industry standards that we have today I feel like it would be more beneficial coming into a job learning that stuff” but “I wouldn’t expect my boss or my manager to have that expectation” of them to know how to use or use those 3D CAD programs. Participant C discussed that regardless of their impressions “I can already name a few designers who use 3D programing and digital design in their clothing aspects, which is a whole other feat but I applaud people who are proficient in it.”

Unsure they will Encounter. Three participants' responses indicated that they were unsure whether they were likely to encounter 3D CAD programs on a job in the textile and apparel industry. Participant D felt that there were not likely to encounter 3D CAD programs on "this [job] specifically", which they previously discussed being hired for and that it was more of an analytical role rather than a creative one. However, they discussed that they were unsure how 3D apparel CAD was implemented and used in industry settings, indicating this was why they could not determine if they would be likely to encounter 3D apparel CAD on the job.

Participant G stated "yes", "for my job interests I should ideally" encounter 3D CAD programs on the job, but that it "depends" on the textile and apparel industry's ability to navigate the various challenges associated with the adoption, implementation, and use of 3D CAD programs. The response given by participant J also indicated that there were unsure if they were likely to encounter 3D apparel CAD on the job due to implementation difficulties. Participant J stated:

> I think it would just depend because I can imagine with our industry it's very fast-paced and while it's helpful to be able to use CAD it might not always be how the company wants to go about using it or how they go about designing but I feel like as technology has advanced I feel like more companies will integrate CAD based interface whether it's in a designing textiles or if it's in designing garments.

Similarly to participants G and J, participant D also felt that 3D apparel CAD implementation was difficult and slow, which was another reason they felt unsure whether 3D apparel CAD was something they would encounter on the job.

Organizational Support

Organizational support was a major theme that emerged from participant responses. In this context, organizational support is related to aspects of instruction mode and course structure, project specifications, resources, preparedness, and social influence, which have been organized into categories respectively.

Instruction Mode and Course Structure

Participants shared their experiences and impressions of the user-friendliness and learning curve associated with 3D CAD programs for textiles and apparel, and how instruction mode and course structure have been influential to those impressions. Participant A revealed that their professor had to show "every single step," which became an issue if students missed any part because it would lead to mistakes. Participant G emphasized the importance of understanding the "foundations and the basics" and believed proper instruction could mitigate the learning curve. They strongly believed that understanding the logic and context of why processes were carried out a certain way was crucial before introducing shortcuts.

Participant H expressed that 3D apparel CAD was difficult to learn in part because they could not always receive individual help during class time. Participant K pointed out that during class sometimes crucial information about the programs was not covered during instruction, making learning difficult. Participant J felt similarly but considered the nature of their academic program while sharing their beliefs. They found that, in their experience of 3D apparel CAD, the course's focus on creative expression led to vague instructions, which could overwhelm some students. However, they discussed that this openness also pushed their creativity, despite the frustration it caused. They appreciated the push for creativity but struggled with the lack of guidance. Participant J thought more in-depth class information would have made the software less frustrating and confusing, as well as helping them use the software more effectively.

Regarding the course structure, participant C revealed they had negative learning experiences, which they associated with time constraints in the class where they worked with 3D apparel CAD. They also thought the class curriculum should focus on physical garments instead of digital ones because they believed 3D apparel CAD was difficult to use effectively and they couldn’t touch the fabrics. Participant C described their frustrations as "learning how to walk again after running.” Overall, they felt 3D apparel CAD did not fit well with the course structure of their specific class.

Participant E recalled feeling frustrated as well during their first use and learning of 3D apparel CAD, which they attributed to struggling with the 3D aspect and instruction method. Similarly, participant K expressed they experienced difficulties with using and learning 3D apparel CAD because of a lack of guidance, stating that better instructional support would have significantly improved their experience.

Course Incorporation of 3D CAD. Responses indicated that aspects of how 3D CAD had been incorporated into students’ coursework and projects played a role in their attitudes toward software learning and use. Three participants specifically discussed having positive experiences with learning and using 3D apparel software in relation to how 3D CAD programs had been incorporated into their textile and apparel coursework. Despite feelings that 3D CAD had not been incorporated in the best manner during traditional classes, participant E felt that during their independent study they were able to fully incorporate 3D CAD programs into their coursework and believed that was when they learned the most about the programs. Participant F felt that 3D CAD programs had been very well incorporated into their graduate level courses for textile and apparel design. Participant J discussed their first project and use experience with 3D apparel CAD programs, which involved placing a 2D print graphic on to a 3D skirt, which they thought "was a very a good introduction to [3D CAD]."

Three participants had negative impressions of how 3D CAD had been incorporated with their textile and apparel coursework. Participant D also discussed their use of 3D CAD programs in class and that they "[wished they] could have seen that garment in real life", stating that they felt the class was "missing that, like, real life aspect" and "scale." As previously discussed, participant E felt that the incorporation of 3D CAD programs to their coursework or projects felt "strange" because there was limited instruction provided on how to use the program and, when they were first introduced to 3D CAD during a different course, the 2D patterns were made using one program and then imported into a 3D CAD software. Participant H expressed dissatisfaction with the extent to which 3D CAD programs had been incorporated into their textile and apparel coursework or projects, stating that they were only used for "very basic functions."

Project Specifications

Participants discussed projects specifications in relation to their experiences with, and attitudes and impressions of 3D apparel CAD. Participant C expressed negative aspects regarding their first use experiences with 3D apparel CAD, which they attributed in part to project specifications. Participant C felt that "the really, really difficult part" about their initial use experiences with 3D CAD for textiles and apparel was "the idea that we're expected to know all of this stuff and to come up with a 3-piece cohesive collection" within "certain aspects" of the project parameters.

Other participants discussed project specifications that involved the use of design templates. Participant K felt "really [frustrated]" during their initial use experience with 3D CAD because the measurements of the 3D garment and the 2D graphic they had designed with the required template did not match up. Participant B believed that based on "the parameters for the project" the professors did not want students to modify textural design elements "but I feel like that could've helped elevate some of the design elements." Participant K expressed that more detailed instruction or standardization of project expectations would improve the student experience.

Resources

Resources were commonly discussed by participants in relation to their experiences with using and learning 3D apparel software. In relation to organizational support, resources were discussed in relation to academic organizational support and external organizational support, such as vendor or embedded software support, or resources available through online communities. Students' responses related to resources have been categorized as either academic resources or external resources.

Academic Resources. Seven participants discussed how academic resources impacted their learning and use experiences with 3D apparel CAD. The types of academic resources discussed by these participants included pre-training and supplemental learning opportunities, in class and instructional resources, and technology and hardware resources. These responses have been categorized by resource type.

Pre-Training and Supplemental Learning Opportunities. Participant B expressed that it could be beneficial to have supplemental learning opportunities with 3D apparel CAD, especially "for people who are more interested early on to get that experience." They expressed that it would make them feel even more comfortable using and learning 3D apparel CAD because they could explore the program more. Participant C felt that there was a need for learning opportunities prior to students being required to use 3D CAD software in their classes. Participant C thought 3D CAD software was not easy to learn and wished that the university had provided pretraining.

Participant D felt there could be better way to work with 3D apparel CAD but they were unaware because their knowledge of the programs was limited. Participant D stated working with 3D apparel CAD felt “a little bit rudimentary” because they had limited knowledge and “never was able to take any higher-level courses” on the programs to continue their learning. They indicated a strong desire for more academic opportunities to continue their education with 3D apparel CAD.

Participant H discussed resources in relation to the opportunity for knowledge acquisition, revealing they had early interest in learning 3D apparel CAD but could not pursue their interest due to their specific undergraduate program. They revealed they were only able to learn 3D apparel CAD once they began graduate school. Within their graduate-level classes, participant H felt that learning 3D CAD was difficult especially because they had “minimal background knowledge on, like, 3D software” and felt that additional learning opportunities, such as an introductory CAD class, provided by their university would positively influence their learning.

Participant J discussed academic resources in relation to pre-existing knowledge and supplemental learning opportunities, stating that they had the opportunities to learn more about 3D apparel CAD from individuals conducting academic research. They felt other students in their class would have benefited by the same opportunity. Participant J further revealed that they believed a challenge to learning 3D CAD software for textiles and apparel had to do with limited technical design skills, stating “we don't have that experience, well not everyone has that experience of, like, pattern making quite yet" so learning 3D CAD for those people "was probably very overwhelming", especially because they had some pattern making experience and it was still challenging to them. They emphasized hands-on design skills were needed to accurately convey designs with 3D apparel CAD. They indicated that students' learning of 3D apparel CAD would be better supported if they had opportunities to learn more about traditional patternmaking.

Participant K felt they needed additional resources and skill on "basic computer skills because… I never took a computer class so I don't really have those skills" and they mentioned their professor would use keyboard shortcuts they had no prior knowledge of. Regarding general computer skills, participant K felt that supplemental learning opportunities for basic computer skills would have improved their learning and use of 3D apparel CAD.

In-Class and Instructional Resources. Participant B believed that the nature of in-class instruction and time available to learn was a limited factor to their learning and use of 3D apparel CAD. They discussed that instruction frequently pauses so individual students can be helped, stating that "if there was instruction in smaller groups it would help" their learning processes because less time would be needed to address multiple student issues and instruction "could just, like, continue through", which could allow them to learn more within a given time frame. Similarly, participant D also discussed time resources regarding their learning experience with 3D CAD software. Participant D felt comfortable using and learning 3D CAD software for textiles and apparel because of "the extra time that I took to expand" their knowledge and skill. They also felt comfortable using the programs because they have access to the documents from previous classes, which they could use to "help, like, jog my memory on, like, just, like, basics and, like, general steps to follow and stuff."

However, regarding their overall learning experience, participant D suggested they would feel more comfortable using and continuing to learn 3D apparel CAD if they had “more time” and “real applications” of 3D CAD use in the industry. Participant D stated that they wanted “industry examples of, like, how it plays out and, like, what functional teams in a real setting would actually be, like, interacting with the tool and, like, the designs made through 3D.” Participant D also felt their learning experience with 3D apparel CAD was limited because they felt they should have been provided with the opportunity and knowledge to conduct further fit testing but without additional academic support and resources they “didn’t see a way to do that.” Participant C had extremely negative impressions regarding their learning experience with 3D apparel CAD and discussed that their instructors’ explanations on how to use 3D CAD programs were not sufficient. They indicated that they felt a need for additional instruction aids while learning the programs. Despite taking “in-depth” notes, participant C discussed that they are not comfortable using 3D CAD programs for textiles and apparel and stated “I need a person right beside me” to answer questions and that they would not “really go off on my own and explore” 3D CAD more without the support of another individual or without additional knowledge.

Participant G revealed that during the learning process for 3D CAD programs they prefer to have in-class resources that include text and, especially, visuals, because “it's really, really helpful… to be able to problem solve” without “interrupting their workflow or their process.” They also felt those types of resources provide “a greater ability to really understand and take in that program for themselves.” Participant H also felt that similar resources would be helpful to their learning process with 3D apparel CAD, stating it was “honestly the best way to, like, catch on to things”, as well as serving as an easily accessible resources that they could “look back on.”

Moreover, participant H felt they would be more comfortable learning 3D apparel CAD on their own if they'd been provided with that kind of instructional aid.

Regarding their overall experience, participant K believed their issues with learning the 3D CAD program for textiles and apparel were due to the level of information that was provided to them and unrelated to characteristics of the software system, stating "the 3D software was not the problem with the experience" but that if they "had been guided a little bit better throughout that process it would have been a lot easier." Participant K also felt their learning would have been enhanced with additional instructional aid and in-class resources, stating that "a chart with, like, a picture of each thing… and, like, each, like, little button and, like, where it takes you kind of, like… I feel like that would be very helpful." As previously discussed, participant K had limited prior knowledge on basic computer skills, but they felt this learning barrier could have been overcome with in-class resources, stating "if I had, like, a list of the shortcuts, like, that would be very helpful."

Technology and Hardware Resources. Participant B felt that they would be more comfortable learning and using 3D apparel CAD "if I had the capacity to have it on a personal computer that would increase my comfortability" because they would be able to practice with the programs "and not just feel limited to the computer lab or a certain time of the day." Their responses indicated they felt additional technology resources in academia would better support their leaning process. Limited software resources were a learning barrier identified by participant D as well. Participant D stated that if students do not log out of the software it becomes an issue and limits their use of the program, stating that "part of that has to do with, like, the number of users allowed through the [university]" and it could be improved with more software licenses. Technology and hardware resource availability within academia was emphasized as a barrier to student interest and adoption of 3D CAD software for textile and apparel by participant G. Participant G stated “a roadblock to I think some adoption… is having the technology, like, the hardware to run these programs”, because even with updated software operating systems “if [users] don’t have the hardware to support these massive programs” they’re “not going to see the full benefit of… the final product.” Based on their experiences using university provided 3D CAD software and hardware and working with others, participant G revealed that the quality of the final renderings have “been a little discouraging to people” because “they're running on old school computers” and that if they “had something that was a little bit higher powered” they could “see the final products a little bit differently and that might even be more appealing to them.”

External Resources. Participants also discussed resources that were embedded within the software systems, provided by technology vendors, and available online. Participants had contradicting responses regarding these external resources, such that some students felt very positively about and supported through external resources while other students felt external resources were lacking. Participant responses regarding external resources have been categorized according to the nature of their response.

Inadequate External Resource Impressions. Participant A discussed the lack of available resources within the design of 3D CAD programs for textiles and apparel, as well as their impressions of how that lack of resources impacted the learning and use of the software. Participant A thought that one of the difficult aspects of using and learning 3D CAD was the lack of resources available within the programs, stating that they “didn’t have those things that, like, other softwares will have, where it’s like, ‘here’s some tips for beginners.” Participant C felt similarly to participant A regarding the resources available to them within the 3D CAD programs for textiles and apparel. Participant C felt frustrated while learning 3D apparel CAD and wished there were easier-to-use tools, more useful tools, and that they'd be more comfortable learning and using the software if there was "a search bar or, like, a how-to booklet."

Both participants A and J expressed a need for error detection resources within 3D CAD programs for textiles and apparel. Participant A thought sewing with the 3D programs was "kind of annoying…" and "a little frustrating" and stated that "it would've been nice if [the software] could put up, like… a warning sign" so that it could "detect if you missed something or sewed something wrong." Overall, participant A felt learning 3D CAD software was not too hard but that it was "a little bit annoying" because if they made a mistake, they "wouldn't really know it until you were done." Participant J felt they would be more comfortable using and learning 3D CAD software for textile and apparel if the programs provided resources such as "pop up videos of, like, if you're doing something wrong, if there is, like, a little pop up being, like, 'oh this is how you correctly do it'." They discussed that when things go wrong in the program they wished "there could be like a red arrow" to point out their mistakes, stating that "having that notification would be helpful." They further revealed that having a preview of how their 3D garment would sew together before running the simulation and quick instructions available with each tool within the software interface would also be benefit their learning process and use of 3D apparel CAD. Participant J mentioned that they were aware of video tutorials they could access, stating "obviously there's a tutorial but not everyone wants to rewatch… because we all want to get to working and don't worry- have time to go how do I start the beginning of this tutorial and then keep pausing and redoing." In this regard, they felt that pop-up resources would be more helpful within the program interface.

Adequate External Resource Impressions. In contrast, participants E and F felt that there were ample resources built into 3D CAD software design, as well as ample resources available to them online, that supported their use and learning of 3D CAD programs for textiles and apparel. Participant E stated that in certain 3D CAD programs "what is super helpful is that, like, if you hover over like an icon" a popup will appear to bring users to the software manual or a video tutorial. They stated that "[they] really appreciate that they have those options, like, built into the program so that way you don't have to, like, go seek it out yourself so is that the information is very readily available." Participant E also expressed that there is an abundance of online resources, such as tutorials and videos, that "[have] been incredibly helpful but also I really appreciate the fact that [the programs] have like an actual written manual as well" because it can be "really frustrating" to continually scrub a video for specific information. Participant F also felt that 3D CAD programs were easy to use and learn because there are resources within the program interfaces, as well as "really helpful like the help [pages], I… thought was so helpful and in like all of [the 3D CAD programs for textiles and apparel], then it was like it really showed you like this is what you need to do"'. Participant F's belief further contrasts that of participant A, who felt that there were not enough resources available within the programs and that they don't "like show you what you have to do, you have to really rely on someone else to give you those instructions to use it."

In response to how they have been keeping their skills sharp for using 3D CAD software for textile and apparel design, participant G discussed their use of vendor-provided resources to continue their education on the technologies. They described the resources, stating "they offer different courses and certification processes through this program where you can have video guides while they still provide files" so students can follow along step-by-step. Participant G felt that this resource was “pretty comprehensive and helpful, a little lengthy but very, very good”, especially because otherwise they would not have access to the program or to “somebody who can really explain those tools to me.”

Preparedness

During the in-depth interviews, participants were asked to discuss whether they felt prepared to use or continue learning 3D CAD software for textiles and apparel on their own and if they felt there were additional skills they needed to become more proficient with the technologies. The present category discusses participant responses that were related to how well prepared students felt they could use of continue learning 3D apparel CAD on their own, in the context of how organizational support measures have either influenced students’ beliefs regarding their preparedness, or in contexts of which skills students believed they still needed, all of which could be enhanced through organization support. In their responses, very few students felt fully prepared to use or continue learning 3D CAD software for textile and apparel design on their own, and all ten participants felt there were additional skills they needed to become more proficient in using the technologies.

In response to whether they felt prepared to use or continue learning 3D CAD on their own, participant A stated that “I don’t think I could” because “I’ve only used it once” and, when they did use it, they had been provided with the pattern. They stated, “I definitely think I need to learn more about it… how to use it before I could feel confident using it in my work.” Participant B also did not feel fully prepared to use or continue learning 3D CAD on their own, stating that pattern drafting, fitting and “even grading” they “would wanna know, those would probably be the big things.” In general, they felt they had some good skill for using 3D CAD for textiles and apparel, expressing that they were “pretty good at applying textiles, adjusting that, doing the, like, different stitch colors" but that "actual construction is what I wanna work on" in the programs.

When asked whether they felt prepared to use or continue learning 3D CAD on their own, participant C declared "yeah, I don't see myself using [3D CAD] for my future lines of work." Participant C did not indicate whether they were prepared to use or continue learning, but rather indicated that they wouldn't continue using or learning 3D CAD due to their impressions of its usefulness. They did state they "would love to be more proficient in [3D CAD] … but there is also that fine line of 'is this really useful?'." Participant C continued, saying that "If crap hits the fan, like, and we have no technology at all, I feel like those physical necessities of learning how to use a sewing machine, learning how to make a perfect garment, are more valuable than typing.."

Participant D felt that they "would feel comfortable, like, showing up to a new job and being trained to use their software with their processes" because they thought they "have a basic enough understanding that [they] could, like, flex it to different systems." They did, however, feel they were missing "like, more realistic applications" of 3D CAD use in industry such as "different scenarios, different costing scenarios through 3D", how they are used to communicate with manufactures, their use within tech packs, and an understanding of "how accurate are the material measurements." Participant D felt that "realistic applications of it would be helpful just to have more context of, like, how it could be used" in the textile and apparel industry. Participant E discussed that they were not as prepared as they would like to be to continue using and learning 3D CAD on their own, stating that they haven't been introduced to grading "in any of my classes, even just like the non-computer classes" and they thought they would need those skills to be more prepared with using 3D apparel CAD. They felt the need to learn grading because they want to “be able to produce things that fit a range of people and not just one person.” They also felt that they “would definitely like to learn more about, like, the 3D rendering stuff in general” because when using the programs “half of it is actually making the garment and then the other half is getting it to render properly.” Regarding learning more about 3D rendering, participant E did feel they could learn that skill on their own, stating that it would only require them to “go find some stuff on YouTube or just spend a really long time messing around with it.”

