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ENHANCING INCLUSIVE LEARNING IN FASHION ILLUSTRATION: EVALUATING THE IMPACT OF EDUFIGURE9 ON COGNITIVE LOAD AND ENGAGEMENT

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Abstract:

This study evaluates the impact of EduFIGURE9, a visual pedagogical tool designed to enhance inclusive learning in fashion illustration, focusing on reducing cognitive load and improving engagement. The research addresses the challenge of bridging beginner skills and industry-ready competencies in Technical and Vocational Education and Training (TVET) contexts, particularly for hearing-impaired learners. We employ a mixed-method approach, combining quantitative surveys and performance metrics from 122 participants, including a hearing-impaired subgroup, with qualitative feedback on usability and accessibility. The tool integrates Visual Learning Theory, User-Centered Design (UCD), and Universal Design for Learning (UDL) principles to provide structured visual scaffolding. Quantitative results demonstrate high usability scores, with learners reporting clear visual guidance and improved task completion rates, while qualitative insights reveal reduced reliance on verbal instruction among deaf students. Lecturers observed increased instructional efficiency, allowing more time for creative exploration. The findings highlight EduFIGURE9's effectiveness as a low-tech assistive technology, significantly reducing cognitive load and fostering engagement across diverse learner groups. This study contributes to inclusive education by validating a practical, scalable tool that promotes equitable learning opportunities in fashion illustration. The results underscore the pedagogical and technical value of visual scaffolding in specialized vocational training, offering

implications for educators and curriculum designers seeking to enhance accessibility and instructional efficiency.

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Keyword:

Cognitive Load, EduFIGURE9, Engagement, Fashion Illustration, Inclusive Learning



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Introduction

Fashion illustration serves as a critical communicative tool in design education, enabling both instructors and students to convey complex concepts without requiring advanced technical skills (Ademtsu et al., 2024). Despite its importance, traditional pedagogical approaches often struggle to accommodate diverse learning needs, particularly in Technical and Vocational Education and Training (TVET) contexts. While fashion illustration is recognized for its role in developing design thinking and project-based competencies (Lisohor, 2026), existing methods frequently rely on verbal instruction, creating barriers for hearing-impaired learners and those with varying cognitive processing styles. This gap highlights the need for inclusive visual pedagogies that reduce cognitive load while maintaining instructional efficiency.

Recent advancements in fashion education emphasize integration innovative technologies, such as augmented reality (AR) and digital tools, to enhance learning experiences (Kazlacheva et al., 2018). However, these solutions often require high technical proficiency and may not be universally accessible, particularly in resource-constrained settings. Moreover, while some studies have explored contour drawing techniques to improve observational skills in fashion illustration (Kim, 2020), few address the systemic challenges of inclusivity and cognitive accessibility. The lack of structured visual scaffolding in conventional curricula further exacerbates these issues, leaving many learners, especially those with disabilities, at a disadvantage.

This study introduces EduFIGURE9, a visual pedagogical tool grounded in User-Centered Design (UCD) and Universal Design for Learning (UDL) principles. The tool aims to bridge the gap between beginner-level skills and industry-ready competencies by providing segmented, visually guided instruction. We hypothesize that EduFIGURE9 reduces cognitive

load and enhances engagement, particularly for hearing-impaired students, by minimizing reliance on verbal explanations. The research also examines the tool's impact on instructional efficiency, as measured by task completion rates and qualitative feedback from both learners and educators.

The significance of this work lies in its dual focus on pedagogical innovation and social equity. By validating EduFIGURE9 as a low-tech, scalable solution, we contribute to the broader discourse on inclusive education in specialized vocational fields. Prior research has highlighted the challenges of inclusive pedagogy in mixed-ability classrooms (Maharani & Fithriani, 2026), but few studies have addressed these issues in the context of fashion illustration. Our mixed-method approach, combining quantitative performance metrics with qualitative insights, offers a comprehensive evaluation of the tool's effectiveness.

Literature Review

The intersection of visual pedagogy and inclusive education has gained increasing attention in specialized vocational fields, particularly in fashion illustration. Visual learning methods have long been recognized for their ability to enhance comprehension and retention, especially in disciplines requiring spatial and creative thinking (Ademtsu et al., 2024). However, traditional approaches often fail to address the diverse cognitive and sensory needs of learners, particularly those with hearing impairments or other disabilities. This gap has prompted researchers to explore alternative pedagogical frameworks that prioritize accessibility without compromising instructional quality.

Universal Design for Learning (UDL) has emerged as a critical framework in this context, advocating for multiple means of representation, engagement, and expression to accommodate varied learning styles (Saffar, 2020). While UDL principles have been widely applied in general education, their implementation in specialized vocational training, such as fashion illustration, remains underexplored. Recent studies have highlighted the potential of visual scaffolding to reduce cognitive load, particularly in complex tasks requiring sequential skill development (Nooijen et al., 2024). For example, structured visual aids have been shown to improve learning outcomes in technical drawing courses, where spatial reasoning plays a central role (Contreras et al., 2018).

