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Realizing Silent Creativity: Virtual Prototyping for Empowering Hearing-Impaired Students' Design Ideas

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Abstract:

This study aims to achieve a dual purpose: first, to enhance the 3D clothing design skills of hearing-impaired students at King Abdulaziz University, Department of Fashion and Textile, using Marvelous Designer, and second, to apply these skills within an academic project focused on modernizing traditional fashion designs using CLO3D. A quasi-experimental design with a one-group post-test structure was employed within a project-based learning framework. To evaluate the learning outcomes, skill performance observation checklists were developed to assess students' performance while executing project tasks, capturing the dynamic interaction between technical proficiency and artistic creativity. The findings revealed significant improvement in students' 3D design skills, particularly in their ability to design traditional fashion using 3D clothing design programs. Moreover, the project outcomes highlight the substantial potential for integrating these technologies into academic projects within fashion and textile programs.

Keywords: 3D virtual prototyping; simulation; CLO3D; hearing-impaired students; skill development.

1. Introduction

The adoption of computer technology has become indispensable for fashion companies in recent years (Hwang &Hahn, 2017). Modern innovations -such as 3D printing and virtual prototyping- have significantly enhanced production efficiency by offering faster and more accurate methods for creating and evaluating prototypes. In addition, these technologies support sustainability efforts by minimizing material waste, as the number of physical samples produced during the quality testing phase has decreased with the emergence of virtual prototypes (Ejeimi,2020; Hodges et al., 2020).

Accordingly, integration of such technologies - particularly 3D virtual prototyping- into Fashion education programs enables students to build relevant skills aligned with industry demands. Among these skills, spatial visualization or 3D visualization is especially crucial, as virtual prototyping facilitates the transformation of flat patterns into three- dimensional representations on avatars (Prasetya et al., 2025). While previous studies have made valuable contribution to developing virtual prototyping skills among fashion and textile students (Baytar, 2017; Hwang& Hahn, 2017; Conlon & Gallery, 2024; Althobaiti, 2025; Shahien et al., 2021), there remains a notable gap in research focusing on enhancing the academic achievement of students with disabilities -particularly the hearing impairments- in fashion-related technologies (Salem & Basaffar, 2023). Given that students with hearing impairments rely heavily

on visual cues and demonstrations for understanding information, 3D virtual technology offers an effective and accessible method for learning. By automatically converting flat designs into 3D visuals, it allows hearing-impaired students to grasp complex patterns more intuitively (Abass et al., 2019).

Despite the growing use of 3D virtual prototyping in fashion education, limited research has focused on its application for hearing-impaired students. Previous studies mainly targeted hearing students, neglecting how visual-based technologies could enhance accessibility and inclusion in fashion design learning environments (Baytar, 2018; Baytar & Meyer, 2013; Hodges et al., 2020).

Therefore, this study aims to serve a dual purpose: first, to develop the virtual modeling skills of hearing-impaired students, and second, to apply these skills in a project focused on modernizing traditional fashion designs.

2. Literature review

2-1 hearing-impaired

Hearing is one of the most vital senses in human life, as individuals rely on it primarily for social interactions with others. Knowledge and information are largely acquired through the senses, and although all of them contribute to learning and development, hearing remains the most influential and significant in educational and communicative contexts. It is the fundamental channel that enables individuals to interact with their surroundings, playing a central role in social and emotional development, in addition to fostering awareness of the environment and its components (Deabes & Tashkandi, 2024).

Hearing impairment refers to a dysfunction in the auditory system that may result from genetic factors, medical causes such as premature birth, or environmental factors such as continuous exposure to noise. Due to the diversity of its causes, various classifications of hearing impairment have emerged, differing in degree and type. Individuals with hearing impairment may be classified as deaf if their condition is severe, or as hard of hearing if their impairment ranges from moderate to mild while retaining residual hearing ability. The level of hearing impairment impacts several characteristics, particularly linguistic, cognitive, and social; Witch affect learning styles. Individuals with hearing impairments rely heavily on visual media to compensate for their hearing loss. A study by Rusli and Ibrahim (2022) confirmed that visual media contributes to enhancing academic achievement among individuals with hearing impairments by compensating for auditory deficiencies.