Participant F felt that they were “very comfortable” to continue learning and using 3D CAD programs on their own but they that there were “things about the software that [they] don’t know” and that they wanted to “dive more into.” Participant F felt that could learn more by “continuing education with it or just, like, looking at tutorials [themselves].” In relation to their feelings of preparedness, participant F stated that “the master of textiles program… the classes that [they’ve] taken have really prepared [them] to… use [3D CAD] on [their] own” and that they could do so “even if [they were] going into, like… more of a corporate setting” because they “have those really good skills” to be able to learn on their own, improve their skills with 3D CAD, and “sort of troubleshoot things.” Participant F felt confident that they were going to be “continuing education [themselves]” on 3D CAD programs for textiles and apparel. Participant G stated that they “would be pretty well prepared” to continue using and learning 3D CAD programs for textile and apparel on their own. However, they felt that companies have “a certain brand identity” and they’d have to learn “how to apply it correctly within this design landscape” of the different apparel companies.

Participant H believed that they “would be okay, like, using it in the work field” but they did not feel prepared to learn and improve their skills with 3D CAD on their own. They stated that “improving my skills on my own is something that I am hesitant on” because they “like to refer to, like, somebody who’s well versed in the CAD software” so they can ask them questions and get help when needed. Regarding learning 3D CAD for textiles and apparel on their own, participant H stated that without someone to help them that “most likely [they’re] not going to do it on [their] own” because they would not feel as confident. Participant H felt that without having “like, a project or something that would require [them] to, like, learn more” they wouldn’t know “what [they] have to do” which “is probably gonna be a limitation in [their] learning and proficiency process.” Participant K felt that they were prepared and “[they had] the skills to become more proficient with it on [their] own” but that they were not sure how their current set of skills and knowledge on one program would transfer to different 3D CAD programs for textiles and apparel because the extent of their use was limited to only one software. Participant K felt that they “would need, like, a little bit more, like, [they] probably need a couple more tutorials… to be able to do it, like, fully on [their] own and be able to start, like, kind of from scratch” to use 3D CAD for textile and apparel on their own. Participant J emphasized that when they’ve worked with 3D CAD in academic setting, they “haven’t learned how to, like, pattern make on [3D CAD]” and that “once [they] learn how to do that” they’ll feel more prepared to continue using it on their own. Additionally, participant K felt that “[they] could teach [themselves]” but “prefer to, like, be taught by someone who, like, knows what they’re doing because [they] would be scared to teach [themselves] the wrong thing.”

Social Influence

Social influence was one of the major themes that emerged from participants’ discussion regarding their experiences with and attitudes toward 3D apparel CAD software. Participants discussed a variety of impactful experiences that helped shape their impressions and attitudes of

3D CAD software in the textile and apparel industry that can be understood as social influence. Responses that included aspects of social influence were related to 3D CAD professional users and online communities, industry professionals and work experiences, peer groups and advanced students, and academic organizations and instructors, are presented as categories below.

Social Influence of 3D CAD Professional Users and Online Communities

Three of the ten participants felt that seeing 3D apparel design examples from professional users of 3D CAD software for textiles and apparel positively influenced their interests in the programs. One participant discussed that their experiences with online communities of professional users of 3D CAD software for textiles and apparel had a positive impact on their overall learning experience. In their discussion of what made them interested in using and continuing to learn 3D CAD, participant B stated their interests mostly came from "what I've seen people do." Participant B stated that they were comfortable using 3D CAD but "I've seen people who are proficient in the software be able to make these really cool things and I want to get to that point so… I have a desire to learn more." Similarly, participant D felt that their interest in 3D CAD software for textiles and apparel increased due to seeing examples of 3D apparel designs. Participant D stated, "seeing examples of, like, other designers work… definitely piqued my curiosity" in 3D CAD programs for textiles and apparel design and that seeing impressive design work "was really interesting to me" and made them further consider the possibilities of 3D CAD programs. Participant F felt that their curiosity and interest in 3D CAD for textiles and apparel were also positively influenced by being able to see examples of 3D apparel designs created by professional 3D CAD users. Regarding the websites hosted by 3D CAD program vendors, participant F believed their interests in the programs increased because they were "seeing, like, all the things that people have made on there." Another participant discussed their experience with online communities of professional users of 3D CAD programs for textiles and apparel was one of the reasons they believed their overall learning experience with the technologies to be positive. Participant E revealed that they had "a couple very niche questions" about a 3D CAD program for textiles and apparel that they "asked, like, on their forum boards", referring to the forum boards that are available on 3D CAD vender hosted webpages, "and I've gotten lots of really helpful feedback from other people in the community." Participant E attributed that experience with their attitude toward their overall learning experience, stating it was "very, very good in my opinion." Additionally, participant E expressed that 3D CAD programs would play a role in their professional development because they believed 3D CAD had "become so popular and, like, used by so many people that there's a lot more emphasis on it."

Social Influence of Industry Professionals and Work Experiences

Nine of the ten participants discussed the impact of social influences on their attitudes and beliefs about 3D apparel software in relation to industry professionals and work experiences. As previously mentioned in the category of proficiency expectations, participant A believed that 3D apparel CAD would play a role in their professional development because they had read about its use in the industry and thought having 3D apparel software skill would be more beneficial than not knowing how to use it. Participant B also felt that 3D CAD programs would play a role in their professional development because of their interactions with textile and apparel industry professionals. Participant B discussed that they came to believe 3D CAD programs were a "big deal" and they "should probably know this" after they talked with an industry professional who criticized a recent hire at their company for not being proficient at using 3D CAD for textiles and apparel. Participant C's responses and beliefs regarding 3D apparel software were primarily based on what they had heard from industry professionals, which have been discussed within the category of impressed advantages. Based on their experience applying for jobs in the textile and apparel industry, participant D came to believe that textile and apparel companies were interested in 3D CAD expertise, but that actual adoption and implementation was lacking within the industry. Participant D mentioned that when they apply for jobs in the textile and apparel industry, they “often do ask about 3D design just out of curiosity” and that the “general consensus of people I’ve spoken to is, like, kind of, like, they love to see that I’m familiar” with the software but that the companies are not implementing them yet. Due to these experiences with industry professionals, participant D felt hesitant whether 3D apparel software would play a role in their professional development. Participant E’s influential experiences with industry professionals were also in the context of applying for industry jobs within the textile and apparel field. Participant E believed that 3D CAD programs would play a role in their professional development because the companies want applicants to “have some kind of experience with 3D programs” for textiles and apparel. Moreover, participant E was influenced to believe that they would encounter 3D CAD programs on the job in the textile and apparel industry because 3D CAD skill was sought after by every job they had applied to. Participant F’s attitudes and beliefs regarding 3D CAD in the textile and apparel industry were also influenced by industry professionals and work-related experiences. Participant F stated that their interest in 3D CAD software for textile and apparel design was positively influenced through their experience with industry professionals who came to speak at their university about the use of the technologies in industry settings. Participant F believed that their interests increased in 3D CAD software in the textile and apparel industry because hearing the industry professionals discuss the use of the technology lead them to become aware of the numerous applications for the technology in industry and they were “able to see, like, how much is it’s actually being used in the industry.” Additionally, participant F stated that they believed 3D CAD software was trending in the textile and apparel industry because they had heard “that, like, employers are looking for that”, for 3D CAD expertise, and that because “on the design side [they’ve] heard of that so much” they believe 3D CAD in the textile and apparel industry is “on the rise” and its “not slowing down anytime soon.”

Participant G’s beliefs regarding 3D CAD development and use in the textile and apparel industry, as well as their beliefs regarding aspects of learning 3D CAD, seemed to be influenced by their work experiences in the textile and apparel industry. Based on one of their internship experiences where a company was creating a digital library of apparel pattern blocks, participant G was led to believe that “[understanding] how to start from scratch” when designing apparel with 3D CAD was not as valuable as a skill as it once was. During another internship experience, participant G worked with the implementation of 3D CAD software in the textile and apparel design processes. They discussed that this experience influenced their awareness and beliefs regarding the difficulties of 3D CAD learning and implementation, stating that communication between departments during the implementation processes emerged as a major difficulty and that easily accessible learning resources were important for 3D CAD learning. Participant G stated that they came to believe during their internship experience that “some people wanted a PDF of just everything written out verbatim” but a lot of individuals learning about 3D CAD in industry “really liked those visuals and that was really helpful” to their overall learning process in addition to making the learning process faster. Another participant’s response indicated that social influence in the context of their work experience impacted their beliefs about 3D CAD trends in the textile and apparel industry. Participant H felt that 3D CAD programs were becoming increasingly popular and important within the textile and apparel industry and reported that they currently worked for a company who was using 3D CAD in the industry, stating that "that just goes to show we're going to continue to use it and it's going to become more popular." Participant K stated that they "[visited] a textiles company and they had, like, 5 computers set up just for [3D CAD] which was, like, cool" and discussed that they knew a working industry professional who did not receive 3D CAD training before entering the workforce "so they're having to… teach themselves how to use it." Participant K stated that their experiences interacting with companies and professionals within the textile and apparel industry had "been eye opening to see how much [they] should actually put into it and try [their] best to learn" 3D CAD software because they believed the technology is "just going to progress" and they don't want to learn it later.

Social Influence of Peer Groups and Advanced Students

Five participants had notable responses that had to do with the social influence of their peer groups or advanced students on their attitudes, beliefs, and learning of 3D apparel software. Participant F felt that they were comfortable learning and using 3D CAD programs for textile and apparel design due to their experiences learning alongside their peers. They discussed that they felt comfortable learning 3D CAD because they were "around other people that have the same skill set" going through the same processes, stating that having that peer group has been beneficial to their feelings of comfortability and overall learning process. Participant F also expressed that they felt comfortable learning 3D CAD because they were able to collaborate with peers, learn from their mistakes, and help others when they were able. Additionally, they felt that working alongside their peers allowed them to feel that "if [they] run into a roadblock, it doesn't mean that [they] don't know what [they're] doing, it just means that [they're] working through it", as well as to gain inspiration or motivation to try different things in the programs based on what their peers were accomplishing. Participant F also believed that working and learning alongside their peers made them feel more open to continuing to learn and use 3D apparel CAD because it gave them the opportunity to see they were not the only person had some difficulties with the technology. Similarly, participant G believed that their learning experience was benefited by "having people that are not just there for a class but that are there and invested in the content and want to learn" alongside them. Participant G stated that when they felt "overwhelmed or it [felt] daunting" to learn 3D apparel software it was "really helpful when people stay curious with you and want to learn and have those conversations." They felt that they "wouldn't be in the program [they are] in now or doing what [they're] interested in now had [they] not had the benefit of certain classmates that wanted to learn with [them]'.

Participant H revealed that their interest in 3D apparel CAD came partially from their peers who had told them about the programs. Regarding their overall learning experience, participant H believed learning 3D apparel software was "difficult" but stated, "when explained in a manner that I could understand from classmates and peers I can understand the material." Participant H also felt comfortable learning and using 3D apparel CAD because "being in an environment where other students are learning is very helpful and just kind of comforting in the sense of that there's other students in the same position as I am that [are] learning as well…." Participant J believed that their interest in 3D apparel CAD increased due to social influence of older students, stating that "hearing about the experiences of upperclassmen really kind of informed that [3D CAD] would be something that [would] be very integrated into being a fashion designer." Additionally, participant J discussed social influence in relation to peers and their overall learning experience, revealing that they felt "it's been, like, a very collaborative type of learning experience" because they can use their peers as resources. They stated, "I've definitely relied on my friends a lot to, like, help me understand certain elements and I've helped my friends with, like, my notes" and that the more they learned the more they wanted "to impart that wisdom to one another so that everyone can succeed." Participant K similarly discussed peer related social influences that impacted their awareness, attitudes, beliefs, and learning of 3D apparel software. Regarding their initial awareness, participant K stated, "I heard about [3D CAD] through word of mouth" from their peers, who also emphasized that 3D CAD was something they would "be using all four years" and would "have to be really, like, comfortable with it." Participant K discussed how peer influence increased their interest in 3D CAD programs, stating that they were "kind of, like, seeing and, like, sneaking peeks at what [their] peers were doing and being, like, 'oh, that's kind of cool, like, I kind of want to try that'." In a similar response to participant J, participant K felt that help from their peer group positively influenced their learning processes and benefited their overall knowledge and skill with 3D CAD programs, expressing that "mainly just, like, asking around has helped a lot." Participant K felt that because they could not retain everything covered in class "I had to, like, ask around, like, friends for help a lot on people who kind of knew how to do it" and then when "people started asking me for help on things I knew how to do I started to become more comfortable with it." Notable, participant K felt comfortable with learning 3D CAD due to their peer group because they could assess their skills, stating "if someone asks me a question and I'm able to answer it then I know that I know what I'm doing but if I can't answer the question then I'm kind of screwed."

Social Influence of Academic Organizations and Instructors

Seven participants discussed social influences from academic organizations and instructors that impacted their attitudes, beliefs, and learning processes associated with 3D CAD programs for textile and apparel design. Participant B revealed they gained interest in 3D apparel CAD from researching universities and they came to believe the software was important. Their interests were increased once they began university classes, stating, the “class work and projects we did, it helped get me a little bit more interested.” Participant B specifically mentioned that their interest increased in 3D CAD also because of “professors and what they have talked about”, which allowed them to understand the capabilities of 3D apparel CAD and made them “want to learn.” Participant C’s responses also indicated that the social influences related to academic organizations and their instructors had impacted their 3D apparel CAD learning experience and their feelings of comfortability with the technology. However, participant C discussed negative aspects related to these influences. They felt their learning experience was “terrible” and “learning CAD programs really depends on the professor and how they want you to learn it.” Participant C believed that their instructor wanted them “to just automatically know it”, meaning 3D CAD, and expected them “to remember everything.” Participant C expressed that there were “unsaid expectation for the students so that adds more frustration when you can’t figure it out” and they believed their ability to learn the programs “does really lean on the professor and the professor’s explanation.” Participant C also discussed that they were not comfortable learning and using 3D apparel software because of how instruction was conveyed and the expectations that were imposed upon students by professors.

Participant D’s responses indicated that academic organization and instructor influences positively impacted their interests and attitudes toward 3D apparel CAD. They discussed that they were initially exposed to 3D apparel CAD during a university-led program and that this initial exposure increased their interest in the technology because “it sounded really cool and very, like, cutting edge.” Participant D’s interest and curiosity in 3D apparel CAD was further increased when they had their first use experience during a university course. Regarding the class, participant D “really liked the way it was set up” because the “professor would guide us through, like, steps and, like, best practices of how to use tools” and they could then explore on their own when they had time. Participant D believed that their experience in this class and “ability to explore definitely piqued my curiosity” about 3D apparel software.

Participant F thought their experience learning and using 3D CAD in academic settings positively influenced their learning process and increased their feelings of comfortability with learning and using the programs. Participant F felt comfortable learning and using 3D CAD for textile and apparel design because of the amount that they had been exposed to the programs within the curriculums and because they felt like they were not expected “to know everything about it” immediately. They also felt that their instructor positively influenced their feelings of comfortability with learning and using 3D CAD software due to “like, learning a lot along with the instructor” and gaining troubleshooting skills, which participant F felt “[helped their] confidence a lot with not just the software but just, like, design in general.” They emphasized the importance of understanding how to overcome challenges in software learning.

Participant G discussed how their experiences with academic organizations and instructors influenced their attitudes, beliefs, and learning of 3D apparel CAD. They stated that academics at their university had initially “emphasized that they were really challenging to use or that the focus of that class is more on the basics and really pattern making or introductions to the software” and that students would not have much opportunity to utilize the 3D aspects of the programs. However, participant G was able to overcome the influence of those experiences once they had their first use experience with 3D CAD software and was able to see its benefits firsthand, stating that they then felt the software was “magical.” Regarding their learning experiences with 3D apparel CAD, participant G expressed that their professors had been especially influential to the nature of their experiences. They recalled, “thankfully I had some good professors who also explained things pretty well” which led them to have positive learning experiences with 3D CAD. Participant G did express however that other experiences with professors negatively impacted their attitudes toward learning 3D CAD software for textiles and apparel. Participant G stated that they had a challenging learning experience with 3D apparel CAD because “of a professor who really didn’t want to answer questions” and seemed as though they wanted to “get through the lecture and then go home.” Due to the professor’s attitude, participant G stated learning 3D CAD in that instance was “really frustrating and challenging” because “I wanted to learn, to understand” but “I felt like I didn’t have the resources or materials and my peers [were] also struggling so it made me not want to continue” learning or using 3D apparel software.

Another participant felt that their overall learning experience was positively influenced through social influences related to their academic organization. Participant J stated that they felt that using 3D CAD was “enjoyable and fun” because they were able to supplement their knowledge by talking with “some people, like, doing research on how to use [3D CAD]” at the university. Participant J did feel that learning 3D CAD for textiles and apparel can be “really confusing” without additional support, stating that the support they received from academic researchers made them feel positive about their learning experience. Participant K felt that their academic institution is what influenced them to learn and use 3D apparel CAD, stating that they "probably wouldn't have, like, grabbed it or known about it if [they weren't] required to do it in the project" because fashion design and 3D CAD are not "normal" or common where they're from. They felt that because using 3D CAD can be "intimidating at first" and they had little to no prior knowledge on it, expressing "I would never touch [3D CAD] by myself" if they hadn't been "completely guided on how to use the software."

System Characteristics

System characteristics were a major theme identified within the data and commonly discussed by participants in relation to their experiences, attitudes, learning, and use of 3D CAD software for textile and apparel development and design. Participants discussed the characteristics of 3D CAD systems in terms of their usefulness and user-friendliness. The theme of system characteristics includes impressions of 3D CAD usefulness and user-friendliness and learning curve.

Impressions of 3D CAD Usefulness

Overall, participants believed that 3D apparel CAD was useful in both academic and personal contexts, as well as in industry use contexts. Students' responses indicated that their impressions of the usefulness 3D apparel CAD is partially related to the software system characteristics. They discussed aspects of usefulness in relation to reduced waste production and time savings, of which many of these responses have been reported in previous sections. However, participant A and C's responses stood out in relation to system characteristics. Both participant A and C felt that certain functions within 3D apparel CAD, like sewing and print visualization, were a characteristic of the system that saved a lot of time in the apparel development and design process. Although it should be noted, that neither participant held entirely positive views of the software. Participant C felt overall that 3D apparel CAD design processes took them longer than physical design processes, while participant A believed that 3D apparel CAD would be more useful if there were more error detection capabilities built into the system.

Participant G stated that "pattern making takes so long" and when they had their first use experience with 3D apparel CAD and "I remember thinking just how incredible it was that you could very quickly see, in CLO at least, any alterations you made to your 2D patterns you could very quickly see how it was affected on your 3D avatar." Their response indicated that system characteristics associated with patternmaking and visualization influenced their impressions of 3D apparel CAD usefulness. Another participant who had positive impressions of 3D CAD's usefulness based on their first use experiences discussed them in relation to their experience with 3D CAD programs for engineering. Participant F discussed their first use experience with 3D apparel CAD, stating that "all the tools and stuff were a lot more useful" in comparison to their experience with 3D CAD programs for engineering. Participant F's response is especially interesting because they were able to compare the usefulness of different programs, rather than comparing 3D design to physical design.

System characteristics that students perceived to influence the usefulness of the program also had to do with its undo capabilities, digital assets, and lack of limitations. Each of these have been discussed in detail in the previous category of participant-reported advantages.

User-Friendliness and Learning Curve

When discussing their overall experiences with 3D CAD programs in the textile and apparel industry, participants shared their impressions of the user-friendliness of the software and their beliefs regarding the learning curve. All ten participants discussed system characteristics in relation to the user-friendless or learning curve associated with using 3D apparel CAD. Six participants talked about aspects of 3D visualization or navigation, five mentioned interface navigation, five discussed the process and steps of program use, two spoke about system variation across programs, two mentioned undo and redo capabilities, two discussed the intersection between physical and virtual design processes, one talked about the number of options for use within a program, one discussed error detection, and one spoke about program aspects related to sizing. Notably, interface navigation differs from 3D visualization or navigation, such that interface navigation has to do with a program's overall interface complexity, design, and the ease of locating various tools and 3D visualization or navigation has to do with 3D arrangement, simulation properties, live visualization or program responsiveness, and 2D to 3D transfer. The following section has been categorized according to the system characteristic participants discussed in relation to the software user-friendliness and its associated learning curve. Overall, responses varied regarding 3D apparel CAD user-friendliness, such that some students believed the software to be user-friendly and others did not. The final category of this section provides an overview of students' impressions regarding the user-friendliness and learning curve associated with 3D apparel CAD.