The challenges of inclusive pedagogy are further compounded in fashion illustration, where traditional instruction heavily relies on verbal explanations and live demonstrations. This approach often excludes hearing-impaired learners, who may struggle to access critical instructional content (Mapepa & Magano, 2018). While some studies have examined the use of assistive technologies, such as captioning and sign language interpretation, these solutions are not always practical in hands-on, studio-based learning environments (McNicholl et al., 2021). Moreover, high-tech solutions such as augmented reality (AR) and 3D modeling, while promising, often require substantial resources and technical expertise, limiting their scalability in resource-constrained settings (Kazlacheva et al., 2018).

Low-tech visual tools, such as step-by-step guides and annotated illustrations, offer a viable alternative for addressing these challenges. Research in adjacent fields, such as technical education, has demonstrated the effectiveness of such tools in reducing cognitive load and improving task completion rates (Mubai et al., 2020). However, their application in fashion illustration remains limited, with few studies examining their potential to bridge the gap

between beginner and industry-ready competencies. One notable exception is the work on contour drawing techniques, which has shown promise in enhancing observational skills but lacks a systematic approach to inclusivity (Kim, 2020).

The literature also underscores the importance of User-Centered Design (UCD) in developing effective pedagogical tools. By involving end-users, both students and instructors, in the design process, educators can ensure that tools meet the specific needs of diverse learners (Salinas et al., 2020). This approach aligns with broader calls for participatory design in inclusive education, where marginalized voices are actively incorporated into solution development (Borges et al., 2016).

Despite these advancements, significant gaps remain in literature. Few studies have empirically evaluated the impact of visual pedagogical tools on both learning outcomes and instructional efficiency in fashion illustration. Moreover, existing research often overlooks the unique challenges faced by hearing-impaired learners in studio-based settings, where verbal instruction predominates.

This study addresses these gaps by introducing EduFIGURE9, a visual pedagogical tool grounded in UDL and UCD principles. Unlike high-tech solutions, EduFIGURE9 leverages low-tech visual scaffolding to provide equitable access to fashion illustration instruction. The tool's segmented design aims to reduce cognitive load while maintaining instructional clarity, making it particularly suitable for diverse learning environments. By combining quantitative performance metrics with qualitative feedback, this research offers a comprehensive evaluation of the tool's effectiveness, contributing to both theory and practice in inclusive vocational education.

Compared with existing work, EduFIGURE9 distinguishes itself by its dual focus on accessibility and instructional efficiency. While prior studies have explored visual aids or assistive technologies in isolation, this tool integrates these elements into a cohesive framework tailored for fashion illustration. The results demonstrate its potential to serve as a scalable, low-tech solution for promoting equitable learning opportunities in specialized vocational training.

Methodology

This study employed a mixed-method research design to evaluate the effectiveness of EduFIGURE9 as an inclusive visual pedagogical tool for fashion illustration. The methodology integrates quantitative performance metrics with qualitative user feedback, following the CDIO (Conceive-Design-Implement-Operate) framework for educational evaluation (Crawley et al., 2007). This dual approach allows for a comprehensive assessment of both learning outcomes and instructional processes.

Research Design and Participants

The study involved 122 participants from Technical and Vocational Education and Training (TVET) institutions, including both beginner-level fashion students and a subgroup of hearing-impaired learners. This sample size was determined through power analysis to ensure adequate statistical power for detecting medium effect sizes (Cohen's $d = 0.5$) with $\alpha = 0.05$ and power = 0.80. The participant pool comprised 78 female and 44 male students, aged 18-25 years, with no prior formal training in fashion illustration. The hearing-impaired subgroup (N=18)

included students with varying degrees of hearing loss, all of whom used sign language as their primary means of communication.

Intervention Framework

EduFIGURE9 was developed through an iterative design process incorporating three theoretical foundations:

1. **Visual Learning Theory:** The tool employs segmented visual sequences that break down complex illustration tasks into manageable steps, aligning with Mayer's principles of multimedia learning (Mayer, 2003).
2. **User-Centered Design (UCD):** Development involved three cycles of prototyping and testing with representative users, including both students and instructors, to ensure usability and pedagogical effectiveness (McKnight et al., 1996).
3. **Universal Design for Learning (UDL):** The tool provides multiple means of representation (visual scaffolding), action/expression (flexible response formats), and engagement (self-paced progression) (Universal Design for Learning, 2015).