2-2 Teaching 3D Virtual Modeling in Clothing Design

3D virtual prototyping has become a valuable tool in apparel patternmaking, as it enables real-time visualization of 2D pattern modifications in a 3D space. Designers can digitally stitch and arrange patterns on virtual models, apply fabric properties, and adjust rendering effects to achieve realistic results. the adoption of 3D virtual prototyping by clothing industry has encouraged wider use across businesses and fashion education. Given the demands of the global market, teaching and training students in both 2D and 3D CAD tools is now essential (Baytar, 2017; Hodges et al., 2020).

Integrating virtual modeling into academic curricula in fashion and textiles-particularly through project-based applications enhances students' production efficiency, strengthens their creative and technical skills, and fosters critical thinking and problem-solving abilities. This is especially significant in overcoming challenges

and errors that often arise when relying on manual methods rather than modern technological approaches (Prasetya et al., 2025).

3. Materials and Methods

3-1 sample

The study sample consisted of 11 female students with hearing impairments, enrolled in the sixth-level Fashion Design program at King Abdulaziz University. The participants were selected using a purposive sampling method, as they represented the specific target population of the study.

3-2 project structure

At the beginning of the semester, and over a period of nine weeks, hearing-impaired students were trained on *Marvelous Designer* as an introductory program, which allowed students to practice basic digital design skills such as modifying fabric patterns, inserting logos and embroidery, and adjusting avatar sizes according to their personal measurements.

By the end of the first phase of the semester, students had made progress in using cad programs; thus, students were introduced to the *CLO3D* program, where they learned foundational garment-making skills. These skills included drawing digital patterns, sewing, simulating garments on virtual models, and classifying and defining patterns according to personal measurements.

Following the application phase on *CLO3D*, students were introduced to a project titled: designing traditional Saudi fashion in a modern, contemporary style. Over three weeks, each student designed six sketches, then selected two designs among the six for flat pattern drafting before simulating them on 3D models in *CLO3D* with personal measurements. The finalized patterns were then printed and sewn to create the physical garments (Figure 1).

3-3 Ethical considerations

The project was conducted as part of a regular academic course in the Fashion and Textile Department at King Abdulaziz University. All participants were officially enrolled students, and their participation formed part of the course requirements. The researcher ensured that students' data and project outcomes were treated confidentially and used solely for academic and research purposes, without any impact on their course grades.

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Flat design | Virtual sample | Real sampel

Figure 1. Example of Students' Designs in the Project Portfolio

3-4 Data collection

The study adopted a quasi-experimental design with a one-group post-test structure, implemented within a project-based learning framework and to evaluate learning outcomes, a performance scale was specifically developed to assess the dynamic interaction between technical and artistic skills demonstrated throughout the project.

3-3-1 Instruments

The observations checklist consisted of 18 measurement items designed to evaluate students' skills across five domains: creative skills, technical skills, practical and execution skills, problem-solving and decision-making skills, and portfolio development. Each item was rated using a Like rt-type scale. Internal consistency reliability for each domain was assessed using Cronbach's alpha, with values ranging from 0.839 to 0.952 (Table 1). Specifically, the Creative Skills scale included 6 items (α = 0.850), while the remaining domains Technical Skills (α = 0.898), Practical and Execution Skills (α = 0.952), Problem-Solving and Decision-Making Skills (α = 0.875), and Portfolio (α = 0.839) were each measured using 3 items. These instruments were developed to ensure a comprehensive evaluation of students' competence in 3D fashion design education, particularly in relation to the use of virtual prototyping technologies.

Table 1. Instruments and reliability statistics (for observations checklist)

Item		α
Design and Creative Skills	6	0.850
Technical Skills	3	0.898
Practical & Execution Skills	3	0.952
Problem-Solving & Decision-Making Skills	3	0.875
Portfolio	3	0.839

3-3-2 Data analysis

For data analysis, the statistical package SPSS version 27 was used. Frequencies and percentages of the students' scores were calculated for each dimension of the observation checklist to determine the frequency of performance and the level of improvement in each dimension, from the most improved to the least improved areas. Additionally, Pearson correlation was conducted to identify the dimensions with the greatest impact on the students' academic achievement in the project.