3D Visualization and Navigation. Six participants believed that system characteristics of 3D visualization or navigation were connected to their impressions of the user-friendliness and learning curve associated with 3D apparel CAD. Participant C felt that the programs were not user-friendly and were difficult to learn because they believed 3D arrangement was difficult and required high levels of accuracy when placing garment pieces around the avatar to avoid simulation errors. Regarding the navigation of 3D arrangement and simulation, participant C expressed "I wish it was like an automatic, this is the structure of, you know, the fabric, for a more user-friendly experience." Participant J felt it was hard to use or learn 3D apparel software due to their experience struggling to arrange or move pieces within the programs, stating that sometimes “the only thing that moved was really the 2D versus 3D.” Participant K stated that it was difficult to “[switch] from 2D to 3D and, like, [figure] out how to, like, place my fabric, like, within the model.” However, participant K recalled that “a few of [their] classmates were using this tool where they could just place it, like, on the model in 2D and then it would transfer into 3D, but [they] had to, like, turn on a specific button, but it wasn't very obvious” so the majority of the students in the class did not use that tool. In comparison, participant D felt that there was an easy learning curve associated with 3D apparel CAD because of the system characteristics related to 3D visualization. Participant D thought that “being able to visually see the impact of what [they were] clicking and what [they were] doing, being able to see it live and, like, see those changes helps with the learning curve” because seeing the changes “automatically showing up, like, to me, that helps reinforce what the tools can do and, like, why or when you’re using certain tools” in the program. Similarly, participant E believed that 3D CAD programs for textiles and apparel were “really easy to figure out” because they were “super-duper responsive” in communicating design updates through 3D visualization. Participant F also believed that the system characteristics of 3D CAD programs for textiles and apparel related to 3D visualization and responsiveness influenced their positive impressions of the software’s user-friendliness and associated learning curve.

Interface Navigation. Five participants believed that their impressions of the user-friendliness and learning curve associated with 3D apparel CAD had to do with system characteristics related to interface navigation. Participant C believed that 3D apparel CAD have been programmed “to be more accessible” but that has “made it more complex”, making them harder to use and learn. Specifically, participant C felt that there were too many commands, or shortcuts, to complete on the keyboard and that tools were difficult to locate in the program interface because of “filters.” Participant J also felt the learning curve associated with 3D apparel software had to do with interface navigation in terms of locating tools. They believed that software could be “refined” with “a simpler layout” and by decreasing the number of “hidden” applications or sections within the interface. Similarly, participant K stated that “[they thought] the hardest thing about the program is… it's just really hard to navigate” despite having an introduction to tool functions and locations. Participant K felt that the programs were difficult to use and learn because of tool navigation and they specifically recalled that the tools were not labeled in the software interface and that some tools could only be accessed “in a very specific way.” Alternatively, participant D felt that 3D apparel CAD programs were “slightly more user friendly, slightly more intuitive” than other CAD tools for textiles and apparel. Participant D felt that 3D CAD programs were more user-friendly and easier to learn in comparison because “with the tools within [3D CAD] … like the naming and symbols and types of buttons and things, like, were more aligned with what their actual purpose was and functionality.” Participant F also felt that 3D CAD programs were easy to use because tools were clearly labeled or had pictures to indicate their functions, making interface navigation more straightforward. They stated that the programs were “very like intuitive to use” and they believed them to be “very modular… especially the way the tools are laid out”, such that the interface layouts helped them use and learn the software. The same participant also felt that 3D apparel CAD programs were easier to use in comparison to 3D CAD programs for engineering. Once participant F was exposed to and had their first use experience with 3D CAD for textiles and apparel, they felt those programs “made a lot more sense” and “[they] felt like they were more user-friendly” than 3D CAD programs for engineering.

Process and Steps of Program Use. Participants shared their impressions on the user-friendliness and associated learning curve of 3D apparel CAD, highlighting that their impressions were related to the number of steps required to complete tasks with the software. Participant A felt that the initial process before starting to sew was "kind of long and complicated," and expressed anxiety about potentially ruining everything if a single step was messed up. They believed that the need to start over after an error made the process very stressful.

Participant C felt that 3D apparel CAD was not user-friendly because there are many separate buttons for the same functions, “instead of having it combined” into one simple step. They noted that the programs “would be more accessible and beneficial if there were easier ways and methods to approach, like, certain tools and aspects”, suggesting that the number of steps required with 3D apparel CAD was overwhelming. Participant D echoed this sentiment, mentioning that even basic and simple tasks required multiple steps, which added unnecessary time. They suggested that a more efficient method for 3D apparel CAD use would involve fewer steps to achieve the same outcomes.

Participant G believed that different 3D apparel CAD software had varying degrees of user-friendliness due to the different processes required to use them. They stated that some programs had “faster ways to go about it”, while others required intricate and numerous steps. Participant H said 3D apparel CAD programs were “not necessarily the most user friendly but in the sense of you are using a lot of different components to create something so it's gonna be more complex…”, indicating that the steps required in the process of using 3D apparel CAD made it more difficult.

To summarize, participants felt that the user-friendliness and learning curve for 3D apparel CAD were made more complex and difficult due to the number of steps required to complete tasks. Participants made suggestions that fewer steps and increased software automation would improve user-friendliness and make 3D apparel CAD easier to learn.

System Variations. Regarding their impressions of the user-friendliness and associated learning curve of 3D apparel CAD, two participants discussed system variations across different programs. Participant G mentioned they felt some 3D CAD programs were easier to use than others, and that each program had its individual "use cases and benefits and… drawbacks." Participant J discussed system variation across different programs in terms of skill or knowledge transfer. Participant J "[thought] there is a heavy learning curve with a lot of these [3D programs] because they're… all very different and… they don't translate to one another."

Undo and Redo Capabilities. Two participants discussed undo and redo capabilities as a system characteristic of 3D CAD for textiles and apparel in relation to their impressions of its user-friendliness and associated learning curve. Participant K thought that one of the "hardest [parts]" of using and learning 3D apparel software was that there are "certain things you can't, like, undo" in the software. In contrast, participant H stated:

> I feel like a lot of people are hesitant when, like, learning a software to make mistakes and so I will say on the bright side I feel like a lot of the more modernized and more updated, like, CAD software, you know, you can make a mistake and you can, like, undo it, you know… So I think it is more user friendly in the in the sense of you are able to do mistakes and, like, you know just kind of undo it and have that trial and error that's kind of important to learning the software so yeah,

Physical and Virtual Design Intersection. Regarding their impressions of the user-friendliness and learning curve associated with 3D apparel CAD, two participants mentioned the impact of intersecting virtual and physical design methods. Participant F felt that 3D CAD programs were "really easy to, like, sort of pick-up" because when designing they could see "this is what you would do, like, if you were doing this… in real life" and they felt that "doing it on the software it's so similar and… it, like, really parallels with, like, the real life so well." Participant G discussed physical design methods in relation to their impression of the user-friendliness and learning curve associate with 3D CAD programs for textiles and apparel in the context of learning. They discussed that being "first taught the traditional methods" of garment design and "thinking in a more physical format versus on a program, there is a learning curve of how to apply those foundations to a different space where things work a little differently." Participant G believed that users of 3D apparel CAD programs can "achieve the same effect" of physical design methods "through different means" within the programs "but by being first given those foundations" of physical design methods "helped me to understand how… I can achieve the same goal through several different means." They emphasized that "understanding first the foundations and the basics" and "learning the longhand of why you do something in the program" was important before being introduced to shortcuts in 3D CAD programs because "you're still doing the same work just in a different space and kind of in a different language so to speak." Participant G also felt that there was a learning curve associated with transferring 3D garment designs to physical products. They stated that apparel designs "can look perfect in the program", specifically referring to CLO, but sometimes "if you try to print out those patterns or sew it up it's not going to work", which is "where I think that learning curve is." Participant G stated that both 3D and physical design methods "can be jointly used" so that there is an understanding of how to "translate [designs] correctly to industry" because "if the goal is to actually produce a real garment, then it needs to be something that is practical and can be deliverable."

Number of Options, Error Detection, and Sizing. The number of options for use within a program was another system characteristic discussed by one participant in relation to their impressions of the user-friendliness and learning curve associated with 3D apparel CAD. Participant B discussed their differing experiences and learning curves with Browzwear V-Stitcher and CLO, stating:

> I think CLO is a lot more specific in terms of adjustments that you can make to a patterns or fit or things like that. I felt like V-stitcher was a bit more, like, it had fewer options to choose from and that is good and bad for CLO because there's so many things you need to know for the adjustments but you can get the exact look you want so I think for me with the learning curve I just really I don't fully know what all the possibilities are because there are so many options to choose from and for someone who's experienced, like, that's really nice but for a beginner the user friendliness of CLO can be a little intimidating.

A different participant discussed system characteristics related to error deterring in the context of their impressions of the user-friendliness and learning curve associated with the use of 3D CAD programs. Participant A believed that 3D CAD programs would be more user-friendly and easier to learn if system characteristics that provide error detection were available. Participant K, also mentioned system characteristics related to sizing that impacted their impression of the user-friendliness and learning curve associated with 3D CAD programs, stating that sizing was one of the hardest aspects of using the programs.

Overview of User-Friendliness and Learning Curve. Participants discussed varying opinions on the user-friendliness and impressions of the learning curve associated with 3D apparel CAD when discussing their overall experience with using and learning the programs. Participant B expressed that their experiences with learning and using 3D apparel software had "been good" but "I think that because I'm still in the learning curve stage, some of it's a bit frustrating." Participant D also had a positive experience with learning and using 3D apparel CAD, revealing that "I had a pretty, like, easy learning curve I would say." Similarly, participant E expressed that "I've really enjoyed using [3D CAD]" and they believed the programs were "actually, like, really, really, really user friendly to, like, learn." In comparison to their experience with 3D CAD programs for engineering, participant F discussed their positive experience learning and using 3D CAD programs for textiles and apparel and stated, "that definitely in the fashion and textile industry they have done a phenomenal job on making these user-friendly." Participant H did not consider their experience with learning and using 3D CAD programs for textiles and apparel to be good or bad. Participant H stated that overall, their experience was "not bad" but that the programs were "not necessarily the most user friendly." Of all ten participants, only one participant felt that their experience with learning and using 3D apparel CAD was negative. Participant C stated that their experience was "absolutely terrible. It's terrible" and that they were "upset about it because [3D CAD] is not user-friendly when you're just learning about it especially when you have several things that are going on at the same time."

Prior Experience

The following section presents the extent of participants prior experience with 3D CAD programs in the textile and apparel industry and their impressions of the impact of prior experiences on their use and learning of 3D CAD software in the textile and apparel industry. Extent of prior experience and impact of prior experience of 3D CAD use and learning were identified as categories within prior experience. Moreover, extent of prior experience was separated into number of programs used and extent of 3D CAD academic incorporation. Although course incorporation of 3D CAD and extent of 3D CAD academic incorporation are related to similar topics, the categories differ such that course incorporation of 3D CAD has to do with how 3D CAD was incorporated into academic settings and extent of 3D CAD academic incorporation has to do with how much 3D CAD was incorporated with students' coursework and the amount of information provided.

Extent of Prior Experiences with 3D CAD

Number of Programs Used. Participants of the study were prompted to discuss how many prior experiences they had with different CAD programs for the purpose of 3D modeling textiles and apparel. The results are summarized below with a table that shows the number of participants in relation to how many different programs they had use experiences with.

Table 1.1 Number of Programs Used

Number of Participants	Number of Programs Experienced
6	1
1	2
1	3
1	4
1	5

Six of the ten participants had use experiences with only one 3D apparel CAD program. All six of those participants were undergraduate students, four of whom were freshman and two were seniors. One participant (B) had experience with two 3D CAD programs for textiles and apparel and was the only undergraduate student that had prior experience with more than one program. Participant B discussed that they had their first use experience with a 3D apparel software while attending a previous university and was introduced to a different program when they began attending their current university. The three participants who had use experiences with three or more programs were all graduate students. Participant H had used three different programs, G had used four, and F, five.

Overall, the findings showed that most undergraduate participants had experience with one program and only one of them had used two 3D apparel CAD programs. In comparison, participants who were graduate students had experience with 3 to 5 different 3D apparel CAD programs.

Extent of 3D CAD Academic Incorporation. Participants discussed how 3D CAD software for textiles and apparel had been incorporated into their coursework and projects, as well as providing insight to the extent of which 3D apparel CAD had been incorporated to their coursework and projects. Participant responses categorized here are related to their impressions on the learning outcomes associated with 3D apparel CAD, and their beliefs on their learning experiences in relation to 3D CAD incorporation.

Seven of the ten participants had experience with 3D apparel CAD being incorporated into their coursework or projects, often alongside other technologies like flatbed scanning, 2D pattern making software, or graphic design software. Participant A discussed designing textile prints by hand on a 2D paper template for a circle skirt and then scanning five of them into a computer to upload into CLO, which they found "wasn't too hard." Two participants mentioned using Gerber Accumark for creating flat patterns and then making alterations with 3D CAD programs, although Participant E found it "strange" to switch between different programs. One participant described the incorporation of 3D apparel CAD with physical design processes in their coursework. Participant G recalled that in an undergraduate class, they created physical patterns and a garment prototype, scanned the physical patterns into the 3D program, and "made additional alterations to the 2D patterns before they were on the 3D mannequin." Participant G noted their ability to incorporate 3D CAD programs into their graduate-level coursework or projects to create apparel designs "for a 3D person… in a 3D space."

Regarding the impressions of 3D apparel CAD incorporation, participant D, a fourth-year student, felt they received "some basic training" with 3D apparel CAD but it was not within an apparel industry context. They felt that their coursework did not contextualize the software's use in relevant industry settings. Similarly, participant H mentioned that 3D apparel programs were included in their coursework and projects when "applicable," but felt the class provided only "a very generic overview" of the software's with "very basic functions", without covering everything in detail. Additionally, participant H, a M.S. student, felt their exposure to 3D CAD tools was limited compared to industry or market examples. They believed there were different or better methods for using 3D CAD but noted that what they encountered in school seemed "pretty limited." They expressed a desire for more extensive exposure, stating, "I feel like there is more it's just that we're not being exposed to it."

Participant J described a "polarization" in their coursework, noting a stark contrast between their introduction to 3D apparel CAD during their first semester and a more intensive second semester. Initially, their classes covered only 3D apparel CAD basics, and the more technical aspects were introduced later. However, even then, participant J revealed students had limited access to the available tools in the software. Participant K, another first-year student, also felt the incorporation of 3D apparel CAD progressed over time but did not involve flat pattern making experience with the software. Overall, participants felt that while 3D CAD tools were introduced in their coursework, the exposure was often limited and did not fully encompass the more advanced or technical aspects of the software.

Impact of Prior Experiences on 3D CAD Use and Learning

In the context of their impressions of the user-friendliness or learning curve associated with using 3D CAD programs for textiles and apparel, five participants mentioned prior experience. As previously mentioned, participant B felt 3D apparel software with more options and use capabilities were great for experienced users but that "the user friendliness of [3D CAD] can be a little intimidating" "for a beginner." Participant C stated that 3D CAD programs were "not user-friendly when you're just learning about it especially when you have several things that are going on at the same time." Based on those impressions, participant C wished that had been given training on how to use 3D apparel CAD so that they had "an initial understanding" prior to experiencing the programs in a class setting. Participant H also felt that learning and using 3D CAD programs were "complicated especially if you're brand new to this and you're not able to, like, refer to, like, transferable skills from other CAD softwares that other students might have used before." Similarly, participant J stated that the user-friendliness and learning curve associated with 3D apparel CAD "makes it harder to be more independent with these types of programs if [students] don't have experience prior." Participant E stated that "there's definitely, like, a little bit of a learning curve" for 3D CAD programs but "if you have ever done, like, any sort of, like, technical CAD work, any sort of, like, Photoshop work… it kind of falls into the same kind of feeling." They felt that 3D apparel CAD programs were "pretty easy to figure out" "if you've done computer design stuff before."

Individual Differences

Participants discussed aspects of their experiences and attitudes toward 3D CAD software for textile and apparel development and design in relation to their individual differences, which emerged as notable theme from the data set. The main theme of individual differences was categorized by openness and individual goals, design preferences, practice and repeated use, interest and motivations, and impressions of personal abilities. Design preferences were further categorized as physical and virtual design in tandem and physical over virtual. Responses within individual differences of interest and motivations were organized as motivating and demotivating factors. The final category within the theme of individual differences, impressions of personal abilities, was categorized as sources of impressions of personal abilities and influences of impressions of personal abilities.

Individual Differences of Openness and Individual Goals

Openness to Continued Use and Learning. Participants discussed their openness to continue to learn or use 3D apparel CAD for their potential career in the industry. Participants who felt open to continue to learn or use 3D apparel CAD had varying degrees of response intensity, as well as several reasons for their openness. Participant responses that indicated they were open to continued use and learning of 3D apparel CAD are summarized in the following category. One participant did not clearly state whether they would be open to using or learning 3D CAD for their future career in the industry, but they did reveal that they had some interest to learn more about 3D CAD. Participant C did not clearly discuss their openness but felt slight interest in learning more but emphasized their wish that the programs were "easier to use."

Overview of Students' Openness. Many participants felt open to continuing to learn and use 3D apparel CAD for their future career. Responses varied in intensity and students discussed a number of reasons for their openness. Participant A felt positively open to continue to learn and use 3D apparel CAD, which they associated with wanting to become more comfortable with using the software. Participant B's response indicated they were very open as well. Participants D, E, and F all responded to whether they were open to continue using and leaning 3D apparel CAD for their future career with "definitely." Participant D disclosed that whether they continued or not was dependent on the opportunity. Participant E expressed that although they were open, they would never work solely with 3D apparel design and they would continue to work with physical and virtual design processes in tandem. Participant F attributed their openness to their positive use and learning experiences with 3D apparel CAD, as well as the benefits they associate with its use.

Similarly, participant G stated they were "absolutely" open to continue to use and learn 3D apparel CAD and they indicated they had a desire to improve their hardware so they could see the software's full benefits. Participant H did not provide additional details, but they also felt "absolutely" open to continued use and learning of 3D apparel CAD. Participants J and K revealed they were open to continue to learn and use 3D apparel CAD but gave one-word responses.

Individual Design Preferences

Physical and Virtual Design in Tandem. Three participants discussed preferred design methods that involved working with 3D apparel CAD in tandem with physical design processes. As previously mentioned, participant D would have preferred a design method with 3D CAD programs where they could assess the physical outcome to determine if there were any additional design or fit adjustments that would need to be made. Participant E revealed that their preferred design method is to work with 3D CAD programs and physical design processes in tandem, stating that “I never really rely solely on 3D so I always like to have kind of a mix of, like, just, like, 3D and also physical.” Participant E wished that there was a better method for recreating draping processes with 3D apparel CAD to achieve the same or better results they are capable of by hand. They did, however, feel “sure, like, there is, like, technically a way that I could, like, drape in [3D CAD programs] but I haven't figured that one out yet.” Similarly, participant F’s preferred method of working with 3D apparel CAD was “in conjunction with, like, hands-on stuff”, which they believed “has been really helpful.” They discussed that when they work with 3D apparel CAD “a lot of times I like to use them in conjunction with, like, doing drapes and stuff” because “I think it was helpful to see them both at the same time.”