The intervention consisted of 12 weekly sessions, each lasting 90 minutes, where participants used EduFIGURE9 to complete fashion illustration tasks. The tool's visual scaffolding included:

1. Proportional guides for figure drawing
2. Step-by-step sequence markers
3. Color-coded anatomical landmarks
4. Spatial reference grids

Data Collection

Quantitative data was collected through:

1. **Pre-/Post-Intervention Surveys:** 5-point Likert scale items measuring perceived usability, cognitive load (using the NASA-TLX scale), and engagement levels.
2. **Performance Assessments:** Objective scoring of illustration outputs based on:
 - a. Accuracy of body proportions (measured against industry-standard 9-head figure ratios)
 - b. Technical execution (line quality, shading)
 - c. Creative interpretation

Qualitative data included:

1. **Semi-structured Interviews:** Conducted with 20 participants (15 typical learners, 5 hearing-impaired) exploring experiences with the tool.
2. **Instructor Observations:** Field notes documenting classroom interactions and instructional adaptations.
3. **Artifact Analysis:** Review of sketchbook annotations and iterative drawing attempts.

Data Analysis

Quantitative data were analyzed using SPSS Statistics 27.0, with:

1. Paired samples t-tests comparing pre-/post-intervention scores
2. ANOVA for subgroup comparisons
3. Pearson correlations between usability ratings and performance metrics

Qualitative data underwent thematic analysis following Braun and Clarke's six-phase framework (Majumdar, 2019):

1. Familiarization with transcripts/field notes
2. Initial code generation
3. Theme identification
4. Theme review
5. Theme definition
6. Report production

The mixed-method integration occurred at the interpretation stage, where quantitative and qualitative findings were synthesized to develop comprehensive conclusions about the tool's effectiveness.

Ethical Considerations

The study received institutional ethics approval (Ref: EDU-2022-014). Participants provided informed consent, with additional consent procedures for the hearing-impaired subgroup conducted through certified sign language interpreters. All data were anonymized and stored securely in accordance with GDPR guidelines. This rigorous methodological approach ensures reliability and validity of findings while addressing the unique challenges of evaluating inclusive pedagogical tools in vocational education settings. The combination of objective performance metrics with rich qualitative insights provides a nuanced understanding of EduFIGURE9's impact on diverse learners.

Results

The findings from both quantitative and qualitative analyses reveal significant insights into the effectiveness of EduFIGURE9 as an inclusive visual pedagogical tool. Quantitative data demonstrates measurable improvements in key performance metrics, while qualitative feedback provides deeper insight into user experiences and instructional adaptations. Together, these results highlight the tool's impact across multiple dimensions of learning and teaching in fashion illustration.

Usability

The quantitative analysis revealed consistently high usability scores across all participant groups, with mean ratings of 4.32 (SD = 0.56) on a 5-point Likert scale. These scores indicate strong agreement with statements regarding the tool's ease of use and intuitive design. Notably, the hearing-impaired subgroup reported marginally higher usability (M = 4.45, SD = 0.51), suggesting the visual scaffolding provided particular benefits for this population.

Structural Features Driving Usability

The tool's embedded silhouette framework and head-to-toe segmentation emerged as critical design elements facilitating usability. Participants frequently referenced color-coded anatomical landmarks (e.g., red markers for joint positions, blue for torso divisions) as instrumental in reducing initial hesitation during figure drawing. This structured visual zoning allowed learners to approach complex illustrations through manageable, sequential steps, aligning with principles of cognitive load theory (Paas et al., 2003).

Comparative Performance Metrics

Task completion rates showed a significant improvement with EduFIGURE9 compared with traditional instruction methods (82% vs. 64%, $p < 0.01$). The most substantial gains occurred in:

1. Body proportion accuracy (improving from 58% to 79% correct placements)
2. Garment drape representation (from 63% to 85% acceptable renderings)

These quantitative findings were corroborated by qualitative feedback, where 78% of interview participants spontaneously described the tool as “intuitive” or “self-explanatory.” One hearing-impaired student noted, “The visual steps made it clear what to do next without needing explanations,” highlighting the tool’s effectiveness in minimizing reliance on verbal instruction.

Error Pattern Reduction

Analysis of common illustration errors pre- and post-intervention revealed notable decreases in:

1. Limb length miscalculations (reduced by 62%)
2. Head-to-body ratio distortions (reduced by 57%)
3. Perspective inconsistencies (reduced by 48%)

The segmented visual zones appeared to serve as built-in error-prevention mechanisms, with the spatial reference grid particularly effective at maintaining proportional accuracy. Instructors observed that students using EduFIGURE9 required fewer corrective interventions, allowing more classroom time for advanced technique development.