4 Results and Discussion

Table 2. Overall score classification for student in project

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	High	6	54.5	54.5	90.9
	Medium	4	36.4	36.4	36.4
	Low	1	9.1	9.1	100.0
	Total	11	100.0	100.0	

The table 2 presents the overall project scores of the students (N = 11) classified into three performance levels. It can be observed that the majority of students (6 students, 54.5%) achieved high scores, while 4 students (36.4%) obtained medium scores, and only 1 student (9.1%) fell into the low category. These results indicate that more than half of the students demonstrated strong performance in the project, with a smaller proportion showing moderate or low achievement, reflecting some variation in students' overall performance across the group.

Table 3. Overall Score Classification of Students in the Project (Design and Creative Skills)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	High	10	90.9	90.9	100.0
	Medium	1	9.1	9.1	9.1
	Total	11	100.0	100.0	

Table 3 illustrates the overall score classification of students in the project in terms of design and creative skills. The findings reveal that most students (90.9%) achieved a high level, while only one student (9.1%) was classified at the medium level.

Table 4. Overall Score Classification of Students in the Project (Technical Skills)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	High	5	45.5	45.5	100.0
	Medium	6	54.5	54.5	54.5
	Total	11	100.0	100.0	

These results indicate that most students demonstrated strong creativity and originality in their project outcome, reflecting the effectiveness of the educational unit in fostering design and creative skills.

Table 4 presents the overall score classification of students in the project with respect to technical skills. The results indicate that slightly more than half of the students (54.5%) were classified at the medium level, while 45.5% reached the highest level. These results suggests that although many students demonstrated good technical skills, there is still room for further development and enhancement in this area.

Table 5. Overall Score Classification of Students in the Project (Practical & Execution Skills)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	High	7	63.6	63.6	100.0
	Medium	4	36.4	36.4	36.4
	Total	11	100.0	100.0	

Table 5 illustrates the overall score classification of students in the project regarding practical and execution skills. The results show that most students (63.6%) were classified at the high level, while 36.4% were at the medium level. These results indicate that most students demonstrated strong practical and execution skills during the implementation of the project.

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Table 6. Overall Score Classification of Students in the Project (Problem-Solving & Decision-Making Skills)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	High	8	72.7	72.7	100.0
	Medium	3	27.3	27.3	27.3
	Total	11	100.0	100.0	

Table 6 presents the overall score classification of students in the project about problem-solving and decision-making skills. The results indicate that most students (72.7%) achieved a high level, while 27.3% were classified at the medium level. This suggests that most students demonstrated strong problem-solving and decision-making skills through the processes of implementing the project.

Table 7. Overall Score Classification of Students in the Project (Portfolio)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	High	5	45.5	45.5	90.9
	Medium	5	45.5	45.5	45.5
	Low	1	9.1	9.1	100.0
	Total	11	100.0	100.0	

Table 7 shows the frequency distribution of students' overall project scores in Portfolio item. As presented, 45.5% of the students achieved a medium level, and another 45.5% reached a high level, while only 9.1% of the students were classified at the low level. This indicates that most of the students' performance in the project ranged from medium to high levels.

As shown in Figure 2, the majority of students achieved high performance levels in most skill domains, particularly in design and creative skills.