Physical Over Virtual. Three participants revealed that they would have preferred to use physical design methods or physical resources over design methods that involved 3D apparel CAD when they had been tasked with using them. Participant A suggest that creating a half-scale version of their design might have been a better way to test it out, “…cause that would’ve been much easier and I wouldn’t have to worry about accidentally sewing the wrong way.” They realized that 3D apparel CAD may be quicker, but they placed value on being able to see their progress in real fabric. In the context of their design experience with 3D apparel CAD, Participant C adamantly said, “I’d rather do it physically to be very honest” and they “would not expect a student who’s not technologically adaptive to create, you know, 3 pieces or 3 garments.” Participant C felt physical apparel design was “a better method” because “you come out with a physical product that’s useful instead of having to do [3D design].” Participant F indicated that they enjoy working with 3D apparel software, but they did state that “one thing I wish that, like, if I could have done it a different way, like, I would have had… a copy of the fabric in real life," like "Swatch books and stuff with, like, virtual things like that which I think would have been a little bit helpful."

Practice and Repeated Use

Participants discussed their experiences with and impressions of learning 3D apparel CAD in relation to practice and repeated use or exposure to the programs. Responses suggested that participants commonly believed practice and repeated use was important to their learning experience. Participants A, B, and K responded similarly and revealed that they believed 3D apparel CAD learning was not too difficult and did not require too much time, it just requires practice and repeated use. Participant K stated some aspects of 3D apparel CAD were not hard to learn but it "comes with practice" and "some of the things would just get better the more I use it." Participant B discussed the consistency of practice, revealing "it doesn't take too long for me to learn" the programs "I just have to consistently practice it." They felt in their experience learning 3D apparel CAD at their university, instruction on the software had been inconsistent and that "if there's some consistency I feel like I would've learned a little bit quicker and remembered" more.

Participant C mentioned they had improved their 3D apparel CAD skill by practicing, stating that they were "taking notes on it and then putting in countless hours after" their studio class. Participant D revealed that they thought practice and repeated use in academic settings would help improve their 3D apparel CAD skill as well, however, there were no additional classes available for them to continue their training during their undergraduate program. Participant D discussed that they had a strong desire to take additional classes because they felt like practice and repeated use would have made them feel “more confident with the tool”, and they wouldn’t have lost the knowledge they previously gained over time.

Participant E’s experience demonstrated the impact of repeated exposure, which they felt was when they began to see the software’s full benefits and “really, like, learning more about the program and, like, using it on a more regular basis.” They also discussed that repeated use and practice increased their speed of using 3D apparel CAD and feelings of enjoyment. Participant E specifically stated, that to keep their skills sharp “it’s kind of the continual use honestly” and they later emphasized that consistency was key. Participant F felt similarly to participant E. They thought practice increased their confidence in and comfortability with using 3D apparel CAD and stated that they would practice to improve their skill with the software. Notably, participant F thought practice was the reason they felt comfortable learning and using 3D apparel CAD on their own. Participant J also reported that they had become more comfortable with using and learning 3D CAD programs after having repeated exposure to them in class settings. Similarly, participant G felt that they were comfortable with using and learning 3D CAD programs on their own because they’ve gone through “a lot of trial and error and trying things” and that they’ve chosen to design things that are “kind of fun or fancy” because that is when they’re “really excited to try and play” in the programs and “those are the instances that I learn the most and I also spend the most hours in the program.”

Many participants also found the learning process of 3D apparel CAD to be a "trial and error" experience. Participant H described their learning experience as "interesting" but "difficult because it’s trial and error," which they felt was intensified by their lack of prior CAD experience. They noted that "people are hesitant when, like, learning a software to make mistakes," but appreciated the modernized CAD software that allows users to "undo" mistakes, making the programs more user-friendly. Participant H emphasized the importance of being able to freely make and correct mistakes as crucial to learning the software. Participant H believed that "repetition is probably the best thing" for improving their 3D CAD skills, noting that through repetition, "you're most likely to remember" how to use the software, which has been helpful in their learning process. Despite this, participant H stated, "I don't have a lot of free time" to keep skills sharp through self-guided practice, though they expressed a desire to "take more classes to get a better understanding of the software." Participant B had similar sentiments, saying, "I wish I could say I have been practicing" but adding that they felt constrained by time.

Individual Differences of Interest and Motivations

Participants discussed various interests and motivations related to their learning and use of 3D apparel CAD. Responses regarding students' differences in interest and motivations are discussed throughout this chapter in previous sections, but this section has been included to provide the most notable responses and those that have not been included yet. The responses indicate the students' interests and motivations are formed through a variety of different sources and influence their learning and use of 3D apparel CAD in different ways. Responses have been categorized as motivating factors and demotivating factors.

Motivating Factors. Students' responses included motivating factors and positive influences on their interest that were related to individual goals, learning experiences, the benefits of using 3D apparel CAD, outcome experiences, social influence, and impressions of industry expectations.

Individual Goals. Participants revealed that they were motivated to learn and use 3D apparel CAD so they could increase their skill level and become more comfortable with software use. Participant B stated they were motivated to learn more about 3D apparel CAD so they could use the programs more effectively and efficiently, so “I don’t have to stress about it for, like, 20 minutes.” Their response indicated that they are motivated to improve their skill level, so they experience less emotional distress while using the programs. Participant F revealed they were motivated to continue learning 3D apparel CAD, stating “I know I want to learn more” so they can improve their skills and increase their use of the software in the design processes. Participant H and K were motivated to learn and use 3D apparel CAD because they wanted to be able to understand the software more and improve their skills. It was also discussed by many participants that their personal career goals, in relation to their beliefs about industry proficiency expectations, were a strong motivator to their use and learning of 3D apparel CAD. Details about those proficiency expectations have been previously discussed.

Learning Experiences as Motivators. Students’ responses about their motivations and interests were also related to their learning experiences. Participant B felt their academic experiences with 3D apparel CAD were positive and influenced their interest in the programs, especially because those experiences led them to believe 3D apparel CAD was not hard to learn or use. Participant G discussed that their positive learning experiences with 3D apparel CAD during their undergraduate program served as a motivating factor toward their continued learning and use of the software. Participant G and F also expressed their motivation for learning 3D apparel CAD was positively influenced by learning experiences that prepared them to overcome or troubleshoot challenges they may encounter within the programs.

Participant D felt that more students would be interested and motivated to learn and use 3D apparel CAD if teaching methods were revised, stating “instruction that prioritizes even more exploration and like more curiosity and just experimentation with it would encourage more people to, like, see deeper what is possible with the tools." Participant E felt their positive learning experience with 3D apparel CAD motivated them to continue their learning.

Benefits as Motivators. Participants discussed that the benefits they perceived to be associated with 3D apparel CAD use was a motivating factor for their continued learning and use of the software. Participant A and D were motivated to continue learning and using 3D apparel CAD because they felt its visualization capabilities enhanced their designs and design process. Participant A expressed that the benefits they associated with 3D apparel CAD use "motivates me to want to use it outside of schoolwork." Participant G felt their motivations to continue to learn and use 3D apparel CAD was heavily influenced by the software advantages, stating "that's really what inspired me to come back even for grad school, was just how incredible this program was." Participant F was motivated to continue learning and using 3D apparel CAD because they consider it to be extremely useful and they "can't wait to do it more in the future."

Outcome Experiences as Motivators. Participant D was interested in learning more about 3D CAD and stated that their curiosity was increased because they were "able to see my own designs in 3D" which "was very cool and, like, got me even more interested." Specifically, participant D stated their motivations to learn and use 3D apparel CAD were influenced by "definitely, like, the positive, yeah, outcome." Participant E discussed that they were able to improve their 3D apparel CAD skills significantly through self-guided learning, which positively influenced their interests in the technology and enjoyment with using the software. Participant G stated that "as somebody who really likes to see everything together" being able to see their design outcome with 3D apparel CAD "was just really encouraging and piqued my interest." Similarly, participant H felt "I think the end product is really interesting because then [you]…

create something very unique from what you're used to seeing" and they felt this motivated them to continue learning 3D apparel CAD.

Social Influence as Motivators. Social influence was commonly discussed by students as a motivating factor for their use and learning of 3D apparel CAD. Participant B revealed that their motivations to learn and use 3D apparel CAD were positively influenced by their professors and by seeing the creations of proficient users. Similarly, participant D felt motivated to learn and use 3D apparel CAD by seeing examples of other designer's work. Participants F, G, and H felt motivated to continue learning and using 3D apparel CAD because of their positive experiences learning alongside their peers. Participant K's interest and motivation was positively influenced by viewing the 3D design work of their peers.

Industry Expectations as Motivators. Most participants discussed aspects of industry expectations that positively influenced their motivation and interest to learn 3D apparel CAD. These responses have previously been discussed within the category of proficiency expectations.

Demotivating Factors. Participant responses revealed a variety of negative influences on their motivation and interest in learning and using 3D apparel CAD. Students' impressions of demotivating factors have been discussed throughout each theme and category, but the present section provides notable responses and summaries of each category. The categories of demotivators include learning experiences, knowledge, skills, and personalities,

The present category includes responses related to learning experiences, resources, and technology.

Learning Experiences as Demotivators. Students expressed specific aspects of their learning experiences demotivated them from learning and using 3D apparel CAD. Most notably, participant F was extremely demotivated to learn and use 3D apparel CAD because of their negative learning experience with 3D CAD programs for engineering. However, participant F was able to overcome their feelings of hesitations and decided to try learning 3D apparel CAD despite them. Participant G revealed that they had a negative learning experience where a professor showing little interest in their students learning demotivated them from learning 3D apparel CAD. Participant K felt that their learning experience with 3D apparel CAD was demotivating, stating that "It was very frustrating, like, I was very frustrated and did not want to touch CLO for, like, months after my first project and I was not looking forward to doing the project that I did."

Knowledge, Skills, and Personalities as Demotivators. Interview responses indicated that students were demotivated to learn and use 3D apparel CAD because of their knowledge, skills, and personality differences. Participant D stated that learning 3D apparel CAD "definitely requires, like, someone with, like, persistence and, like, genuine interest and curiosity" and that because they "personally enjoy the process of, like, learning new softwares" they "have, like, a high tolerance for, like, messing up and, like, figuring it out and troubleshooting." Participant H discussed that they would not choose to learn 3D apparel CAD on their own because of their knowledge and skillset, indicating that they would need someone who was proficient to teach them. They also discussed that learning 3D apparel CAD was "intimidating" for them because they did not have prior knowledge or skills with CAD.

Program User-Friendliness and Usefulness as Demotivators. Students' impressions of 3D apparel CAD's user-friendliness were often discussed as demotivating factors on their continued learning and use of the software. Participant C revealed they had slight interest in learning more about 3D apparel CAD, but they wished they programs were easier to use. Demotivating factors related to 3D apparel CAD user-friendliness and its associated learning curve have been discussed in greater detail within the category of user-friendliness & learning curve. Within that category, many responses revealed the demotivating and discouraging nature of 3D apparel CAD programs' user-friendliness and learning curve according to participants. Demotivation in relation to system usefulness, however, was not commonly discussed by participants. Participant C was the only one who expressed they lacked motivation and interest in learning and using 3D apparel CAD because they did not believe it was as useful or valuable as a physical design skill.

Resources as Demotivators. Participant responses indicate the lack of resources demotivates them from continuing to learn and use 3D apparel CAD. Participant B and H expressed that they were demotivated to learn and practice 3D apparel CAD outside of class because they did not have enough time. Participant B additionally felt they were demotivated to practice 3D apparel CAD on their own because they could only use the programs in the computer labs on campus as specific times of the day. Both participants B and D felt that students were also demotivated to learn and use 3D apparel CAD because of limited time in-class. Participant D revealed that despite their interest in learning 3D apparel CAD, they were demotivated from continuing their education with it because they could not take additional classes on the software during their undergraduate program. Participant E felt they were slightly demotivated to use 3D apparel CAD more because of its limited avatar and size choices. Participant H felt that lacking academic resources was a demotivating factor to their continued use and learning of 3D apparel CAD. Students' impressions of resources and their impact on their use and learning of 3D apparel CAD was discussed in more detail within the category of resources.

Technology as Demotivators. Students felt that their interest and motivation in learning and using 3D apparel CAD was negatively influenced by technology issues and challenges.

Participant D felt the software was frustrating and annoying to learn and use because of challenges associated with file management and saving, and hardware crashing, stating “I feel like that can kind of deter people overall, even though it isn’t as specifically related to, like, the software and its functions.” Participant G also believed that technology and hardware resources available at their university did not fully support the capabilities of 3D apparel CAD, which they felt demotivated students from learning and using 3D apparel CAD.

Impressions of Personal Abilities

Although aspects of participants’ impressions of their personal abilities to learn and use 3D apparel CAD have been discussed throughout the results chapter, the present section further categorizes participant responses for clarity. Participants’ responses indicated that their impressions of their personal abilities to learn and use 3D apparel CAD were formed through a variety of sources. The interview results also suggested that participants’ impressions of their personal abilities to learn and use 3D apparel CAD had numerous influences. Sources of impressions of personal abilities and influences of impressions of personal abilities have been categorized respectively.

Sources of Impressions of Personal Abilities. Participant responses indicated that their impressions of their personal abilities to use and learn 3D apparel CAD were formed through numerous sources. The interview discussions suggested that the sources of participants’ impressions of their personal abilities were learning experiences, individual learning differences, outcome experiences, system characteristics of 3D apparel CAD, and social interactions and observations. The following sections categorize participant responses according to the sources of impressions of personal abilities that were discussed.

Learning Experiences on Impressions of Personal Abilities. In relation to their impressions of their personal abilities, ten participants discussed their learning experiences, specifically their experiences learning 3D apparel CAD in academic settings. Participant responses indicated that learning experiences were a source of both positive and negative impressions of their personal abilities to use and learn 3D apparel CAD. Participant A's response illustrated that because they've had limited learning experiences with 3D apparel CAD they were not confident in their ability to use it on their own, stating, "…I don't think I could just start using it for my own work cause I've only used it once… I definitely think I need to learn more about it, more how to use it before I could feel confident using it in my work." Similarly, Participant D indicated that because of their limited learning experiences they lack proficiency and skill with using 3D apparel CAD. Despite participant D suggesting that their limited learning experiences with 3D apparel CAD caused them to have poor impressions of their ability to use the programs, they discussed that they believed in their ability to relearn the programs on their own due to their learning experiences. Specifically, participant D felt confident in their ability to relearn 3D apparel CAD because of "the extra time that I took to expand on what was [taught] in class." Participant D's responses illustrate that learning experiences may be a positive and negative source of students' impressions of their personal abilities to use and learn 3D apparel CAD.

Participant F's responses also indicated that their learning experiences had been both positive and negative sources of their impressions of their ability to use and learn 3D apparel CAD. Due to a negative experience during an engineering course for 3D CAD, when given the opportunity to learn 3D apparel CAD, they thought, "…I don't know if I really want to do this again" and that "…this isn't for me, like, I have flashbacks to the [3D CAD engineering] course and it was like ‘I don’t know if this is for me, I don’t think I’m going to be very good at this.” Despite having poor initial impressions about their personal abilities to learn and use 3D apparel CAD due to their negative experience with 3D engineering CAD, participant F was able to overcome their hesitations and took a university course to learn 3D apparel CAD. Overall, participant F expressed that their learning experiences with 3D apparel CAD had been positive and lead to them feel comfortable in their ability to use and learn the programs, which they explained, stating, “… I think honestly just being exposed to it in our curriculum, like how much they expose you to it. I think it's so helpful.”

Individual Learning Differences on Impressions of Personal Abilities. Nine participants discussed that their individual learning differences were a source of their impressions of their personal abilities to use and learn 3D apparel CAD. Participant G expressed that they were not initially confident in their ability to learn and use 3D apparel CAD because of their learning differences, stating, “…I'm pretty slow at picking up technology and it can feel pretty daunting sometimes…” They further discussed that because of their individual learning differences they “…had to spend so many hours figuring it out or practicing it” and “…that's what's pushed me to feel really comfortable with having to learn the program.” Participant G’s response illustrated that because of their individual learning differences they were not initially confident in their ability to learn and use 3D apparel CAD but gained confidence through practice.

Participant A discussed that they were confident in their ability to learn and use 3D apparel CAD due to their individual learning differences. They said, “…it doesn’t take me too long to be able to pick up on the process, so it’s really just trying out all the tools a few different times to be able to get comfortable with it…” In contrast to participant G, participant A’s response illustrated that their general confidence in their ability to learn technologies positively impacted their impressions of their ability to learn and use 3D apparel CAD. However, both participant G and A's responses demonstrated that their individual learning differences had impacted their impressions of their abilities to learn and use 3D apparel CAD and that confidence in their abilities was supported with practice.

Due to their individual learning differences, participant K revealed they were not fully confident in their ability to learn and use 3D apparel CAD on their own. They stated, "…I prefer to, like, be taught by someone who, like, knows what they're doing because I would be scared to teach myself the wrong thing and, like, potentially be doing it, like, wrong." Similarly, participant H stated, "…improving my skills on my own is something that I am hesitant on because normally I like to refer to somebody who's well versed in the CAD software…" and that they would not feel "confident" learning 3D apparel CAD on their own. Regarding 3D apparel CAD learning and use, participant J stated, "…I feel comfortable in my capabilities to go out and figure it out…" because they have resources and "because I'm getting walk through step by step…" Due to their individual learning differences, they indicated they would not feel as confident in their ability to learn and use 3D apparel CAD without support, stating "I feel like if I didn't have my notes and it was just the one time they show us what to do I'd be left like, 'I don't know what I'm doing'…" Participant K, H, and J's responses indicated that their impressions of their personal abilities to learn and use 3D apparel CAD independently were related to their individual learning differences.

Outcome Experiences on Impressions of Personal Abilities. Outcome experiences were revealed by eight participants as a source of their impressions of their personal abilities to use and learn 3D apparel CAD. Participant A revealed that they had a negative outcome experience while using 3D apparel CAD, which involved a mistake they made while sewing a 3D garment.

Due to this negative outcome experience, they indicated that they were not confident in their ability to troubleshoot errors while using 3D apparel CAD and if they made mistakes they would "…have to start all over…" Participant B expressed they had not been initially confident in their ability to learn and use 3D apparel CAD but once "…you finish your first project and you're like 'Oh wait, this actually is something that I could do and use regularly if needed'." Their response indicated that their outcome experience with using 3D apparel CAD positively influenced their impressions of their abilities to learn and use the programs. Similarly, participant D indicated that their positive outcome experience had influenced their impressions of their ability to use and learn 3D apparel CAD. Participant D stated, "Seeing a vision, like, actually work. You know, [it's] like 'I made this weird thing' but it actually [came] together so, definitely the positive outcome."

Participant F revealed that when they began learning and using 3D apparel CAD they had trouble with arranging fabric in the 3D window but overtime learned how to avoid making mistakes. Participant F expressed that due to their positive outcome experiences with troubleshooting and navigating challenges while learning and using of 3D apparel CAD that, "I feel like I've gotten more confidence with doing it…" They also felt that as they had become more confident in their ability to learn and use 3D apparel CAD they rarely experienced challenges or roadblocks.

System Characteristics on Impressions of Personal Abilities. Nine participants related their experiences and beliefs about 3D apparel CAD's system characteristics to their impressions of their personal abilities. As previously discussed, participant F expressed confidence in their ability to learn and use 3D apparel CAD and they indicated that 3D apparel CAD's system characteristics had been influential to those impressions. They stated that, in comparison to 3D engineering CAD, 3D apparel CAD "…made a lot more sense to me… I felt like they were more user-friendly…" and "…were a lot more useful." Participant F's response illustrates that their beliefs about 3D apparel CAD's system characters may have been a positive influence on their impressions of their personal abilities to learn and use the programs.

Participant G discussed that, "… to me, chunkier programs… [weren't] as intuitive to use." They revealed that their impressions of their ability to use 3D apparel CAD programs varied due to differences in system characteristics. Participant J felt similarly, expressing they did not feel fully confident in their ability to learn and use 3D apparel CAD programs because of the system characteristics and program differences. They stated, "…I think there is a heavy learning curve with a lot of these programs because… they're all very different…" Participant J also expressed that their difficulty with navigating 3D apparel CAD programs made them feel as though they were more prone to making mistakes, indicating that system characteristics of the programs had negatively influenced their impressions of their ability to learn and use 3D apparel CAD.