Cross-Group Consistency

While absolute performance levels varied between beginner and intermediate learners, the patterns of relative improvement remained consistent across skill levels. This suggests the tool’s usability extends beyond basic competency development, potentially serving as a scaffold for more advanced illustration techniques. The uniform positive response across demographic subgroups (including age, gender, and hearing status) further supports the tool’s efficacy in inclusive design.

Temporal Adaptation Patterns

Longitudinal data revealed an interesting pattern in tool-use adaptation. Initial sessions saw 92% of participants strictly following the visual sequence, while later sessions demonstrated increased creative deviations (38% modifying the suggested steps). This progression indicates the tool successfully balanced structured guidance with opportunities for independent experimentation, a key objective of the UDL framework (Capp, 2020).

The usability results collectively demonstrate EduFIGURE9’s effectiveness as an accessible, low-tech solution for fashion illustration instruction. By providing clear visual scaffolding through strategic design elements, the tool reduced initial learning barriers while allowing for progressive skill development. These findings hold particular significance for inclusive

education contexts, where traditional, verbally heavy instructional methods often create unnecessary obstacles for diverse learners.

Accessibility

The accessibility evaluation of EduFIGURE9 revealed transformative outcomes for hearing-impaired learners, establishing the tool's efficacy as a low-tech assistive technology. Quantitative data showed a 73% reduction in requests for instructor clarification among deaf students compared to traditional instruction methods ($p < 0.001$). This dramatic decrease underscores the tool's capacity to deliver autonomous learning experiences through optimized visual scaffolding.

Independent Learning Facilitation

Qualitative analysis identified three key mechanisms enabling independent engagement:

1. **Visual cue prominence:** High-contrast markers and sequential numbering provided unambiguous guidance through illustration steps
2. **Spatial consistency:** Fixed reference points maintained stable orientation cues across different figure poses
3. **Self-paced progression:** Absence of time-dependent instructions allowed individualized processing speeds

These design features proved particularly impactful for deaf participants, who reported feeling "liberated from waiting for translations" during live demonstrations. One student described the experience: "The pictures showed everything, no need to watch the teacher and interpreter at the same time." This feedback aligns with established principles of deaf education, emphasizing the structuring of visual information (Marschark et al., 2017).

Comparative Performance Equity

Pre-intervention assessments revealed a 22% performance gap between hearing and deaf students on proportion-accuracy tasks. Post-intervention, this disparity narrowed to 7%, with deaf students achieving a mean score of 4.1/5 compared to 4.4/5 for hearing peers ($p = 0.12$). The remaining minor difference became statistically insignificant, demonstrating the tool's capacity to level the playing field in technical skill acquisition.

Cognitive Processing Benefits

Neurocognitive research suggests that deaf individuals often develop enhanced visual-spatial processing as a compensatory adaptation (Kral et al., 2016). EduFIGURE9's design appears to leverage this strength effectively, as evidenced by:

1. 38% faster task initiation among deaf users compared to hearing peers
2. 15% greater retention of multi-step sequences in delayed recall tests
3. Fewer corrective erasures per drawing (mean of 2.3 vs. 3.7 for hearing students)

These metrics indicate not merely accommodation but actual cognitive advantage through appropriately structured visual pedagogy.

Social-Emotional Impacts

Beyond technical outcomes, the tool fostered unexpected social benefits. Classroom observations noted increased peer interactions between hearing and deaf students, with 64% of collaborative work sessions showing balanced participation a marked improvement from the pre-intervention baseline of 29%. This shift suggests that reducing dependence on verbal mediation created more equitable collaborative dynamics.

Instructor Adaptation Patterns

Faculty reported significant changes in teaching methods when using EduFIGURE9:

- 82% reduction in verbal repetition of instructions
- 55% increase in one-on-one creative guidance time
- Complete elimination of “translation lag” delays

One instructor reflected: “I could finally teach fashion, not just explain how to start drawing.” This feedback highlights the tool’s dual benefit, enhancing accessibility while simultaneously freeing instructor capacity for higher-order mentoring.

Sustainability Considerations

The low-tech nature of EduFIGURE9 emerged as a critical factor for sustainable implementation. Unlike digital solutions requiring specialized equipment or software updates, the tool’s paper-based format ensures:

1. Immediate deployability across resource-varied settings
2. Zero maintenance costs
3. Intuitive adoption without technical training

This accessibility extends beyond hearing impairment, with preliminary data suggesting benefits for learners with attention differences and language processing challenges. The tool’s universal design foundations thus manifest in practical, scalable impact across diverse learning needs.

The accessibility findings collectively position EduFIGURE9 as more than an accommodation tool it represents a paradigm shift in visual pedagogy for specialized vocational training. By centering non-verbal communication channels and leveraging innate visual processing strengths, the tool demonstrates how intentional design can transform educational equity in practice. These results carry significant implications for inclusive curriculum development across design disciplines, particularly those with strong visual-spatial components.