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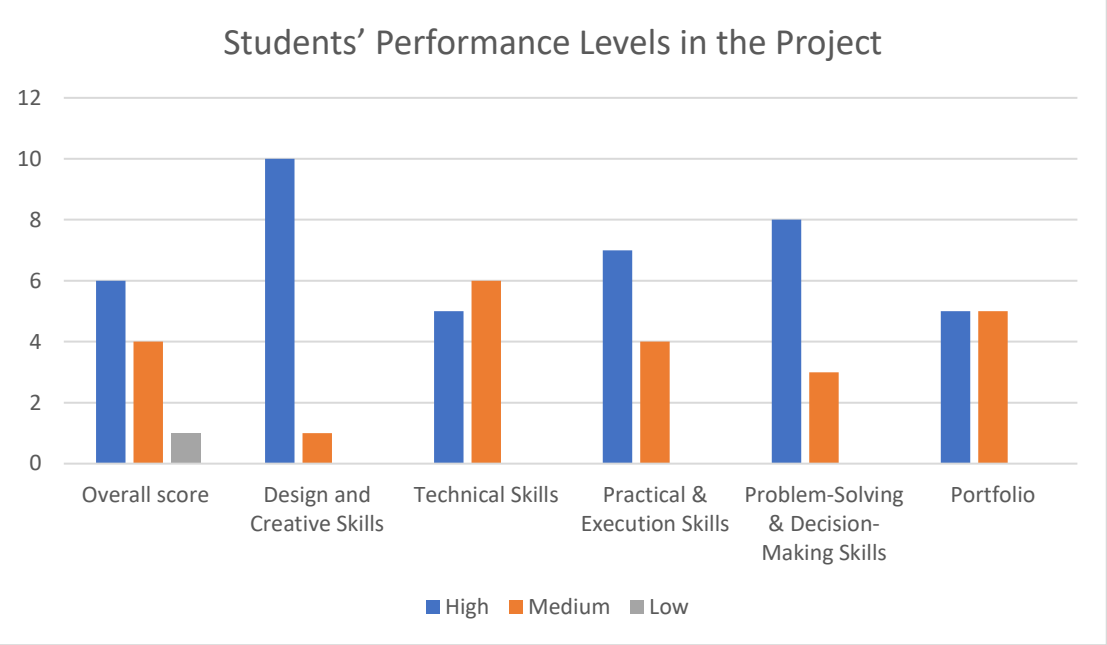

Figure 2. Students' Performance Levels in the Project

Overall, the results across all tables indicate that the majority of students demonstrated strong performance in the project, particularly in design and creative skills, as well as in problem-solving and decision-making, where most students reached the high level. Practical and execution skills also showed positive results, with more than half of the students achieving high scores. On the other hand, technical skills and portfolio performance reflected more balanced distributions, with a noticeable proportion of students at the medium level, suggesting areas that require further development. These findings highlight the effectiveness of the educational unit in enhancing students' creative, practical, and cognitive abilities, while also pointing to the need for additional support in technical proficiency and portfolio presentation to achieve more consistent outcomes across all skill domains.

Table 8. Correlation Analysis Between Overall Project Score and Skill Dimensions

		Design and Creative Skills	Technical Skills	Practical & Execution Skills	Problem-Solving & Decision-Making Skills	Portfolio
Overall Score Classification of Students in the Project	Pearson Correlation	.748**	.625*	.754**	.770**	.584
	Sig. (2-tailed)	.008	.040	.007	.006	.059
	N	11	11	11	11	11

The correlation analysis presented in Table 8 showed that all skill dimensions were positively correlated with the students' overall project scores. Most correlations were statistically significant, with values ranging from moderate to high. Specifically, Design and Creative Skills (r = .748, p = .008), Technical Skills (r = .625, p = .040), Practical & Execution Skills (r = .754, p = .007), and Problem-Solving & Decision-Making Skills (r = .770, p = .006) demonstrated strong and significant correlations with overall performance. Portfolio scores showed a positive correlation as well (r = .584), though they were marginally non-significant (p = .059). These results suggest that all assessed skill dimensions contribute to students' overall project performance, with problem-solving, design creativity, and practical execution showing particularly strong alignment with the total scores.

The findings of the present study align closely with previous research on the integration of digital and 3D technologies in fashion design student projects aimed at developing traditional clothing (Hu & Wang, 2025). Regarding design and creative skills, the majority of students achieved high scores, reflecting strong creativity and originality. This is consistent with Kazlacheva et al. (2018), who reported that innovative technologies in fashion education facilitate faster knowledge acquisition and enhance students' creative and visual thinking. Similarly, the study by Hu and Wang (2025) demonstrated that the use of CLO3D for precise 3D modeling and realistic virtual simulation, supporting creative design processes and enhancing aesthetic decision-making.