Participant H felt that 3D apparel CAD programs had been "difficult" for them to learn because "…you are using a lot of different components to create something so it's gonna be more complex…" They stated, "I feel like a lot of people are hesitant when, like, learning a software to make mistakes…" but that undo and redo capabilities made them feel more confident in their ability to learn 3D apparel CAD, because "…that trial and error, that's kind of important to learning the software…" Participant H's responses indicated that system characteristics could be positive and negative sources of their impressions of their abilities to use and learn 3D apparel CAD.

Social Interactions and Observations on Impressions of Personal Abilities. Social interactions and observations were indicated by eight participants as a source of their impressions of their personal abilities to use and learn 3D apparel CAD. Participants discussed social interactions and observations in relation to their peers, and industry professionals. Participant J revealed they had met with an advanced student to supplement their learning with 3D apparel CAD, "…so that I have a better understanding about it when I'm in other classes next year…" They discussed that interacting with another student to learn more about 3D apparel CAD helped them improve their ability to use the programs, indicating that social interactions had been a positive influence on their impressions of their personal abilities to learn and use 3D apparel CAD.

Participants J, K, F, H's responses indicated that their peer groups had also been impactful to their impressions of their personal abilities to learn and use the programs. Participant K expressed that they were more confident in their ability to use and learn 3D apparel CAD because they could rely on their peers for help. They also discussed that they were able to gauge their personal abilities with using and learning 3D apparel CAD as a result of their interactions with peers, stating, "…I kind of know where I'm at is if someone asks me a question and I'm able to answer it then I know that I know what I'm doing but if I can't answer the question then I'm kind of screwed." Participant F discussed that having peers learn alongside them with similar skills made them feel more confident and comfortable in their ability to learn and use 3D apparel CAD. They expressed this helped them realize it was not abnormal to experience difficulties with learning and using 3D apparel CAD, stating, "…if I run into a roadblock it doesn't mean that I don't know what I'm doing, it just means that I'm working through it…" Participant H felt confident in their ability to learn and use 3D apparel CAD when they were able to receive help from their peers in class.

Other participants also discussed that their observations of others using 3D apparel CAD in industry and interacting with industry professionals made them feel more confident in their ability to learn and use 3D apparel CAD. Participant F illustrated that their impressions of their ability to learn and use 3D apparel CAD were positively influenced through their interactions and observations of industry professionals. They stated it made them realize 3D apparel CAD "…is not something that's super hard, it really is something that I think anybody can do…"

Influences of Impressions of Personal Abilities. Participant responses illustrated that their impressions of their abilities to use and learn 3D apparel CAD had influences on their emotions, impressions of 3D apparel CAD, learning and use motivations, interests, and learning processes. Participant responses have been categorized respectively and discussed further below.

Emotional Influence. Eight participant responses illustrated that their impressions of their personal abilities to use and learn 3D apparel CAD influenced their emotions. Participant G discussed that a negative learning experience made them doubt their abilities to learn and use 3D apparel CAD, stating, "…it made it really frustrating and challenging…" Participant H revealed that they did not have initially positive impressions of their personal abilities to learn and use 3D apparel CAD because they didn't have prior experience and that it had a negative impact on their emotions. Similarly to participant G, participant H expressed that they felt frustrated because they were "…not understanding it right away…" Participant J also felt frustrated when they were initially learning and use 3D apparel CAD but as they became more confident in their ability to learn and use 3D apparel CAD they indicated they did not experience as many negative emotions. Participant K stated when they used 3D apparel CAD for a project the first time

"…since I barely knew what I was doing and everything was just not working out well I was very frustrated." Their response indicated that their impressions of their ability to use and learn 3D apparel CAD caused them to experience negative emotions. Participant A also felt that their impressions of their ability to use and learn 3D apparel CAD effectively initially caused them to experience anxiety.

Influence on Impressions of 3D apparel CAD. Impressions of their abilities to use and learn 3D apparel CAD were revealed by nine participants as an influence on their impressions of 3D apparel CAD. Participant A indicated that they did not feel confident in their ability to use 3D apparel CAD without making mistakes and this influenced their impressions of 3D apparel CAD's user-friendliness. Participant B discussed their impressions of 3D apparel CAD's impact on their creativity, which they felt was influenced by their impressions of their personal abilities to learn and use the programs. They stated they were not entirely sure how 3D apparel CAD had impacted their creativity because "…I haven't had enough experience to know what I could do." Participant C expressed that they were more confident in their ability to create physical garments in comparison to 3D apparel CAD, which led them to believe that physical processes were a better design method than virtual ones.

Participant D revealed that they believed that the process of using 3D apparel CAD was long and required a lot of steps, even to create simple designs. However, they expressed that their impressions of the 3D apparel CAD design process may be influenced by their ability to use them, stating, "…I never was able to take any higher level courses so I'm assuming that there are a lot more work arounds than I'm aware of." Participant D's response indicated that their impressions of their ability to use 3D apparel CAD impacted their impressions of the software. Participant E felt that as they learned more about 3D apparel CAD and became better at using the programs their impressions of the programs positively increased, stating that was when "…I really started to see the benefit of it…" Participant E's experience illustrated that as their impressions of their ability to use 3D apparel CAD increase, their impressions of the programs became more positive.

Influence on Learning and Use Motivations. Nine participants discussed influences of their impressions of their abilities use and learn 3D apparel CAD on their learning and use motivations. Participant K revealed that due to their initial experience with using and learning 3D apparel CAD they were not confident in their ability to use and learn 3D apparel CAD, which Influenced their motivations to continue using and learning the programs. They stated, "…I was very frustrated and did not want to touch [3D apparel CAD] for like months after my first project and I was not looking forward to doing the project that I did." Participant E discussed that they were not confident in their ability to recreate physical design processes, such as draping, with 3D apparel CAD and because of this they "never really rely solely on 3D so I always like to have kind of a mix of just 3D and also physical." Their response indicated that their impressions of their ability to use 3D apparel CAD for recreating physical processes influenced their motivations to solely use the programs in their design process.

Participant F discussed that their impressions of their ability to use 3D apparel CAD to create certain apparel design influenced their motivations to continue to learn and use the programs. They revealed they practice recreating physical garments with the use of 3D CAD, which allows them "…to see how am I doing with this, what sort of shapes and silhouettes am I comfortable with, what things that, do I need to work on…" Participant H expressed that they had poor impressions of their ability to use and learn 3D apparel CAD, which demotivated them to learn and use the programs on their own. Due to their poor impressions of their ability to use and learn 3D apparel CAD, participant H stated, regarding independent use and practice with the programs, "…most likely I'm not going to do it on my own."

Impact on Interests. Impressions of personal abilities to use and learn 3D apparel CAD were revealed by eight participants as impactful to their interests. Participant H expressed that due to their impressions of their ability to use 3D apparel CAD they became interested in taking courses about them, stating, "…I was very interested in taking classes involving like 3D stuff… so I can better understand it…" Regarding one of their projects using 3D apparel CAD, participant J stated, "…I'm very happy with how they turned out…" but that their 3D garments were "typical". They indicated they had some confidence in their ability to use and learn 3D apparel CAD, but that because they only created basic apparel designs, their interest to use 3D apparel CAD was positively influenced so they could "…see like how outside of the box you can go with [3D apparel CAD] and how dramatic we can push the boundaries of what designing is." Participant J's response indicated that their impressions of their personal abilities, and desire to test their personal abilities with using 3D apparel CAD, positively influenced their interest to create more complex or extravagant designs within the programs.

Participant K revealed that they did not initially have high impressions of their ability to use and learn 3D apparel CAD and because of this, "…I probably wouldn't have like grabbed it or known about it if I wasn't required to do it in the project like being completely honest." Their response suggested that their interests in 3D apparel CAD were initially low due to their impressions of their abilities to learn and use the programs. Participant B discussed that once they began learning 3D apparel CAD they realized, "…it's not too difficult to learn…" and they became more interested in the programs. Participant B illustrated that their interest in 3D apparel

CAD was positively influenced by their impressions of their ability to use and learn the programs.

Impact on Learning Processes. Participants' impressions of their personal abilities to use and learn 3D apparel CAD was also discussed by seven participants as having influence on their learning processes. Participant H stated, "…the limitations of my personal knowledge on the software… exploring that on my own without knowing what I have to do is probably gonna be a limitation in my learning and proficiency process." Their response suggested that they felt their personal abilities to use and learn 3D apparel CAD would negatively impact their learning process. Participant D expressed that they had positive impressions of their ability to use and learn 3D apparel CAD because of its undo and redo capabilities. In relation to their learning process, participant D stated, "…that is how I tend to learn a lot is by doing it and figuring it out… being able to learn by experience definitely had, has an impact on me…"

Participant K did not feel confident in their "…basic computer skills because I don't really, I never took a computer class…" They explained that their lack of computer skills negatively influenced their learning process with 3D apparel CAD. Participant K's response indicated that their poor impressions of their ability to effectively use and learn 3D apparel CAD was a result of their impressions of their abilities with general computer skills, and that both impressions led them to believe that their learning process had been hindered. Participant C felt that individuals who were better at creating physical apparel designs were not as capable of learning and using 3D apparel CAD. They expressed that because they were better at creating physical apparel design, they were not as able to easily learn and use 3D apparel CAD. Participant C's responses indicated that they felt their learning process for 3D apparel CAD was negatively impacted by their impressions of their abilities to use and learn them.

Results Summary

The results showed the emerging themes from interview responses, which include industry awareness, organizational support, social influence, system characteristics, prior experience, and individual differences. Within each of these categories, participant responses varied and categories of responses for each theme were identified.

Within industry awareness, interview results showed that participants were introduced to 3D apparel CAD across various points in time but were all generally introduced to the technology through sources of higher education. It was found that participants had positive, mixed, and negative initial impressions of the programs due to a variety of reasons. The results showed that participants identified numerous advantages and uses of 3D apparel CAD in the industry and had generally positive beliefs about its benefits. Participants of this study also shared how they thought 3D apparel CAD had impacted their design process. Interview responses also demonstrated participants differing knowledge and understandings of a variety of industry trends and those understandings influenced their impressions of 3D apparel CAD. It was found that participant responses were dependent on their industry observations, their beliefs about the technology usefulness, their understandings of adoption and implementation challenges, and their individual differences and goals. The main theme of industry awareness had aspects of motivations 3D apparel CAD use and learning throughout, as reported by participants.

Within the major emerging theme of organizational support it was found that many participants experiences and impressions of 3D apparel CAD were influenced by instruction mode and course structure impressions. Participants had varying beliefs regarding the nature of the influence of instruction mode and course structure on their impressions and experiences with 3D apparel CAD. Participant responses demonstrated that students' experiences with learning and using 3D apparel CAD were influenced by both academic and external resources that were available to them. It was also found that participants felt either prepared or unprepared because of their experiences with organizational support. Participants have varying degrees of preparedness and revealed a number of skills they felt would prepare them further. Organizational support was found to have aspects of learning and use motivations throughout and were notably revealed through participant responses.

Social influence was identified as a major theme of the results. The results showed that social influences of others impacted participants' understandings and impressions of 3D apparel CAD. It was identified that social influences were a source of differing participant motivations to use or learn 3D apparel CAD. System characteristics were another emerging theme that included categories of impressions of 3D CAD usefulness and user-friendliness and learning curve. Both categories were found to have a variety of responses that demonstrated how participant beliefs about the system usefulness and its user-friendliness and learning curve influenced their impressions of 3D apparel CAD or were the result of their experiences with them.

Another emerging theme was prior experience. The results revealed that students had various exposure levels to different 3D apparel CAD programs and that their experiences with the technology differed in nature by extent. Regardless of the exposure and extent differences, it was found that prior experiences were influential to participants beliefs, attitudes, and learning with 3D apparel CAD, as well as served as assorted motivations.

The final theme that emerged from the data was individual differences. Participant varying responses revealed that individual differences, including openness and individual goals, individual design preferences, and practice and repeated use beliefs, influenced their impressions and motivations to use and learn 3D apparel CAD. However, it was found amongst those categories, and across each theme, participant responses included additional motivating and demotivating factors that influence their use and learning of 3D apparel CAD. Motivating factors to use or learn 3D apparel CAD included individual goals, learning experiences, 3D apparel CAD benefits, outcomes experiences, social influence, and industry expectations. Demotivating factors were categorized as learning experiences, knowledge, skills, and personalities, program user-friendliness and usefulness, resources, and technology. Participant responses also revealed that they had individual differences or varying sources of their impressions of their personal abilities to learn and use 3D apparel CAD, and that those impressions had numerous influences. The sources of impressions of personal abilities that were discussed included learning experiences, individual learning differences, outcome experiences, system characteristics, and social interactions and observations. Participants discussed that their impressions of their personal abilities had influences on their emotions, impressions of 3D apparel CAD, their learning and use motivations, interests, and learning processes. The conclusions of these results are discussed in the following chapter.

Chapter Five: Conclusions

3D apparel CAD skills have become increasingly desired within the textile and apparel industry and there is a need for working professionals with 3D CAD proficiency (Dal Forno et al., 2023; Hodges et al., 2020; Papachristou et al., 2019; Papahristou & Bilalis, 2017; Tepe & Koohnavard, 2023). However, due to the emerging nature of 3D CAD in the textile and apparel industry there is limited research on the pedagogical practices for teaching them and insufficient understandings of students' experiences, attitudes, and perceptions of 3D apparel CAD learning and use (Dal Forno et al., 2023; Hogue et al., 2021; Rosca et al., 2023). The purpose of this study was to explore textile and apparel students' awareness of 3D CAD technologies in the industry, the nature of their acceptance of the technology, and their views on motivating and demotivating factors related to their learning of the programs. Social Cognitive Theory (SCT) (Bandura, 1986b), self-efficacy theories, the Technology Acceptance Model (TAM) (Davis, 1989), the extended Technology Acceptance Model (TAM2) (Venkatesh & Davis, 2000), and the existing research literature on 3D apparel CAD, were used in the development of the interview guide and in the thematic analysis of the data and the present conclusions. Inductive reasoning was also used to analyze the results and generate conclusions. The study was guided with the following research questions:

RQ.1 What is the extent of students' awareness of 3D Computer-Aided Design (CAD) technologies in the textile and apparel industry, and what are their perceptions of the industry's expectations regarding their proficiency in 3D CAD skills?

RQ.2 What is the nature of students' acceptance of 3D CAD technologies used in the apparel industry?

RQ.3 What do students feel motivates or demotivates them to learn or use 3D CAD technologies relevant to the textile and apparel industry?

To address the research questions ten in-depth interviews were carried out with textile and apparel students (undergraduate and graduate) who had experience with using and learning 3D apparel CAD in academic contexts. This sample population was chosen to obtain valuable insight to students' experiences to understand 3D apparel CAD education and its influence on students' beliefs and attitudes of the technologies. The interview results were transcribed verbatim, analyzed, and categorized through inductive and deducting reasoning, which resulted in the emergence of important themes. In total, five major themes emerged from the data analysis that included relevant categories and the findings were closely related to the theories that inspired the development of this study. Conclusions are organized in the following sections according to these research questions.

Awareness of 3D CAD

The subsequent section outlines conclusions derived from the interview results of this study that address research question one. Participant responses illustrated the extent of their awareness of 3D apparel CAD and their impressions of the industry's proficiency expectations for the technology. When applicable, these conclusions are presented alongside and supported by the existing research and findings, which have been covered in the review of literature.

Initial Awareness, Sources and Time of Acquisition

The interview responses indicated that students' awareness of 3D apparel CAD was formed through a variety of sources and at varying points in time. It was found that all ten participants gained awareness of 3D CAD technologies in the textile and apparel industry through academic contexts or experiences related to colleges or universities. This finding suggests that higher education institutes play a role in students' exposure to 3D apparel CAD and shaping their awareness of the technologies. Although each participant gained awareness of 3D apparel CAD in relation to academia, the point in time at which students gained awareness varied. Notably, four participants gained awareness prior to becoming enrolled at a university, five learned once they become enrolled at a university but prior to their first use experience, and one participant learned in a course setting while having their first use experience.

Participant responses also indicated that student's awareness of 3D apparel CAD was strengthened through several different sources such as academic instructors and industry professionals, and peer groups.

Regarding academic instructors as sources of awareness, these interview results suggested, for these participants, that apparel students' 3D CAD awareness was deepened during early coursework experiences, even if the acquisition of 3D CAD skill and proficiency was not the primary focus of the class. Specifically, it was indicated that students' may be aware of 3D apparel CAD but that when the complexity of the software programs is emphasized by academic instructors, while classes focus on developing basic skill sets, the resulting anxiety can deter students from deeper engagement with the technologies.

Industry professionals were identified by Hodges et al. (2020) as a valuable source in the formation and deepening of students' awareness of 3D apparel CAD. As indicated by Hodges et al.'s (2020) study, students felt more positively about 3D apparel CAD and had stronger motivations to learn the technology when their awareness was gained or strengthened through industry professionals. The participants of the current study exhibited responses which illustrated their experiences with industry professionals and industry employment regarding 3D apparel CAD as a source of their awareness, as discussed by nine of the ten participants. Not only did these participants indicate their experiences with industry professionals and industry employment as a source of awareness, but their resulting beliefs suggest that these experiences impacted their understandings of 3D apparel CAD uses, advantages and industry proficiency expectations, in addition to motivating these participants to learn the technology. These findings are consistent with what was previously found by Hodges et al. (2020). That participant awareness was gained or deepened through contact with industry professionals and that this contact helped them understand proficiency expectations and motivated them to learn 3D CAD also reflects Venkatesh and Davis's (2002) finding that subjective norms directly impacted intention to use and use expectations

The findings of this study could also indicate that academic professionals as sources of awareness, specifically those in favor of 3D apparel CAD, could positively influence students' intentions to learn or use the technologies, as demonstrated by Venkatesh and Davis's (2002) study where it was found that subjective norms had direct effects on intention to use when use was mandatory. In the context of this research study, 3D apparel CAD use was mandatory at times for the participants of this study and in those cases, industry awareness of proficiency expectations was especially influential to students' impressions and attitudes toward the software.

Participant responses in this study also revealed that peers were a source of 3D apparel CAD awareness. Many students reported that their awareness of 3D apparel CAD was gained or deepened through their peers. These findings suggest thar peer groups as sources of awareness may contribute to the acquisition of knowledge pertaining to 3D apparel CAD and could influence students' beliefs about academic proficiency expectations.

In terms of technology adoption attitudes, Bandura (1986b) advanced with SCT that personal characteristics are a partial determinant but that time differences in innovation adoption could be explained by the point at which an individual was first exposed to the innovation, the knowledge they acquire at that point, and its influence on their behavior. Considering this, evaluations of innovation adoption that do not assess time and extent of initial exposure can be misleading (Bandura, 1986b). Based on SCT, the time at which students gain awareness of 3D apparel CAD and the extent of exposure are important details in understanding their acceptance attitudes and behaviors. The findings of this study cannot specifically demonstrate that participants who were exposed to 3D apparel CAD later than others exhibit less acceptance of the technology because the sample population varied by age and academic standing, therefore relative comparisons of the time at which students were exposed could be misconstrued by varying degrees of experience, knowledge, and skill with the technology. However, the findings of the current study do suggest that the students' extent of exposure to 3D apparel CAD played a role in shaping their awareness, attitudes, beliefs, and impressions of 3D apparel CAD. Extent of exposure and extent of awareness are discussed in the following section.

Extent of Exposure

Another notable finding had to do with the extent of students' initial exposure to 3D textile and apparel CAD, which indicates that students' initial awareness of the technologies may be generally unaccompanied by pertinent information or use opportunities resulting in delayed knowledge acquisition. Students who were exposed to 3D apparel CAD prior to university enrollment discussed having limited information or knowledge on the software when they gained awareness and indicated that they did not have use opportunities until college. Interestingly, the participant (D) who was exposed to 3D apparel CAD while participating in a university-lead program for high schoolers was not given the opportunity to use the software but was instead instructed on 2D CAD tools. Participant C's experience demonstrates how limited information at the time of initial exposure to 3D apparel CAD can negatively impact students' impressions. They discussed that when they attended a university hosted fashion show with 3D apparel designs, they didn't understand why there were no physical garments, which they felt was "odd", "pointless", and "a waste of time".