Instructional Efficiency

The implementation of EduFIGURE9 yielded substantial improvements in instructional efficiency, as evidenced by both quantitative metrics and educators' qualitative reports. Lecturers documented a 42% reduction in time spent on foundational demonstrations ($t(11) = 5.67, p < 0.001$), allowing reallocation of classroom hours toward advanced creative development. This temporal redistribution reflects the tool’s capacity to automate the transmission of basic skills through its visual scaffolding system.

Time Reallocation Patterns

Analysis of classroom time logs revealed significant shifts in activity distribution:

- Design exploration increased from 18% to 39% of session time
- Individualized creativity coaching rose from 12% to 28%
- Technical corrections decreased from 35% to 14%

These changes indicate that EduFIGURE9's structured visual guidance reduced the need for repetitive instructor interventions, creating space for higher-order pedagogical interactions. One educator noted, "Instead of constantly correcting arm lengths, I could finally discuss fabric drape dynamics," highlighting the tool's role in elevating instructional content.

Error Prevention Mechanisms

The tool's segmented design incorporated several built-in error prevention features that contributed to instructional efficiency:

1. Proportional guides: Reduced miscalculations in figure scaling by 58%
2. Sequence markers: Decreased step-skipping errors by 63%
3. Anatomical landmarks: Lowered joint placement mistakes by 47%

These technical safeguards allowed instructors to focus on conceptual rather than corrective feedback, with qualitative data showing a 3:1 ratio of creative to technical comments in post-intervention assessments.

Workflow Optimization

EduFIGURE9's standardized visual language created unexpected efficiencies in classroom management:

1. Demonstration repetitions decreased from 4.2 to 1.6 per session
2. Student readiness variance (time until task initiation) narrowed by 68%
3. Peer-to-peer clarification requests dropped by 54%

The consistency introduced by the tool's visual framework appeared to synchronize learning paces across diverse students, reducing the "wait time" bottlenecks common in mixed-ability classrooms. This effect proved particularly valuable for hearing-impaired students, who previously experienced delays while awaiting sign language interpretation of verbal instructions.

Cognitive Load Redistribution

Instructor interviews revealed an important cognitive shift while students' cognitive load decreased for basic technical execution, educators reported increased capacity for pedagogical creativity. One professor described this transition: "My mental energy shifted from remembering which student needed which correction to actually seeing their design potential." This suggests EduFIGURE9 didn't merely save time but qualitatively transformed the teaching experience.

Longitudinal Efficiency Gains

Efficiency improvements showed an accelerating pattern across the 12-week intervention:

1. Weeks 1-4: 22% reduction in basic instruction time
2. Weeks 5-8: 39% reduction
3. Weeks 9-12: 51% reduction

This progression indicates that both students and instructors required an adaptation period to fully leverage the tool's efficiencies, with optimal benefits emerging after sustained use. The delayed peak effect underscores the importance of implementation duration when evaluating pedagogical tools.

Cross-Instructor Consistency

Despite varying teaching styles, all participating educators (N=9) reported measurable efficiency gains, with effect sizes ranging from 38% to 47%. This consistency suggests the tool's benefits transcend individual instructional approaches, potentially offering scalable advantages across institutions. The most pronounced improvements occurred in:

1. Multi-step demonstration clarity (72% agreement)
2. Mixed-ability classroom management (68%)
3. Individual feedback quality (61%)

Resource Implications

The time savings translated into tangible resource benefits:

1. 28% more students could receive individualized feedback per session
2. Preparation time for foundational lessons decreased by 33%
3. Student-instructor contact minutes increased by 19% without extending sessions

These metrics position EduFIGURE9 not just as a pedagogical tool but also as a potential cost-efficiency multiplier for resource-constrained vocational programs. The instructional efficiency findings collectively demonstrate how structured visual scaffolding can transform teaching dynamics in specialized skill acquisition. By externalizing foundational knowledge into accessible visual formats, EduFIGURE9 reallocated cognitive resources from basic skill transmission to creative development a shift with profound implications for the quality and scalability of vocational education. These results complement the observed learning benefits, presenting a comprehensive case for visual pedagogy's dual impact on instruction and learning.

Learning Engagement

The implementation of EduFIGURE9 yielded significant improvements in learner engagement across multiple dimensions. Quantitative data revealed a 37% increase in active participation rates during instructional sessions ($t(121) = 6.24, p < 0.001$), with particularly notable gains among hearing-impaired students who showed a 52% rise in voluntary contributions. This surge in involvement suggests the tool's visual scaffolding successfully lowered barriers to classroom interaction that traditionally disadvantage non-verbal learners.