In terms of Technical Skills, the results showed a balanced distribution, indicating that while students acquired solid technical competencies, there remains room for improvement. This finding aligns with previous studies emphasizing that effective use of digital tools requires both training and iterative practice to achieve mastery (Hodges et al., 2020; Conlon & Gallery, 2024). The use of CLO3D in this study enabled students to translate 2D patterns into accurate 3D models, mirroring the technical precision reported in digital garment restoration.

In terms of practical and execution skills, most students achieved high levels, demonstrating the ability to implement designs effectively. This reflects the benefits of project-based learning combined with 3D software, which allows learners to practice garment construction and virtual fitting before physical production (Prasetya et al., 2025; Habib & Alam, 2024).

Regarding problem-solving and decision-making skills, high scores were observed for most students, suggesting that the interactive and iterative nature of 3D digital design encourages critical thinking and informed decision-making. This outcome is supported by prior studies showing that virtual prototyping enhances students' ability to experiment with designs, anticipate fitting issues, and refine solutions (Baytar, 2018).

Finally, the Portfolio results indicate a range from medium to high performance, highlighting the importance of consolidating students' work and reflecting on their process. This aligns with Coats (2025), who emphasized that digital projects not only improve technical output but also strengthen students' reflective skills and presentation quality.

Overall, these findings reinforce the conclusion that integrating CLO3D and 3D virtual prototyping in fashion design education, particularly for hearing-impaired students effectively enhances creativity, technical competence, practical skills, and problem-solving abilities, consistent with outcomes reported in previous research.

5 Conclusions

The study concluded that the adoption of modern technologies, particularly virtual prototyping programs that integrate flat patterns with three-dimensional modeling, significantly enhanced the performance of hearing-impaired students. These programs enabled the students to transform their creative ideas into tangible outcomes more quickly and efficiently, thereby fostering their creativity and the quality of their work in academic projects. Additionally, the use of these technologies contributed to improving productivity and developing both technical and artistic skills, highlighting the crucial role of digital technology in supporting hands-on learning and promoting innovation in fashion design. This study employed a quantitative methodology; and to achieve more insightful results that would improve teaching strategies related to CAD programs for hearing-impaired students, mixed methods studies are recommended for future studies.

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تحقيق الإبداع الصامت: النمذجة الافتراضية لتمكين أفكار التصميم لدى الطلاب ذوي الإعاقة السمعية

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الملخص:

هدفت الدراسة الحالية إلى تنمية مهارات الطالبات ذوات الإعاقة السمعية الشديدة في تصميم الملابس ثلاثية الأبعاد باستخدام برنامج (Marvelous Designer) بجامعة الملك عبد العزيز، قسم الأزياء والنسيج،برنامج صناعة الأزياء، كما هدفت الدراسة إلى توظيف مهارات الطالبات ضمن مشروع أكاديمي يركز على إعادة تصميم الملابس التقليدية بأسلوب عصري باستخدام برنامج (CLO3D). واعتمدت الدراسة على المنهج شبه التجريبي ذو المجموعة الواحدة للتطبيق البعدي، ضمن إطار استراتيجية التعلم القائم على المشاريع. ولتقييم مخرجات التعلم لدى الطالبات ذوات الإعاقة السمعية الشديدة في المشروع الأكاديمي، تم تصميم قوائم ملاحظة الأداء المهاري والتي تعتبر أداة البحث لتقييم مهارات الطالبات ذوات الإعاقة السمعية في المشروع الأكاديمي. وأظهرت نتائج الدراسة تحسناً وتطوراً ملحوظاً في مهارات الطالبات ذوات الإعاقة السمعية الشديدة، وارتفاع قدرتهن على تصميم الأزياء التقليدية باستخدام برامج تصميم الملابس ثلاثية الأبعاد، مما يعزز الإمكانات الكبيرة ويوصي بالتوسع في إدراج هذه التقنية ضمن المشاريع الأكاديمية في تخصصات الأزياء والنسيج،كما يوصي البحث باستخدام الدراسات ذات المنهج المختلط في الدراسات المستقبلية.

كلمات مفتاحية:

النمذجة الافتراضية ثلاثية الأبعاد، المحاكاة، الطالبات ذوات الإعاقة السمعية، تطوير المهارات.