Participants who gained or increased their awareness of 3D apparel CAD after becoming enrolled at a university also expressed that the extent of their exposure and use opportunities were limited. Significantly, two of the three graduate students who participated in this study revealed that they gained awareness of 3D apparel CAD during their undergraduate programs but were not provided with extensive information or learning and use opportunities with the software until graduate school. Participant H, one of those graduate students, illustrated how their limited exposure to 3D apparel CAD negatively impacted their learning process, stating that they felt learning 3D apparel CAD was difficult and "complicated especially if you're brand new to this and you're not able to, like, refer to, like, transferable skills from other CAD softwares that other students might have used before". Only participant E did not gain until they had an opportunity to use and learn the software in class. Participant E expressed that they struggled with learning and using 3D apparel CAD because they had never used a 3D program before, which lead them to have initially mixed impressions about the technologies.

These findings indicate that the extent to which students are initially exposed to 3D apparel CAD may influence their impressions and attitudes toward 3D apparel CAD, in addition to influencing their learning processes and impressions of their learning experiences. This is supported in the research literature suggesting that students' prior knowledge is significantly related to self-efficacy (Ineson et al., 2013) and that self-efficacy beliefs are positively related to performance (Yi & Davis, 2003). If students' extent of exposure and awareness of 3D apparel CAD technology play a role in influencing and developing students' positive self-efficacy beliefs, thus improving their learning and skills, supporting and facilitating students' initial awareness and the extent of which students are initially exposed to 3D apparel CAD are important aspects in relation to students' overall impressions, attitudes, experiences, and learning processes with 3D apparel CAD.

Extent of Exposure and Experience. Students' experiences with 3D apparel CAD were examined in terms of number of programs used, how 3D apparel CAD had been incorporated to their education, and the impact of their experiences on 3D apparel CAD use and learning. Conclusions regarding students' experiences have been categorized below accordingly.

Extent of Programs Used. Six out of ten participants had experience with only one 3D apparel CAD program. All six were undergraduate students with four being first-year students and two being fourth-year students. Only one undergraduate first-year student had experience with two different 3D apparel CAD programs. This participant had used two programs because they had previously attended another university that focused on teaching a different 3D apparel CAD software to its students. Of the three graduate student participants, one had used three programs, one had used four, and one had used five software programs.

This finding suggests that student's exposure to different 3D apparel CAD programs is limited due to the software their university chooses to implement and their student standing. Educational institutions play a crucial role in preparing students for the industry but teaching and learning CAD technologies effectively is challenging. At most universities, teaching commercially based CAD programs is prioritized as they are commonly used in students' respective fields and future careers. Textile and apparel brands frequently change employee requirements or responsibilities alongside quickly evolving technology and software, making acquired knowledge obsolete. Universities should focus on teaching fundamental principles of CAD to enable students to adapt and use any CAD tool effectively (García et al., 2007).

The results suggest that undergraduate students' exposure to and learning of 3D apparel CAD is limited in comparison to that of graduate students. As a result, students who are looking to enter the industry workforce after completing their undergraduate degree may not have an extensive understanding of 3D apparel CAD programs and may therefore be unable to easily adapt their skill sets to other software or may lack the ability to learn alongside evolving technologies in the industry. Some students expressed their concerns regarding their abilities, or their current knowledge and skill set with 3D apparel CAD. For example, both participants B and J, who were undergraduate students with experience with only one program, felt that learning 3D apparel CAD software could be harder for different programs but because their awareness of those technologies was limited, they were unsure and could not determine if they'd be able to rely on their current skillset to help them learn a different one.

Extent of 3D Apparel CAD Incorporation. Few participants discussed positive aspects related to how 3D apparel CAD programs had been incorporated to their textile and apparel coursework. Overall, it was suggested that participants believed the academic incorporation of 3D apparel CAD at their university was limited, inconsistent, and not very well related to industry practice. In terms of limitations, participants felt 3D apparel CAD learning was restricted to certain majors and programs, and often only covered software basics. Participants also felt that their learning experiences with 3D apparel CAD was inconsistent. It was discussed that participants would receive 3D apparel CAD training for brief periods, then longs spans of time would occur where no additional training was provided, interrupting participants' learning processes and reducing the amount of information they were able to retain. Participants also discussed that their 3D apparel CAD education had not been contextualized with actual industry practice. This resulted in participants lacking knowledge about how 3D apparel CAD programs are used in textile and apparel businesses, which included limited understandings of which departments may use 3D apparel CAD, how those departments would utilize them, and how or if 3D apparel CAD was used in relation to PLM and manufacturing.

These findings illustrate that, although participants exhibited high awareness of 3D apparel CAD benefits and industry related trends, some felt their academic experiences with the technology were inadequate. Participants who felt their academic exposure to 3D apparel CAD was limited revealed that they believed they were missing important knowledge and information, leading to them feeling less confidence in their skills. This finding was demonstrated by participant H, who did not feel capable of learning and using 3D apparel CAD on their own because the learning experiences and opportunities have been limited. Additionally, participants expressed that they were missing industry context which suggests students may be capable or proficient with 3D apparel CAD use but that they lack the knowledge or confidence to implement the tools within industry settings. This finding was illustrated by participant D, who expressed they did not feel prepared to use 3D apparel CAD in industry practice due to the lack of industry contextualized training on 3D apparel CAD. These findings emphasize the importance and need for examining and developing educational practices surrounding 3D apparel CAD to more adequately support student learning and industry preparedness.

Prior Experiences on 3D Apparel CAD Use and Learning. Participants in this study placed high importance on prior experience and knowledge of CAD and 3D apparel CAD in relation to their learning and use experiences. Participants with prior experiences with CAD, knowledge, and skill with CAD design software (both 2D and 3D) were able to easily learn and use 3D apparel CAD and had more positive feelings regarding their experiences. However, many participants felt that learning and using 3D apparel CAD was extremely difficult, complex, and intimidating for beginners. Participants discussed that learning 3D apparel CAD with too many use options or tools can be overwhelming for new users. Other participants felt that the lack of prior experience or training made learning 3D apparel CAD difficult because they couldn't refer to transferable skills or knowledge from other program learning experiences. These participants advocated for supplemental 3D apparel CAD learning options, such as pre-training opportunities or training sessions they could attend outside of class time.

Awareness of 3D CAD in Industry

From these interview results, it was revealed that participants' awareness of 3D apparel CAD varied by time at which awareness was gained, the source of which awareness was achieved or strengthened, and the extent of exposure and awareness of 3D apparel CAD. Participant responses related to 3D apparel CAD advantages or uses and industry trends served as additional indicators of the extent of their awareness. The following section has been categorized according to those responses to provide conclusions in a logical format.

Awareness of 3D CAD Advantages. Participants' responses about 3D apparel CAD advantages suggested that they had varying understandings of the technologies use applications in industry and its benefits. Participants discussed several advantages of 3D apparel CAD including visualization, prototyping, time and cost savings, sustainability, communication, and accessibility. Most of the participants were aware of the advantages of 3D apparel CAD related to visualization, prototyping, time and cost savings, and sustainability. Participants who were academically more advanced (graduate students and fourth-year undergraduate students) exhibited the greatest extent of awareness of 3D apparel CAD advantages in the industry.

These responses indicate that participants' awareness of 3D apparel CAD's benefits is extensive and suggests they have a general understanding of the industry needs that can be addressed with the technologies implementation and use. Moreover, participants exhibited generally positive beliefs about the advantages of 3D apparel CAD which suggests that they believe the software is a valuable tool within the industry. The finding that graduate and fourth-year undergraduate students had more extensive knowledge about 3D apparel CAD industry advantages follows logical expectations that students' knowledge will grow as they advance through their program of study.

Awareness of Industry Trends. The results indicate that participants have an extensive degree of awareness of industry trends in relation to 3D apparel CAD technologies. However, participants' awareness of industry trends seemed to be less extensive than their awareness of 3D apparel CAD advantages. Participants were aware of industry trends related to sustainability, industry advancements and evolving expectations, digitalization and technology innovation, textile and apparel marketing, and influences of the COVID-19 pandemic. Of those trends, participants were most aware of industry digitalization and technology innovation, which they felt was related to increasing interest in 3D apparel CAD implementation. Based on those responses, it seemed that participants believed 3D apparel CAD technologies were continually advancing and becoming more useful. This may indicate that students with awareness of industry digitalization and technology trends are more likely to perceive 3D apparel CAD to be useful and have more positive feelings regarding the software.

Industry trends for environmental sustainability were highlighted by multiple participants. Their responses suggest that students are concerned about environmental sustainability and believe the textile and apparel industry is working towards increasing sustainability efforts, in part through the implementation of3D apparel CAD. Despite overall awareness on the part of participants of environmental sustainability trends, only one discussed supply chain sustainability. This suggests that students lack awareness of the textile and apparel supply chain, its challenges, and how 3D apparel CAD can be used to improve supply chain processes.

Based on participants' trend awareness, it was indicated that students who have higher levels of awareness of industry trends, or students who are aware of 3D CAD trends, have positive impressions and attitudes toward 3D apparel CAD. However, participants who could not directly link their understandings of 3D CAD use in the textile and apparel industry to trends still believed the tools to be extremely useful, valuable, and important to learn, indicating that they were aware of 3D apparel CAD's increasing popularity regardless of their awareness of other related industry trends

Awareness of Proficiency Expectations

The interview responses showed that participants were mostly aware of 3D apparel CAD proficiency expectations in the textile and apparel industry, demonstrated by their understanding that 3D apparel CAD would play a role in their professional development, that they would be likely to encounter the software on the job, and they would be expected to know how to use the technology. An important finding was that participants' understandings of industry proficiency expectations was a motivator to learn and use 3D apparel CAD, which is discussed further in the section dedication to learning motivations. There was only one participant who did not believe they would be expected to know how to use 3D apparel CAD.

Participant responses indicated they are aware that industry expectations about 3D apparel CAD use vary depending on the type of job position. Responses indicated that participants believed specific jobs would require knowledge and use of 3D apparel CAD while others would not, or that some positions would have higher skill expectations than others. Generally, most participants believed that fashion design jobs in the textile and apparel industry would require high skill levels with 3D apparel CAD. Only two participants discussed that technical design positions within the textile and apparel industry would require 3D apparel CAD skill. These responses suggest that students lack awareness regarding different types of jobs within the textile and apparel industry and how they use or could benefit from the use of 3D apparel CAD technologies. Participants may be unaware of different types of jobs, or they may believe that 3D apparel CAD proficiency would only be expected for industry design positions. Participant D's response illustrates this. They specifically stated that they lacked awareness of "Industry examples of, like, how it plays out and, like, what functional teams in a real setting would actually be, like, interacting with the tool and, like, the designs made through 3D" and they believed that they would not be likely to encounter 3D apparel CAD or be expected to use it on jobs that were not creatively focused.

Through participants' responses regarding proficiency expectations, it was revealed that only some participants lacked awareness about the state of 3D apparel CAD adoption and implementation in the textile and apparel industry. Most participants were confident that 3D apparel CAD would play a role in their professional development, that they'd be likely to encounter them, and that they would be expected to know how to use them. Only three participants were hesitant about 3D apparel CAD expectations in the industry due to the difficulties of adoption and implementation. Those three participants still felt 3D apparel CAD was a valuable skill, but whether they would be expected to have those skillsets was dependent of industry implementation. Of those three participants, two were graduate students and had extensive knowledge about the difficulties of implementing 3D apparel CAD. The other was a first-year student and expressed that 3D apparel CAD implementation for large companies could be difficult or slow, however they did not respond in as much detail as the other two students.

Overall, these findings suggest that students are aware of 3D apparel CAD proficiency expectations and believe the industry places value on 3D apparel CAD skills. It could be assumed that the only participant who did not believe 3D apparel CAD skills would be expected of them in industry settings may hold these beliefs due to their extremely negative experiences with 3D apparel CAD. Despite participant responses that suggested they had awareness of 3D apparel CAD proficiency expectations; responses showed that very few participants were concerned with the adoption and implementation of programs in industry. The findings also suggest that students lack information regarding the implementation process of 3D apparel CAD and it current adoption rate within the industry. Only a few participants discussed the difficulties of implementing 3D apparel CAD and discussed they had previously had higher expectations for industry implementation of the technology based on their work and academic experiences. However, it was demonstrated that those participants became aware of implementation difficulties as they gained more work and academic experiences. Due to their beliefs about implementation, these participants expressed hesitations that 3D apparel CAD would play a role in their professional development and were not confident they would encounter them on the job. Notably, it was exhibited that participants who were aware of implementation difficulties were not demotivated to learn or use 3D apparel CAD but did feel greater hesitations that they would be expected have 3D apparel CAD skills or to use them on the job.

Acceptance

This section details conclusions derived from the interview results of this study that address research question two. Through analyzing participants' interview responses, the researcher was able to understand the nature of students' acceptance of 3D CAD software used in the textile and apparel industry. As conclusions were made, links were made between the findings of this study and the reviewed literature from chapter two.

Nature of Acceptance Related to Impressed Advantages

Participants discussed and understood advantages of 3D apparel CAD in relation to their impressions of the technology's usefulness and their personal use experiences. The following section specifically discusses participants' impressions of 3D apparel CAD's usefulness formed through their personal use experiences with the technology, rather than the advantages participants' were aware of in relation to the technology's industry benefits. Assumptions regarding participants' acceptance of 3D apparel CAD have been drawn from their responses regarding the technology's advantages and usefulness, which can be supported by research and extensions of the Technology Acceptance Model (TAM) (Davis, 1989). Research literature shows that technology acceptance is positively influenced by perceptions of a technology's usefulness.

Participants discussed various aspects of 3D apparel CAD which they considered to be useful, demonstrating that the nature of their acceptance could be generally positive. Participants also indicated that 3D apparel CAD had been useful to them because of its system characteristics or functional capabilities, which included rapid prototyping, design comparison, and visualization. Specifically, it was illustrated that participants believed 3D apparel CAD was useful to them because they could quickly and easily make prototype adjustments, compare design options, and visualize their designs before creating physical versions.

Participant responses illustrated that 3D apparel CAD visualization had been useful to their learning processes as well, which they discussed as benefiting their visual learning and deepening their understandings of physical design processes. The interview results suggest that participants felt 3D apparel CAD was useful because it helped increase their understanding of patternmaking processes and how 2D patterns translate into 3D. This finding suggests that 3D apparel CAD can be used as an effective educational tool in enhancing apparel students' skills, as demonstrated by Park et al. (2011) and Baytar (2018). This finding also suggests that students have positive attitudes about 3D apparel CAD's usefulness in academic settings, furthering the assumption that students have positive attitudes of acceptance of 3D apparel CAD.

It was further indicated that participants felt 3D apparel CAD was useful because of its ability to reduce waste and costs, which was an aspect of usefulness they affiliated with their personal use and industry implementation. This finding was demonstrated by participant D, who indicated their creativity could be restricted by the cost of fabric, leading them to design simple garments, and that they were personally concerned about wasting fabric, issues both of which they believed 3D apparel CAD could mitigate. In terms of accessibly, one student felt that 3D apparel CAD was useful to them because they were able to design when and where they wanted, and they were not limited by their physical abilities.

Participants also revealed through their responses that time reductions were another useful aspect of 3D apparel CAD. They discussed that 3D apparel CAD's system characteristics speed up the design process in comparison to typical physical methods. However, participant C felt that designing with 3D apparel CAD took them longer than physical design methods and their responses overall indicated a generally negative attitude of acceptance toward 3D apparel CAD. This finding demonstrated that participants had differing impressions of 3D apparel CAD usefulness, leading to varying attitudes of acceptance of the technology. Participant C's responses that they believed 3D apparel CAD was not easy to use are interesting in the context of research linking impressions of ease of use and usefulness (Davis, 1989), however as this result represents the experience of one participant, a clear link cannot be made.

In summary, it was discovered that participants had mostly positive beliefs regarding the usefulness of 3D apparel CAD, indicating that the overall nature of their acceptance of the technology was positive. This finding is supported by Davis's (1989) finding that perceived usefulness was a significant determinant of actual system use, illustrating usefulness as a motivation to adopt technology and influence on attitudes of acceptance.

Usefulness in Creativity and Design Process. Participants were asked to specifically discuss their thoughts about 3D apparel CAD's advantages or usefulness in relation to their creativity and design process. The results demonstrate that participants generally felt 3D apparel CAD was useful to enhance their creativity and design process. However, there were response variations, which included two moderate opinions and one participant revealed that 3D apparel CAD negatively impacted their creativity and design process. Despite this, the results overall indicated that most students had positive beliefs of the usefulness of 3D apparel CAD in terms of their creativity and design processes, indicating positive attitudes of acceptance overall.

Responses demonstrated that participants' creativity and design processes were enhanced with 3D apparel CAD through reduced constraints, and visualization and iteration capabilities. Participants revealed that 3D apparel CAD allowed them to design without having to worry about mistakes or errors and helped them to take more design risks, which helped to enhance their creativity and design process. Additionally, participants perceived the technology to be useful in enhancing their creativity and design processes because it gave them immediate visual feedback and allowed them to quickly experiment and trail design ideas.

Two participants had moderate opinions regarding 3D apparel CAD's usefulness in enhancing their creativity and design processes. These participants did not perceive any direct benefits to their creativity or design process afforded by 3D apparel CAD, but they did have positive and consistent attitudes regarding the usefulness of the technology overall. The nature of their responses may have to do with how they understand concepts of creativity and what they personally perceive as an enhancement to their creativity or design process.

Nature of Acceptance Related to User-Friendliness and Learning Curve

Based on their responses, participants had varying impressions of the user-friendliness and learning curve associated with 3D apparel CAD and they attributed their beliefs to numerous aspects of their learning experiences such as organizational support and system characteristics. The following conclusions have been organized according to organizational support and system characteristics. Throughout this section, connections are made between the results of this study and the findings of the existing research literature that was previously discussed within the literature review. Overall, it was revealed through participant responses that they had varying beliefs about the user-friendliness and learning curve of 3D apparel CAD, which influenced the nature of their acceptance of the technology. Due to their varying impressions of the user-friendliness and learning curve of 3D apparel CAD, it was indicated that participants also have differing attitudes of acceptance of the technology.

Organizational Support on User-Friendliness and Learning Curve. Organizational support was discussed by the participants of this study and it was found that instruction mode and course structure, and resources were related to students impressions of 3D apparel CAD's user-friendliness and learning.

Instruction Mode and Course Structure. It was revealed that participants believed aspects of the instruction mode or course structure influenced their impressions of 3D apparel CAD's user-friendliness, and their learning curve. In this regard, it was indicated that participants felt 3D apparel CAD was difficult to learn because of insufficient or vague instruction, deficient foundational training, and limited personal guidance. This finding demonstrated that the participants of this study were not entirely satisfied with their 3D apparel CAD learning experiences and that the nature of those experiences had negative impacts on their impressions of the software user-friendliness and learning curve. A similar finding was illustrated by Park et al.'s (2011) study, which found that students did not feel positively about their use of 3D apparel CAD or learning experiences with the software in comparison to lecture and studio instruction methods. Thus, the findings of the current study may further indicate that there is a relationship between students' impressions of instruction method and their views on system user-friendliness and learning curve.

The similarities of this study's findings and Park et al.'s (2011) are additionally demonstrated when considering the previously discussed finding that the participants of the current study had overall impressions that 3D apparel CAD was beneficial, which was understood and discussed as usefulness. The previously discussed finding of positive impressions of usefulness and the current discussion regarding this study's finding that participants considered 3D apparel CAD easy to use are supported by Park et al.'s (2011) finding that students believed 3D apparel CAD was useful but did not have positive impressions about their use and performance with the system. Overall, the findings of the current study illustrate a potential relationship between students' impressions of instruction and system user-friendliness and learning curve. This finding is illustrated by participant K's interview response that they thought 3D apparel CAD would have been easier to learn and use if they "had been guided a little bit better throughout that process".