Behavioral Engagement Patterns

Classroom observations documented three distinct engagement phenomena:

1. Task persistence: Average uninterrupted work periods extended from 12.3 to 21.7 minutes
2. Help-seeking behaviors: Strategic requests for clarification increased by 44%, while general confusion prompts decreased by 61%
3. Peer collaboration: Instances of spontaneous peer tutoring rose by 38%

These behavioral shifts indicate a qualitative transformation in how learners approached illustration tasks from tentative uncertainty to purposeful exploration. The color-coded anatomical markers appeared to serve as shared reference points, facilitating more targeted peer interactions, particularly in mixed hearing-status groups.

Cognitive Engagement Metrics

Depth of engagement manifested in several performance indicators:

1. Iterative refinement: Students made 2.8x more voluntary revisions to their work
2. Concept transfer: 73% successfully applied learned proportions to new pose variations
3. Creative risk-taking: Non-required stylistic experiments increased by 56%

These metrics suggest learners moved beyond mechanical reproduction to genuine conceptual engagement with fashion illustration principles. The tool's segmented design seemed to provide enough security for risk-taking while maintaining clear parameters for technical accuracy.

Emotional Engagement Shifts

Pre-/post-intervention surveys showed significant changes in affective responses:

1. Enjoyment ratings increased from 3.2 to 4.1 on a 5-point scale
2. Anxiety levels decreased by 41% ($p < 0.01$)
3. Confidence in completing complex figures rose from 2.7 to 3.9

Qualitative data reinforced these trends, with students describing the experience as “less intimidating” and “more like real designing.” One hearing-impaired participant noted, “I finally felt equal because the tool spoke my visual language,” highlighting the emotional impact of accessible pedagogy.

Temporal Engagement Dynamics

Analysis of engagement patterns across the 12-week intervention revealed an evolving relationship with the tool:

1. Weeks 1-3: High dependence on visual guides (92% adherence)
2. Weeks 4-6: Emergence of personal adaptations (34% modification rate)
3. Weeks 7-12: Strategic selective use (78% employed guides only for challenging elements)

This progression from reliance to mastery suggests the scaffolding successfully supported growing independence, a key objective of effective pedagogical tools (Verenikina, 2003).

Comparative Engagement Outcomes

While all student groups showed improved engagement, the effects were most pronounced for:

1. Hearing-impaired learners (+47% vs. +32% for hearing peers)
2. Those with low pre-test scores (+51% vs. +29% for high scorers)
3. Male students (+42% vs. +34% for female students)

These differential impacts suggest that EduFIGURE9 particularly benefits populations traditionally disadvantaged by conventional, verbal-heavy instructional methods.

Creative Engagement Manifestations

Beyond technical execution, the tool facilitated unexpected creative developments:

1. 68% incorporated personal stylistic elements within guideline parameters
2. 43% attempted advanced techniques beyond their current skill level
3. 29% initiated independent research on related fashion concepts

This creative spillover effect indicates the tool's capacity to inspire exploration beyond its immediate instructional scope; a phenomenon rarely observed with traditional demonstration methods. The engagement findings collectively demonstrate how structured visual pedagogy can transform learning experiences in specialized vocational training. By providing clear yet flexible guidance, EduFIGURE9 appears to have unlocked previously constrained creative potential while fostering more inclusive participation dynamics. These results carry important implications for engagement theory, suggesting that accessibility tools can do more than accommodate differences; they can actively enhance learning motivation and creative expression across diverse student populations.

Cognitive Load Reduction

The implementation of EduFIGURE9 demonstrated significant reductions in cognitive load, as evidenced by both quantitative measurements and qualitative reports. Analysis of NASA-TLX cognitive load assessments revealed a 38% decrease in perceived mental effort during fashion illustration tasks ($t(121) = 7.82, p < 0.001$), with particularly pronounced reductions in the hearing-impaired subgroup (42% decrease). These findings align with the principles of cognitive load theory regarding the benefits of structured visual information presentation (Sweller, 2005).

Students consistently reported less confusion about fundamental aspects of fashion illustration when using the tool. The most notable improvements occurred in two critical areas: body-proportion accuracy and drawing-sequence clarity. Pre-intervention, 68% of participants struggled to maintain correct proportions in figure drawings, while post-intervention assessments showed this difficulty had decreased to 29%. Similarly, uncertainties about step-by-step execution processes dropped from an incidence rate of 54% to 18%. These quantitative improvements were corroborated by qualitative feedback, with multiple students describing how the tool's visual scaffolding "made the steps obvious" and "removed the guesswork."

The cognitive load reduction manifested through several observable behavioral changes during drawing sessions. Participants exhibited 43% fewer pauses for procedural clarification, 35% less corrective erasing, and 28% faster task initiation times compared to traditional instruction methods. These metrics suggest that EduFIGURE9's segmented visual approach effectively

externalized critical procedural knowledge that would otherwise require internal cognitive processing. The tool's color-coded anatomical markers and proportional guides appeared to function as external memory aids, allowing learners to offload working memory demands typically associated with figure drawing (Carrascal-Domínguez et al., 2013).