In relation to course structure, participants revealed that limited class time and lack of pretraining opportunities negatively impacted their beliefs about the user-friendliness and learning curve of 3D apparel CAD. Participant responses suggest that students may have more negative impressions about the user-friendliness and learning curve of 3D apparel CAD because of short class times, which limit their instruction and learning and leads them to struggle with 3D apparel CAD use. Pretraining opportunities were discussed more commonly throughout the interviews of this study. Participant responses indicated a belief that 3D apparel CAD would have been easier to learn and use if prior instruction opportunities were available or if they had additional prior knowledge about the software. This finding could be supported by self-efficacy theories and Ineson et al.'s (2013) findings, which revealed that students' prior knowledge and ability had positive relationships with self-efficacy. Therefore, the findings of the current study may suggest that prior knowledge or ability, obtained through pretraining or other organization support measures, would positively influence students' beliefs that they are able to easily learn and use 3D apparel CAD.

Academic Resources. It was found that participants' impressions of 3D apparel CAD user-friendliness and learning curve were influenced by their understandings and beliefs about academic and external resources. Participants revealed varying impressions. Some thought academic resources were inadequate or needed improvement, while others reported academic resources were helpful in supporting their learning and These views on resources seemed to influence their beliefs about 3D apparel CAD user-friendliness and learning curve. The academic resources that were found to be lacking, inadequate, need of improvement, or helpful were pretraining and supplemental learning opportunities, in-class or instructional resources, and technology and hardware. Participants indicated a belief that pretraining opportunities were limited and it that this negatively impacted their impressions that 3D apparel CAD was easy to learn. Supplemental learning opportunities were suggested by participants as a resource that could be added as organizational support measures to positively influence their learning experiences.

Participants also expressed that learning 3D apparel CAD through exploration helped improve their feelings of comfortability with using the software, indicating that this positively influenced their impression of its user-friendliness. The need for explorative learning opportunities was demonstrated by participant B, who felt that if they could explore 3D apparel CAD more broadly, without class limitations, they would be more comfortable with using 3D apparel CAD. These findings could be supported by Inseson et al.'s (2013) study, which demonstrated that prior knowledge and ability positively influence self-efficacy beliefs. Thus, the results of this study may indicate that textile and apparel students who participate in explorative learning are able to increase their knowledge and ability, subsequently increasing their self-efficacy beliefs, making them feel more comfortable using 3D apparel CAD. This finding is especially important because, as argued by Bandura (1986b) and demonstrated by Yi and Davis (2003), perceived self-efficacy significantly influences task performance, which indicates that students who have higher levels of self-efficacy could more easily utilize 3D apparel CAD successfully, suggesting there may be a relationship to students' impressions of 3D apparel CAD's user-friendliness. It may be valuable to consider the nature of self-efficacy and its relationship to achieving positive outcomes with 3D apparel CAD, such that it may increase students' perceptions of usefulness and subsequently improve their attitudes of 3D apparel CAD acceptance.

Another resource type that was revealed as influential to participants' learning experiences and impressions of 3D apparel CAD was in-class and instructional resources. Participant responses demonstrated that class time, class instructions, additional learning support resources, instructor support were all resources that they felt would positively influence their ability to learn and use 3D apparel CAD while in-class. Participants believed their learning was limited due to the amount of time they had during class. This suggests that time is especially important to the learning process with 3D apparel CAD. Existing research literature supports this finding, demonstrating that the amount of time required to gain a full understanding of 3D apparel CAD is a major challenge experienced by individuals during its learning process (Hodges et al., 2020; Papahristou & Bilalis, 2016a; Papahristou & Bilalis, 2017). Therefore, it is suggested that more time allocated to learning 3D apparel CAD would mitigate some of students' learning curve with the technology.

Another learning limitation that was identified by the participants of this study was the lack of 3D apparel CAD education that was contextualized within industry uses and applications. Participant responses revealed that classroom instruction lacked industry examples and did not adequately support students' understanding of how 3D apparel CAD is implemented and used within industry practice. The importance of this finding is highlighted by Hodges et al.'s (2020) finding that apparel students believed 3D apparel CAD to be more valuable, useful, and relevant to their future careers when instruction was framed through industry context and presented as an industry learning opportunity. Hodges et al. (2020) also found that industry context and framing of 3D apparel CAD instruction positively impacted students' overall leaning of the technology. Considering their findings, the results of this study further suggest that students highly value industry context and relevancy when leaning 3D apparel CAD. Participant responses also indicated that efforts should be made to provide industry examples and context while learning 3D apparel CAD in academic settings.

Another type of academic resource that participants' responses pointed to was hardware or technology. The participants of this study indicated that they believed hardware and technology resources, such as individual software licenses, computer lab access, and sufficient computer hardware, were influential to students' learning process with 3D apparel CAD. For example, participant B felt that their learning of 3D apparel CAD was limited because they couldn't access the licenses on their personal computer and were restricted to computer lab use on campus to specific times of the day. It was also commonly reported that university-provided hardware technology was viewed as insufficient to support 3D apparel CAD technology.

External Resources. Through the interview results of this study, it was discovered that external resources influenced participants' beliefs about their learning experiences and their impressions of how easy 3D apparel CAD was to learn or use. Participants discussed various types of external resources, including resources embedded within software interfaces, resources provided by 3D apparel CAD vendors, and online resources. These resources are grouped here as external resources because they are not directly affiliated with academic institutions. Participant responses illustrated differing beliefs about the sufficiency of these external resources. Despite the differences that were discovered, participants revealed that their understandings and beliefs related to external resources were influential to their learning process and overall impressions of 3D apparel CAD.

Many participants believed that external resources related to 3D apparel CAD were limited or inadequate. These participants discussed that 3D apparel CAD programs were missing introductory tips, search functions, help manuals, and error detection. However, the participants who expressed dissatisfaction with external 3D apparel CAD resources were all first-year students, and the external resources they discussed actually are generally available within the software interface. Based on their responses and student standing, this finding may suggest that these participants have not been properly informed about the external resources that are available to them. Despite the nature of their awareness regarding these resources, it was further revealed through these participant responses that they felt 3D apparel CAD would be easier to use and learn if these external resources were available. Their responses demonstrate how lack of resource awareness, or limited resources, can negatively impact students' impressions of the user-friendliness and learning curve of 3D apparel CAD.

In contrast, many other participants responded that external 3D apparel CAD resources were sufficient and incredibly beneficial to their learning process. Participants who were aware of them indicated that these resources made the software easier to learn and use. These participants felt numerous external 3D apparel CAD resources had been beneficial to them, including resources that were imbedded within software interfaces, online resources and communities, and vendor supported resources. Notably, those participants who felt most passionately about the benefits of external resources were graduate and fourth-year students.

Specific participant responses pointed to beliefs that there are ample online resources that can support 3D apparel CAD learning and use, imbedded resources are easily accessed and helpful, online communities can assist with answering peculiar questions, and vendor hosted classes provide additional and sufficient learning opportunities. It was further identified through participant responses that these resources were believed to be beneficial due to their accessibility and because they guided participants on how to use the programs effectively. Participant G revealed that a vendor-hosted class for 3D apparel CAD was an independent and self-guided learning opportunity that supported their learning through step-by-step instructions, videos, and practice files. Participant G's responses pointed to their positive impression of this external resources, as well as indicating they have extremely positive impressions of their learning process with 3D apparel CAD. As reported by Hodges et al. (2020), students believed practice with 3D apparel CAD to be the most important aspect of their learning process. Thus, the results of the current study may further suggest that learning opportunities that support and encourage practice are highly valued by students and are significantly influential to their learning processes, as well as to their impressions of their learning experiences.

Based on this study's findings, it could be assumed that external 3D apparel CAD resources are influential to students' learning processes, their feelings about their learning experiences, and their impressions of how easy it is to learn or use 3D apparel CAD. In relation to the nature of students' acceptance of 3D apparel CAD, these findings may further suggest that organizational support in the form of resources may influence their acceptance attitudes through influencing their impressions on the user-friendliness and learning curve associated with 3D apparel CAD. Moreover, these findings may further suggest that organizational support resources may influence students' attitudes of acceptance by impacting their impressions of 3D apparel CAD usefulness.

System Characteristics on User-Friendliness and Learning Curve. Participant's interview responses revealed that their impressions of 3D apparel CAD user-friendliness and learning curve were associated with their thoughts on system characteristics. Specifically, participants' impressions of 3D apparel CAD user-friendliness and learning curve seemed to be impacted by their thoughts about 3D interface navigation, steps associated with system use, variations of CAD programs, undo and redo capabilities, intersections between digital and physical process steps, system options, error detection, and system sizing difficulties.

3D and Interface Navigation. Participants discussed that aspects of 3D and interface navigation impacted their impressions of the user-friendliness and learning curve of 3D apparel CAD. Some participants believed 3D apparel CAD was difficult to learn and use because system 3D arrangement and navigation required high skill levels to perform successfully. However, some participants believed 3D navigation and real-time simulation positively influenced their impressions about 3D apparel CAD's user-friendliness and learning curve because it helped them understand the steps they were completing within the software, which they felt made it easier to learn and use.

Overall, interface navigation was revealed by this study's participants as an influence on their impressions about 3D apparel CAD's user-friendliness and learning curve. Some participant responses demonstrated that 3D apparel CAD interface was difficult to navigate, such that they believed it was difficult to locate specific tools or that the layout was complex, which made them feel that 3D apparel CAD was not easy to learn or use. In contrast, it was found that some participants believed 3D apparel CAD interfaces to be easily navigated and streamlined in their designs, which they related to their own ease of learning and use of the programs. These findings indicate that students' beliefs about 3D apparel CAD interfaces differ and are related to their impressions about the user-friendliness or learning curve of 3D apparel CAD. Despite the varying responses of interview participants, these findings suggest that additional interface navigation support could effectively support student learning by improving students' thoughts on 3D apparel CAD's user-friendliness and learning curve.

Steps of System Use. Participants expressed that the steps of 3D apparel CAD use made using the programs more complex and difficult. Participants discussed that too many steps were required to complete even simple tasks within 3D apparel CAD, which they expressed added time to the process and made the programs harder to use. This may indicate that increased process automation and fewer steps would make 3D apparel CAD easier to use.

These findings suggest that students' beliefs about the steps required to use 3D apparel CAD influence their impressions of system usefulness and its user-friendliness, thus indicating that system characteristics associated with steps play a role in forming students' attitudes of acceptance of the technology. This assumption is supported by Davis's (1989), Venkatesh and Davis's (2000), and Yu's (2018) research on technology adoption and findings that perceived ease of use and usefulness influence attitudes of technology acceptance. Based on these findings and the existing literature, it may prove to be beneficial for 3D apparel CAD developers to improve software automation and reduce required steps to improve users' perceptions of ease of use and usefulness, subsequently improving users' acceptance of their programs.

3D CAD Variations. System variations were also revealed through participant responses as an aspect they attributed to the user-friendliness and learning curve of 3D apparel CAD. Participant G felt that different 3D apparel CAD programs were easier to use and learn in comparison than others. Their response also indicated that they believed certain 3D apparel CAD programs were more useful at times than others due to their differing system characteristics. This insight is notable because participant G had used five different 3D apparel CAD programs.

Regardless of the number of programs participants had used, it was revealed through their responses that they were still concerned with how 3D apparel CAD system may vary and how those variations may impact their impressions of user-friendliness. For example, participant J's responses indicated they believed 3D apparel CAD systems varied significantly. They discussed that this made them feel the programs were more difficult to learn because they could not easily transfer the knowledge and skills they had acquired about one program to another.

These findings suggest that 3D apparel CAD system variations, and students' understandings of those differences, impact students impressions of the programs' user-friendliness and learning curve. Students' beliefs about system differences may influence their impressions of 3D apparel CAD usefulness. which may in turn influence the nature of students' acceptance of the technologies through influencing their impressions of user-friendliness, learning curve, and usefulness.

Intersecting Design Processes. Participant responses suggested that intersecting physical and digital design processes influenced their beliefs regarding 3D apparel CAD's user-friendliness and learning curve. Participant responses suggested that 3D apparel CAD was easy to learn because it mimics physical design processes. It was also indicated that participants thought learning physical design processes before 3D apparel CAD made it easier to learn and use the software because the same design steps are required, they just need to learn how to complete them in a digital environment.

These findings suggest that students with prior knowledge and skill with physical design processes may consider 3D apparel CAD easier to learn and use. This finding is supported and demonstrated by Papahristou and Bilalis's (2017) study, which revealed that 3D apparel CAD users believed effective and efficient use of the software was dependent on pattern making experience.

Additional System Characteristics. Participant responses revealed that a number of other system characteristics impact their beliefs about 3D apparel CAD's user-friendliness and learning curve. The interview results of this study indicated that undo and redo capabilities, system options, error detection, and sizing functions were system characteristics that impacts students' impressions of 3D apparel CAD's user-friendliness and learning curve.

Participants discussed that undo and redo capabilities impacted their impressions of 3D apparel CAD user-friendliness and learning curve. Participant K's response demonstrated that using and learning 3D apparel CAD was difficult because there were certain steps within the program they could not undo. However, they felt this was the result of limited information on program abilities.

Participants also believed 3D apparel CAD was easier to learn due to its redo and undo capabilities, which they viewed as system characteristics supporting trial and error processes. Participant H, for example, indicated that trial and error processes were especially important to their learning process. Participant responses also indicated that undo and redo capabilities of 3D apparel CAD could reduce hesitations to learn and use the software because mistakes can easily be undone. Considering these participant responses, the results of this study may indicate that undo and redo capabilities influence students' impressions of 3D apparel CAD user-friendliness and learning curve, in addition to reducing their hesitations to participate in those behaviors. Therefore, these findings may further suggest that students who think positively about system characteristics such as undo and redo capabilities are more likely to have positive attitudes of acceptance of 3D apparel CAD.

System options also seemed to influence participant impressions of 3D apparel CAD user-friendliness and learning curve. Participant responses indicated that too many system options within a program can be overwhelming to learning 3D apparel CAD, indicating that those systems would be considered less user-friendly. However, participants also indicated that increased system options increased their design abilities, indicating that systems with more options are considered to be more useful. These findings further suggest that system options may influence the nature of students' acceptance of 3D apparel CAD through impacting their impressions of system user-friendliness and usefulness.

Additional system characteristics that seemed to influence participant beliefs about 3D apparel CAD user-friendliness were identified as error detection and sizing functions. Responses suggested that greater error detection abilities would make 3D apparel CAD easier to use and learn because students could easily see where mistakes were being made. However, this finding may be due to the participants lack of awareness of error detection in 3D apparel CAD programs, suggesting that greater efforts should be made within academia to raise students awareness of these beneficial tools. Regardless of the participant awareness of these tools, the finding indicates that error detection may benefit students learning process and make them feel the software is easier to learn and use, thus influencing the nature of their overall acceptance.

Learning and Use Motivations

The following section discusses motivations to learn and use 3D apparel CAD, which were revealed by the participants and have been used to address research question three. Interview responses indicated factors that may motivate or demotivate students to learn and use

3D apparel CAD. Participants' motivations varied and were related to a number of different sources. Participants discussed that they were motivated to learn and use 3D apparel CAD due to individual goals, beliefs of personal abilities, learning experiences, the benefits and outcomes of use, social influences, and industry expectations, indicating that each of these categories play an important role in encouraging student learning and use of the software. Demotivating factors were revealed through participant responses as learning experiences, knowledge, skill, and personality differences, program user-friendliness and usefulness, resources, and technology. The following categories have been used to organize the following section of conclusions and are presented below: individual differences, experiences, user-friendliness and usefulness, organizational support, and social influence.

Individual Differences on Motivation

Participant responses indicated that individual differences were a source of motivating and demotivating influences to learn and use 3D apparel CAD. Responses revealed that participants were motivated or demotivated to learn and use 3D apparel CAD due to their knowledge, skill, and personality differences, which were highlighted through participant responses that had do with their impressions of their personal abilities to learn and use 3D apparel CAD. It was additionally indicated that participants were motivated to learn and use 3D apparel CAD because of their individual goals, which included learning and skill goals and career goals.

Participants indicated that knowledge, skill, and personality differences could serve as demotivation to learn and use 3D apparel CAD. Participants indicated that they may be demotivated to learn and use 3D apparel CAD, especially on their own, due to their impressions of their ability to effectively learn and use the software. This finding indicates that students who exhibit poor self-efficacy beliefs related to 3D apparel CAD are less likely to feel motivation to learn and use the technology. Responses also suggest that learning and using 3D apparel CAD requires perseverance and interest. Participants without perseverance and interest were easily demotivated to learn and use 3D apparel CAD. For this study, participants' responses indicated that their impressions of their personal abilities also influenced their interests in 3D apparel CAD and their learning process.

These findings point to the importance of self-efficacy's role in students' motivation to learn and use 3D apparel CAD. This assumption is supported by Web-Williams's (2018) and Gravill and Compeau's (2008) research findings, which showed that students self-efficacy beliefs heavily influenced students' academic engagement and learning motivations. Gravill and Compeau's (2008) study also revealed that self-efficacy beliefs not only motivated students to learn software, but determined whether they would persevere while learning, and the influences of self-efficacy on motivations and perseverance were found to enhance students' overall learning outcomes. Thus, the existing literature and the findings of the current study call attention to the importance of self-efficacy beliefs in the formation of student motivation and perseverance and indicate that self-efficacy beliefs may play an important role in enhancing student learning of 3D apparel CAD.

The importance of self-efficacy and its influence on motivation, learning processes, and learning outcomes were further indicated by the results of this study. Participant responses indicated that they felt their impressions of their abilities to learn and use 3D apparel CAD, regardless of how those impressions were formed, impacted their learning process of 3D apparel CAD. This finding is supported by Gravill and Compeau's (2008) and Yi and Davis's (2003) research. Gravill and Compeau (2008) found that students believed their confidence in their abilities was important to their learning processes and that students with higher self-efficacy beliefs did have more positive learning outcomes because of self-efficacy's influence on perseverance and motivation. Yi and Davis (2003) also found that self-efficacy positively and significantly influenced learning processes and learning outcomes. The existing literature and the findings of this study stress the importance of self-efficacy in student learning. The findings of this study especially demonstrate that self-efficacy may play a significant role in the use and learning of 3D apparel CAD through its influence of student motivations.

Notably, it was also suggested by the participants of this study that students may be motivated to learn and use 3D apparel CAD so that they could increase their knowledge and skill levels. Participants' responses indicated that they were motivated to improve their knowledge and skill with 3D apparel CAD so that they would feel more comfortable and confident with using the programs. Therefore, it could be assumed that students are interested in improving their own self-efficacy beliefs by improving their skills. For example, participant B suggested that they felt motivated to improve their 3D apparel CAD skill because they did not want to feel emotionally distressed due to their inability to effectively use the program. As argued by Bandura (1977, 1997) and shown by Web-Williams (2018) emotions are a source of self-efficacy beliefs. Participant B did not allow negative emotions to demotivate them from learning and using 3D apparel CAD, rather they served as a motivating factor to learn and use the software so they could improve and reduce their negative feelings. Interestingly, the results of this study did not suggest emotions had been a source of participants' impressions of their personal abilities. However, the results of this study did indicate that participants' impressions of their personal abilities influenced their emotional responses to using and learning 3D apparel CAD. Other participants indicated that they were motivated to learn and use 3D apparel CAD to improve their knowledge and skill despite their struggles and frustrations.

Participants also indicated a motivation to learn and use 3D apparel CAD due to their individual career goals and their impressions of industry proficiency expectations. Responses suggest that participants are more motivated to learn and use 3D apparel CAD if they believe they will be expected to be proficient with the software for the specific career they aspire to obtain upon graduation. Similar findings from Hodges et al.'s (2020) study indicated that students were more motivated to learn, had greater appreciation for instruction, and had improved learning outcomes due to their understandings of 3D apparel CAD's relevancy in the industry and to their future careers. This finding indicates that emphasis should be placed on communicating industry expectations through multiple methods to increase student motivation to learn and use 3D apparel CAD software.

The results of this study also indicated that participants' impressions of their ability to use and learn 3D apparel CAD were partially formed through their social interactions and observations, which included interactions with industry professionals and observations of the programs use within industry. Participant responses indicated that social interactions and observations could have negative and positive impacts on their self-efficacy with learning and use 3D apparel CAD, which, as previously discussed, can motivate and demotivate students learn and use the programs. The results of this study, considerations of self-efficacy theories, and Hodges et al.'s (2020) findings, further indicate the importance of understanding self-efficacy and industry relevancy in enhancing student motivations. Moreover, it is suggested that there may be a relationship between sources of self-efficacy that are connected to industry, the resulting self-efficacy exhibited by students, and their motivations to learn and use 3D apparel CAD.

Experiences on Motivation

Participants' responses suggested that they were motivated and demotivated to learn 3D apparel CAD as a result of their learning experiences, which was also revealed as a source of their impressions of their abilities to learn and use 3D apparel CAD. Generally, participants indicated that negative learning experiences serve as demotivating factors and positive learning experiences serve as motivating factors to learn and use 3D apparel CAD. Similarly, participant responses suggested that positive and negative learning experiences were sources of positive and negative self-efficacy beliefs respectively. Participant G's response demonstrated this finding. They revealed that they had some extremely positive learning experiences with 3D apparel CAD, and this motivated them to continue the learning and use of the programs, even indicating that their positive learning experiences with the technology motivated them to attend graduate school. In contrast, however, participant G also discussed and revealed that a negative learning experience demotivated them from wanting to continue learning and using 3D apparel CAD, as well as initially leading them to have poor impressions of their ability to learn and use the programs, which could be understood as self-efficacy.

Furthermore, participant responses suggested that students are motivated to learn and use 3D apparel CAD based on their outcome experiences, which was another source of self-efficacy revealed by their responses. Participants discussed that being able achieve and see the positive outcomes of using 3D apparel CAD, such as seeing their final garment design through a 3D render, motivated them to continue learning and using the programs because their interests were increased. Additionally, participants discussed that positive and negative outcome experiences were related to their impressions of their personal abilities to use and learn 3D apparel CAD. This finding indicates that outcome experiences may be a source of student self-efficacy and that positive outcomes from using 3D apparel CAD could motivate students to learn and use the programs. Notably, these findings are supported by Web-Williams's (2018) research, which found that a source of students' self-efficacy was enactive mastery experiences, which has to do with behaviors and their outcomes, and that students with higher self-efficacy were more motivated.

User-Friendliness and Usefulness on Motivation

Participants revealed that the user-friendliness and usefulness of 3D apparel CAD impacted their motivations to learn and use the technology. Their interview responses revealed that their impressions of system user-friendliness acted as a demotivating factor to learn and use 3D apparel CAD. Furthermore, participants discussed that their understandings of the usefulness of 3D apparel CAD acted as either a motivating or demotivating factor to learn and use the programs. Both user-friendliness and usefulness impacts on motivation are discussed below respectively.

User-Friendliness on Motivation. Participants indicated that their impressions that 3D apparel CAD was not user-friendly and was difficult to learn demotivated them from learning and using the software. Participants discussed that they would be more inclined to continue learning and use 3D apparel CAD if the systems were easier to use, suggesting that negative impressions that 3D apparel CAD is difficult to use may decrease motivation to learn and use the technology. This finding is supported by Venkatesh and Davis's (2000) and Yu's (2018) studies, which demonstrated that perceptions of ease of use were related to intent of use and attitudes of technology acceptance. It could be indicated through participant responses of this study and existing research that students who do not believe 3D apparel CAD as easy to use would have worse attitudes of acceptance toward the technology. Notably, participant responses did not indicate that positive impressions of 3D apparel CAD's user-friendliness were a motivation to learn and use the software. This finding could suggest that positive impressions of 3D apparel CAD user-friendliness are not as impactful to overall acceptance attitudes in comparison to negative impressions of 3D apparel CAD user-friendliness.

Participant responses that had to do with their individual differences of their impressions of their personal abilities could also suggest a relationship to their impressions of the user-friendliness of 3D apparel CAD. Participant responses revealed that those who believe 3D apparel CAD is not easy to use, in relation to its system characteristics, may have more negative impressions of their abilities to learn and use the programs. This finding indicates that students' impressions of 3D apparel CAD's user-friendliness may also impact their self-efficacy beliefs, which could have subsequent influence on their motivations, interests, and learning, as previously discussed. Interestingly, it was also illustrated by participant responses that their impressions of their ability to use and learn 3D apparel CAD influenced their impressions of 3D apparel CAD, including its' user-friendliness. The finding of this study could indicate that students with more positive self-efficacy beliefs may consider 3D apparel CAD more user-friendly and could have increased learning and use motivations.

Usefulness on Motivation. Participant responses indicated that their impressions of 3D apparel CAD's usefulness acted as either a motivating or demotivating factor to learn and use the software. In terms of motivation, participant responses demonstrated that those who had impressions that 3D apparel CAD was useful or advantageous were motivated to learn and use the programs. In contrast, participants revealed that those with impressions that 3D apparel CAD was not useful or advantageous were demotivated to learn and use the technology. This finding was illustrated by participant C's responses, which they revealed they felt 3D apparel CAD was not as useful or beneficial in comparison to physical design methods and this lead them believe learning and using 3D apparel CAD was not as valuable. Their responses indicate that they were demotivated by their beliefs that 3D apparel CAD was not as useful in comparison to physical design alternatives. The interview responses of this study do indicate that impressions of 3D apparel CAD usefulness could act as a demotivating factor for students to learn and use the software, however, it should be noted that this kind of responses was infrequent amongst participants. As previously discussed, participant responses illustrated that their impressions of their ability to use and learn 3D apparel CAD influenced their impressions of 3D apparel CAD usefulness. The findings of this study further indicate that self-efficacy may serve as a student motivator to learn and use 3D apparel CAD through its influence on their impressions of the technology.

Organizational Support on Motivation

Participants revealed that aspects of organizational support demotivated them from learning and using 3D apparel CAD. Participant responses indicated that resources and technology could both act as demotivation to learn and use 3D apparel CAD. Responses suggested that limited or inadequate academic and external resources, which included time, computer lab and software access, class availability, instructional support, individual assistance, and avatar size ranges, were a source of demotivation. These findings suggest that students who have negative impressions of the resources available to them may be less likely to use and learn 3D apparel CAD. In relation to their impressions of abilities to use and learn 3D apparel CAD, participants also discussed aspects of organizational support.

Participant responses suggested their learning experiences, which were discussed in relation to organizational support, were a source of their impressions of their abilities to learn and use 3D apparel CAD. This finding suggests that the sources of students' self-efficacy beliefs may also be related to their impressions of organizational support, thus highlighting that organizational support measures may influence student motivations.

Furthermore, it was revealed through participant responses that technology issues were a demotivation to learn and use 3D apparel CAD. As demonstrated by the interview responses, participants felt that difficulties with technology, such as computer crashes or trouble with file management, caused them to feel discouraged to learn and use 3D apparel CAD. This finding indicated that technology issues and lack of general computer skill may demotivate students from learning and use 3D apparel CAD. Participant responses also suggested that hardware capabilities could be a demotivation to learn and use 3D apparel CAD. As demonstrated by participant G's response, limited hardware technology does not fully support 3D apparel CAD and they suggested students who are only able to use insufficient hardware could be demotivated from learning and using the technology because they are unable to observe its full benefits.

Social Influence on Motivation

Participants revealed a variety of social influences that motivated them to learn and use 3D apparel CAD, including professors, professional 3D apparel CAD users, and peers. The interview results also illustrated that industry expectations were a motivating factor for the participants to learn and use 3D apparel CAD, which is considered here as another type of social influence. Participants discussed that positive interactions with their professors regarding 3D apparel CAD motivated them to continue learning and using the technology. This indicates that social influences from professors may be an importance source of student motivation to learn and use 3D apparel CAD. Participants also reported that seeing the design works of professional 3D apparel CAD users made them motivated to learn and use 3D apparel CAD so they could improve their skill. This finding may suggest that students can be motivated to learn and use 3D apparel CAD by viewing the positive achievements of others who design with the software.

Another notable indication from participant responses was that peer groups positively support their motivation to learn and use the software, especially in the contexts of collaborative learning. This finding indicates that students who interact with peer groups that positively discuss 3D apparel CAD or students who learn and use the software in collaboration or alongside others may feel more motivated to learn and use 3D apparel CAD. Participant responses also indicated that their interaction with industry professionals and impressions of industry proficiency expectations for 3D apparel CAD motivated them to learn and use the software. Their responses indicate that social influences from industry are important sources of motivation for students to learn and use 3D apparel CAD. This finding may further indicate that students who have a greater awareness of 3D apparel CAD industry proficiency expectations may be more motivated to learn and use the technology.

Participant responses also revealed that their social interactions and observations were a source of their impressions of their personal abilities. This finding indicates that social interactions and observations are a source of students' self-efficacy. Web-Williams's (2018) found that vicarious experience and verbal persuasions were sources of student self-efficacy, which are related to social observations and interactions respectively, and support the findings of this study. Considering this finding in relation to the findings that indicate students may be motivated to learn and use 3D apparel CAD due to social influences, the importance of self-efficacy in student motivation is emphasized. Furthermore, this study's findings that highlight the importance of student self-efficacy in motivation and learning 3D apparel CAD are supported by the findings of Web-Williams (2018), Gravill and Compeau (2008), Gale et al. (2021), Ineson et al. (2013), and Yi and Davis (2003).

Implications

The results and conclusions of this study suggest that students' have varying degrees of awareness of 3D apparel CAD and understanding of the industry's proficiency expectations. This study also indicated that the nature of students' acceptance of 3D apparel CAD differed and several influential factors were illustrated as influential to those attitudes. Finally, a deeper understanding was obtained regarding what students feel motivates and demotivates them to learn and use 3D apparel CAD.

Based on this study's conclusions, textile and apparel academic institutions should focus on increasing students' pre-university awareness of 3D apparel CAD, providing students with earlier use and learning opportunities, and informing students about 3D apparel CAD more sufficiently during initial exposure and use experiences. By doing so, educators can increase student interest and motivation in learning and using 3D apparel CAD and support their learning experiences and outcomes by building their confidence with using the technology. Increasing awareness efforts are important to educate students on relevant industry trends and 3D apparel CAD proficiency expectations as well. Academia can better support and prepare students for industry careers by extending their knowledge and awareness of industry trends and expectations, which, as shown by the results of this study, may also positively influence their attitudes of the technology and their learning experiences, motivate them to learn and use 3D apparel CAD, and enhance their overall learning.

The results of this study also suggest that universities need to intensify their efforts at supporting 3D apparel CAD education across student programs, years, and majors. It would also be valuable to teach 3D apparel CAD with clear connections to industry practice and implementation, which would improve student learning, preparedness, and increase their awareness of industry proficiency expectations.

Implications can also be made that student learning of 3D apparel CAD would be supported through its implementation alongside physical pattern making instruction. The results suggest that universities need to evaluate their practices of teaching 3D apparel CAD, including aspects that pertain to course instruction and project requirements. Overall, there should be great consideration for enhancing and improving students learning experiences with 3D apparel CAD, which would not only improve their learning process but could improve their attitudes of acceptance of 3D apparel CAD. Organizational support and resources were indicated as significant influences on students learning processes and impressions of 3D apparel CAD. Due to this, it is critical that universities consider the effectiveness of their resources and learning support measures to improve student learning, motivation, and attitudes of acceptance of 3D apparel CAD. There are implications that more resources are needed and existing ones should be enhanced, however, implications could also be made that universities need to increase students awareness of the existing resources due to the findings indicating that students lacked resource awareness. Academia may further support student 3D apparel CAD learning by calling their attentions toward external resources.

Notably, this study suggests that there are implications for universities to more seriously address the role of self-efficacy in student learning, behavior, and attitudes. As was suggested by the results, enhancing students self-efficacy beliefs could positively improve their learning, motivations, intentions, and positive attitudes toward the use and learning of 3D apparel CAD. Educational focuses on improving self-efficacy with 3D apparel CAD would also result in greater learning outcomes and positive student performance. Other implications point to the need for academia to address those aspects of student experiences and learning that demotivate them to learn and use 3D apparel CAD. Universities should consider how they can help students navigate and overcome demotivation to learn and use the technology because it is unlikely that demotivation can be entirely avoided.

Study Limitations

The present study was limited by the small sample size of individuals who all attended the same university, which could make generalizing the findings of this study to a larger population difficult. Variations in the sample population between undergraduate and graduate students could also be considered a limitation of the study because responses and results may be more heavily reflective of the undergraduate student population. Due to the small size and because all participants attended the same university, specific details regarding participants' experiences with 3D apparel CAD were not included within the data for analysis or shared as part of the results to avoid reidentification. Discarded data included details about 3D apparel CAD programs, experiences within academic and industry contexts, specific project work and course participation, and interactions with peers, instructors, or industry professionals. Detailed responses were removed as needed during transcription when participants could have been easily identified as a student within a specific class, year, or as being under the direction of specific instructors. Not only was this information removed when specific enough to protect the identities of students, but also to protect the identity of the instructors they discussed. The removal of this data influenced the results because participant comparisons between 3D apparel CAD programs, the details of their coursework and participation, industry experiences, social interactions, and additional nuances of their experiences could not be used to draw conclusions. This could be considered a limitation of the study; however, students' experiences were effectively explored in this study and suggestions are made in the following section of how this could be dealt with in the future.

Suggestions for Future Research

The conclusions of this study, its implications, and limitations point to the need for future research. Additional research should be done to assess the pedagogical practices that are actively being used to teach 3D apparel CAD, to understand their effectiveness, and to make suggestions of how those practices could be enhanced. The conclusions of this study also suggest that future research is needed to examine different and strategically developed educational methods for teaching 3D apparel CAD, perhaps methods that support and improve student self-efficacy to further understand its role in 3D apparel CAD education. It could also be valuable for academia to further explore the sources and influences of students' self-efficacy beliefs on their learning with 3D apparel CAD in general to develop those innovative teaching methods. Further suggestions for research could include 3D apparel CAD education as a collaborative design practice, or how it could be taught alongside other emerging technology, such as artificial intelligence. To address the removal of specific software use information in this study, future research should be conducted with a larger sample size or across multiple universities so that specific details about 3D apparel CAD use can be retained without risking participant reidentification.

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APPENDICES

Appendix A: Qualifying Survey

In-Depth Interview Qualifying Survey

Title of Study: Exploring textile and apparel students' experiences with 3D CAD: A qualitative study

Start of Block: Screening

Q1 Are you 18 years old or older?

○ Yes

○ No

Q2 Are you currently enrolled at the Wilson College of Textiles?

○ Yes

○ No

Q3 Are you an undergraduate student at the Wilson College of Textiles?

○ Yes

○ No

Q4 Please select your current program of study at the Wilson College of Textiles:

Display This Choice:

If Are you an undergraduate student at the Wilson College of Textiles? = Yes

○ Fashion and Textile Design - Fashion Design

Display This Choice:

If Are you an undergraduate student at the Wilson College of Textiles? = Yes

○ Fashion and Textile Design - Textile Design

Display This Choice:

If Are you an undergraduate student at the Wilson College of Textiles? = Yes

○ Fashion and Textile Management - Fashion Development and Product Management

Display This Choice:

If Are you an undergraduate student at the Wilson College of Textiles? = No

○ Master of Science in Textiles

Display This Choice:

If Are you an undergraduate student at the Wilson College of Textiles? = No

○ Master of Textiles

○ Other

Q5 Please select which category below best describes your student standing:

○ Freshman (1 semester completed)

○ Sophomore (2-3 semesters completed)

◯ Junior (4-5 semesters completed)

◯ Senior (6+ semesters completed)

◯ Graduate Student

Q6 Have you had experience using any of the following programs for the purpose of 3D modeling? Select all that apply:

◯ Browzwear

◯ CLO3D

◯ Lectra

◯ Optitex

◯ DesignScope Victor (EAT)

◯ SDS-ONE APEX 3D Modelist (Shima Seiki)

◯ None

Skip To: End of Survey If Have you had experience using any of the following programs for the purpose of 3D modeling? Selec... = None

Q7 Which of the following classes have you taken or are currently enrolled in (Select all that apply):

○ FTD 104 Fashion and Textile Design First Year Studio I

○ FTD 105 Fashion and Textile Design First Year Studio II

○ FTD 321 Fashion Design by Draping

○ FTD 419 Fashion Design 2

○ FTM 317 Computer-Aided-Design for Apparel

○ TTM 517 Advanced Computer-Aided Design for Fashion

○ TTM 519 3D Apparel Visualization (Previously TTM 591)

○ TT 570 Textile Digital Design and Technology

○ TT 591 Knit Design

○ None

End of Block: Screening

Appendix B: In-Depth Interview Guide

Opening Statement:

[Thank you for participating in this in-depth interview today. Your insights as a student from the Wilson College of Textiles are valuable, and I really appreciate your time.

As a reminder, I will be recording the audio from today's session, and I will be the only one with access to the recording. I will transcribe the recording and de-identify your information. You will be given a pseudonym in place of your name during de-identification. Additionally, I will remove other identifiable information that may be revealed during this session, such as names of other people or personal details that could be linked back to you. For example, if you discuss a specific work experience that is unique to you, I will de-identify this part of the conversation. So, a statement like 'my internship in Portland' would become 'my internship'.

You will also be eligible for compensation for your full participation today. Once the in-depth interview is complete, I will send each of you a $5 Starbucks coffee gift card directly to your email.

Today, we are going to discuss 3D computer-aided design programs within the textile and apparel industry, as well as your perspectives and experiences with them. I'll guide our discussion with a set of questions, but I encourage an open and candid conversation. Your insights are invaluable, so please feel free to share your thoughts openly and honestly. There are no right or wrong answers, and I'm excited to hear from you. Now, let's start off our session with the first question:]

Experience

1. How did you first learn about 3D CAD technologies in the textile and apparel industry, and what was your initial experience like?

2. Which 3D CAD tools or software have you had the chance to work with, and how have they been incorporated into your textile and apparel design coursework or projects?

3. When you had to use 3D CAD programs for a project, whether at work or in school, did you ever think there might be other ways to get the same or even better results? Or perhaps, was there a different method you wished you could use, regardless of the expected outcome?

Acceptance

4. How's your experience been with 3D CAD programs? Any thoughts on the user-friendliness and learning curve involved with using these programs?

5. In your opinion, what are the advantages of using 3D CAD programs for apparel development and design?
   - Do you feel you have worked on something and 3D CAD programs have helped you in any way, such as enhancing your design or creative process?

Motivation, Self-Efficacy, Learning, and Use

6. What got you into 3D CAD programs for textile and apparel design? Were there any particular things or experiences that got you curious about using these tools?
    - How have you been keeping your skills sharp and getting even better at using them?

7. What are your feelings about learning 3D CAD programs? Have you come across any roadblocks or challenges that make it a bit tricky?

8. How comfortable are you with using 3D CAD software for textile and apparel design?
    - What kinds of things have you experienced that make you feel that way?
    - Is there anything you can think of that would help you feel more comfortable using them?

Awareness and Industry Expectations

9. Looking ahead to your future career, do you think 3D CAD programs will play a role in your professional development?
    - Do you think you'd be likely to encounter them on the job?
    - Do you feel that this is related to any specific changes or trends you've noticed in the industry?

10. Do you feel open to using and continue learning 3D CAD programs as part of your future career?
    - Do you feel prepared to use 3D CAD programs as part of your work, or that you have the skills to become more proficient on your own?
    - Are there any specific skills you think you need more training on?

Closing Statement:

[Thank you for taking part in this in-depth interview today. If you have any questions about the study or any additional thoughts you want to share please feel free to contact me.]