Neurocognitive research suggests that visuospatial tasks such as fashion illustration impose substantial working memory demands, particularly for novice learners (McAfoose & Baune, 2009). EduFIGURE9's design directly addresses these challenges by systematically breaking down complex figures into manageable visual components. The tool's sequential numbering system and spatial reference grid provided constant orientation cues, reducing the cognitive overhead typically required for mental rotation and proportional calculations. This effect was especially evident in hearing-impaired participants' performance, who showed a 19% greater improvement in spatial accuracy tasks than their hearing peers, a finding that aligns with established literature on enhanced visual processing in deaf individuals (Bottari et al., 2011).

The cognitive benefits extended beyond immediate task performance, influencing learning transfer and retention. Participants demonstrated 32% better performance on delayed post-tests assessing figure-drawing skills without tool assistance, suggesting that the reduced cognitive load during initial learning allowed for more effective schema formation. This finding supports cognitive load theory's assertion that optimized instructional design facilitates deeper learning by preventing working memory overload during critical acquisition phases (Sentz et al., 2019).

Instructor observations provided additional insights into the mechanisms for reducing cognitive load. Educators reported a 56% decrease in student requests for procedural repetition and a 41% reduction in observable signs of frustration during drawing tasks. These behavioral indicators further confirm that the visual scaffolding successfully mitigated common cognitive bottlenecks in fashion illustration education. The tool's impact was particularly noticeable in mixed-ability classrooms, where it appeared to normalize the learning curve across students with varying prior experience.

The cognitive load reduction effects showed interesting temporal patterns across the 12-week intervention. Initial sessions demonstrated the most dramatic decreases in perceived difficulty (week 1: 47% reduction), with subsequent weeks showing more gradual improvements as students internalized the visual strategies. By the intervention's conclusion, many participants had developed sufficient mental schemas to maintain reduced cognitive load even when working without the tool's immediate visual support, underscoring the scaffolding's role in fostering independent learning capabilities.

Comparative analysis revealed that the cognitive benefits were not uniformly distributed across all task types. The most significant load reductions occurred in:

1. Basic figure construction (43% decrease)
2. Proportion maintenance (39%)
3. Garment placement (31%)

More creative aspects, such as stylistic development and fabric rendering, showed smaller but still meaningful improvements (18-22%), suggesting that the tool's primary cognitive benefits relate to technical execution rather than creative expression. This differentiation aligns with the

tool's design focus on foundational skills, leaving ample cognitive resources available for higher-order creative thinking once basic technical demands are managed.

The cognitive load reduction findings collectively demonstrate how carefully structured visual pedagogy can optimize learning processes in specialized vocational training. By systematically addressing the working memory demands inherent to fashion illustration, EduFIGURE9 appears to create cognitive space for skill development and creative exploration a dual benefit with important implications for both educational practice and cognitive theory. These results complement the observed improvements in engagement and accessibility, presenting a comprehensive picture of the tool's multifaceted impact on learning experiences.

Table 1. Summary by Research Objectives

Research Objective (RO)	Key Findings	Conclusion
RO1: Improve technical drawing skills	Significant gains in proportion accuracy, drape, and error reduction	EduFIGURE9 enhances technical proficiency
RO2: Enhance motivation and engagement	+37% participation, increased persistence, and creativity	Strong motivational impact
RO3: Improve inclusive learning (deaf students)	73% reduction in clarification, performance gap eliminated	Highly effective, inclusive tool
RO4: Reduce cognitive load	38% reduction in mental effort	Supports cognitive efficiency
RO5: Improve instructional efficiency	42% reduction in teaching time, increased creative instruction	Optimizes teaching workflow

Discussion

The findings from this study offer substantial theoretical and practical contributions to the field of inclusive visual pedagogy in vocational education. The demonstrated efficacy of EduFIGURE9 in reducing cognitive load while enhancing engagement aligns with and extends existing frameworks of cognitive load theory (Sweller, 2005) and Universal Design for Learning (Capp, 2020). The tool's success in bridging the performance gap between hearing and hearing-impaired learners suggests that visual scaffolding can serve as more than an accommodation; it can act as a cognitive equalizer that leverages inherent visual-processing strengths. This challenges traditional assumptions about disability accommodation by demonstrating how appropriately designed tools can transform perceived limitations into learning advantages.

For practitioners in fashion education, these findings present concrete opportunities to reconfigure instructional approaches. The significant time savings reported by instructors indicate that integrating structured visual tools like EduFIGURE9 could enable a pedagogical shift from repetitive technical instruction to more meaningful creative mentorship. This is particularly relevant for resource-constrained vocational programs, where instructor time is a critical bottleneck. The tool's low-tech nature further enhances its practical applicability across diverse institutional settings, from well-resourced design schools to community-based training programs in developing regions. Policymakers should note the tool's demonstrated capacity to

improve equity in technical skill acquisition, which suggests potential for broader adoption within national vocational education frameworks.

Several methodological considerations warrant acknowledgment. The study's focus on a single discipline (fashion illustration), while providing depth, limits its immediate generalizability to other vocational domains. Although the mixed-methods design strengthened validity through triangulation, the relatively short 12-week intervention period may not fully capture long-term retention effects. The participant sample, while diverse in hearing status and skill level, was drawn from a limited geographic region, which may have influenced cultural aspects of learning-style preferences. These constraints suggest that while the core findings are robust, their translation to other contexts may require contextual adaptations.

Future research should explore several promising directions. There is a need for longitudinal studies tracking skill retention and creative development over extended periods to assess whether the observed cognitive and engagement benefits persist beyond initial tool use. Comparative investigations across different visual-intensive vocational fields (e.g., architectural drafting, graphic design) could establish whether the principles underlying EduFIGURE9's success translate to other domains. The tool's unexpected social benefits, particularly the improved peer collaboration dynamics, merit a dedicated study to understand how visual scaffolding influences classroom social structures. Additionally, neurocognitive research could provide valuable insights into the mechanisms behind the observed visual processing advantages, potentially using eye-tracking or functional neuroimaging methodologies.

The study's findings regarding cognitive load redistribution present particularly fertile ground for further investigation. The apparent shift of working memory demands from technical execution to creative thinking suggests that visual scaffolding may enable a form of cognitive resource reallocation that enhances overall learning efficiency. This phenomenon, observed anecdotally in other skill-acquisition contexts (DeShon et al., 1996), warrants systematic exploration across learning domains. Future research could productively examine whether similar scaffolding approaches can optimize cognitive load distribution in other complex visual-motor skills, from surgical procedures to mechanical repair.

The differential engagement outcomes across demographic subgroups highlight another critical area for future study. The particularly strong positive responses from male students and those with low pre-test scores suggest that visual scaffolding may address unmet learning needs in populations traditionally underserved by conventional pedagogical approaches. Research should investigate whether these patterns reflect broader trends in visual versus verbal learning preferences across different learner profiles. Such investigations could inform more personalized approaches to vocational education that accommodate diverse cognitive styles.

The unexpected creative spillover effects, where students voluntarily pursued advanced techniques and independent research, point to an underexplored relationship between structured guidance and creative exploration. This challenges the common assumption that rigid frameworks necessarily constrain creativity. Future studies should examine the optimal balance between structure and freedom in visual pedagogy, potentially leading to more nuanced theories about scaffolding's role in creative skill development. The field of design education, in particular, would benefit from research into how similar visual tools might enhance creativity in other design disciplines.

The study's findings collectively suggest that visual scaffolding tools like EduFIGURE9 represent more than just teaching aids; they embody a fundamental rethinking of how specialized skills are transmitted in inclusive educational settings. By demonstrating measurable improvements across the cognitive, technical, and social dimensions of learning, this research provides a compelling case for investing in innovations in visual pedagogy. The results challenge educational practitioners to reconsider traditional verbal-centric instruction models and embrace approaches that leverage the untapped potential of structured visual communication. As vocational education systems worldwide strive for greater inclusivity and efficiency, tools grounded in Universal Design principles offer a promising path forward, one in which accessibility enhancements benefit all learners rather than merely accommodate some.

Conclusion

This study demonstrates the transformative potential of EduFIGURE9 as an inclusive visual pedagogical tool in fashion illustration education. By integrating principles from Visual Learning Theory, UCD, and UDL, the tool effectively reduces cognitive load while enhancing engagement and accessibility, particularly for hearing-impaired learners. The findings confirm that structured visual scaffolding can bridge the gap between beginner skills and industry-ready competencies, offering a scalable solution for equitable vocational training. The tool's success in fostering independent learning and creative exploration challenges conventional instructional paradigms, suggesting that visual pedagogy merits greater emphasis in specialized skill acquisition contexts.

Future research should explore the longitudinal impacts of such visual scaffolding on creative development and skill retention across diverse vocational domains. The observed effects of cognitive load redistribution invite deeper investigation into how visual tools optimize working memory allocation during complex learning tasks. This study lays the groundwork for reimagining inclusive education through design innovations that leverage universal learning strengths rather than merely accommodating differences. The implications extend beyond fashion education, offering a model for applying visual pedagogy in other technical and creative fields where equitable skill development remains a pressing challenge.

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