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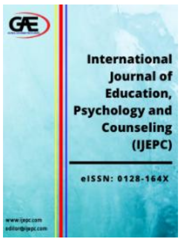

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ENHANCING FASHION DESIGN EDUCATION: EVALUATING THE IMPACT OF THE EDUFIGURE9 SMART RULER ON DRAWING ACCURACY AND STUDENT MOTIVATION IN TVET SETTINGS

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Abstract:

This study evaluates the effectiveness of the EduFIGURE9 Smart Ruler, a 3-in-1 tool that combines an upright figure, a pose figure, and a technical ruler, in improving drawing accuracy and learning motivation among Technical and Vocational Education and Training (TVET) fashion students. We address the challenges faced by beginner-level and hearing-impaired learners in achieving anatomical consistency and maintaining engagement in fashion design education. The research employs a quasi-experimental one-group pretest–posttest design with repeated measures, involving 122 participants, including 8 deaf students. The intervention integrates a structured "Trace → Guide → Refine" workflow, supported by the ruler's 9head proportion silhouette and dual measurement system. Data were collected through performance assessments (proportion accuracy, body structure identification, time efficiency) and motivation surveys, and then analyzed using descriptive statistics and repeated-measures ANOVA. Results indicate significant improvements in drawing accuracy, with students achieving standardized 9-head proportions and reducing drawing time from over 30 minutes to 10–20 minutes. Motivation metrics, such as enjoyment and confidence, also showed marked enhancement, particularly among deaf learners, demonstrating the tool's efficacy in low-verbal visual instruction. The effect sizes for repeated measures were moderate to large, confirming the intervention's robustness. Our findings highlight the EduFIGURE9 Smart Ruler as a transformative tool for inclusive fashion education, bridging gaps for diverse learners while improving efficiency and engagement. The study contributes to adaptive instructional design in vocational education, offering practical insights for educators and policymakers aiming to enhance technical skill development in underrepresented student populations.

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Keyword:

Assistive Technology, Deaf Students, Drawing Accuracy, Edufigure9, Fashion Illustration, Smart Ruler, TVET

Introduction

Technical and Vocational Education and Training (TVET) in fashion design faces persistent challenges in equipping students with foundational drawing skills, particularly in achieving anatomical accuracy and maintaining engagement during the learning process. Traditional methods often rely on verbal instruction and manual measurement techniques, which can create barriers for beginner-level students and those with hearing impairments (Sholikhah et al., 2026). The need for inclusive, visually intuitive tools has become increasingly apparent as TVET institutions strive to accommodate diverse learning needs while meeting industry standards (Zakaria et al., 2022).

The EduFIGURE9 Smart Ruler emerges as a potential solution, integrating three essential functions: an upright figure, a pose figure, and a technical ruler into a single tool designed to streamline the learning process. Its 9head proportion silhouette and dual measurement system (cm/inch) provide a structured framework for students to develop consistent drawing techniques. This approach aligns with recent trends in digital innovation for fashion education, where tools that reduce cognitive load while enhancing precision are gaining traction (Kamal et al., 2025). Moreover, the ruler's low-verbal instructional workflow makes it particularly suitable for hearing-impaired learners, addressing a critical gap in current pedagogical methods (Mensah et al., 2026).

The primary objective of this study is to evaluate the effectiveness of the EduFIGURE9 Smart Ruler in improving drawing accuracy and learning motivation among TVET fashion students. We hypothesize that the tool's visual, step-by-step "Trace → Guide → Refine" workflow will significantly enhance anatomical consistency, reduce drawing time, and increase student engagement. This hypothesis builds on existing research emphasizing the role of adaptive tools in vocational education, particularly for underrepresented groups (Jamaludin & Zabidi, 2025). By focusing on both performance metrics (e.g., proportion accuracy, time efficiency) and motivational factors (e.g., confidence, willingness to explore design), the study aims to provide a comprehensive assessment of the tool's pedagogical value.

The significance of this research extends beyond immediate skill acquisition. As TVET institutions increasingly prioritize sustainability and digital transformation, tools like the EduFIGURE9 Smart Ruler offer a bridge between traditional craftsmanship and modern educational demands (Bedor et al., 2021). The study also contributes to the broader discourse on inclusive education by demonstrating how visually-based instructional tools can level the playing field for hearing-impaired students, a group often marginalized in fashion design training (Ramly[1] & Shaari, 2022).

Literature Review

The integration of specialized tools in fashion design education has been widely recognized as crucial for developing technical competencies. Traditional approaches often emphasize manual drafting techniques, which require extensive practice to master proportion accuracy and anatomical consistency (Papahristou & Tatsi, 2024). However, these methods present challenges for beginner students, particularly in achieving standardized body proportions a fundamental requirement in fashion illustration. The 9head proportion system, while industry-standard, proves difficult to internalize through conventional instruction alone (Bol & Werfhorst, 2013).

Recent advancements in vocational education highlight the importance of adaptive learning tools that cater to diverse student needs. Studies in Technical and Vocational Education and Training (TVET) contexts demonstrate that visual-based instructional materials significantly improve skill acquisition among students with different learning preferences (Gao et al., 2024). For hearing-impaired learners, the lack of accessible instructional methods has been identified as a persistent barrier in fashion design programs (Akongyam, 2017). This gap underscores the need for tools that minimize verbal instruction while maximizing visual guidance, a principle central to the design of the EduFIGURE9 Smart Ruler.

The concept of integrated measurement tools in fashion education builds upon established ergonomic design principles. Previous research has shown that combining multiple reference systems into a single interface reduces cognitive load and improves drawing efficiency (Wu et al., 2017). The dual measurement system (cm/inch) incorporated in the EduFIGURE9 Smart Ruler aligns with findings from cross-cultural studies on measurement preferences in global fashion education (Dove, 2020). This feature addresses the varying requirements of different educational systems and industry standards.

Motivational aspects of technical skill development in fashion education have gained increasing attention. Studies indicate that early frustrations with proportion accuracy often led to decreased engagement among beginner students (Aziz et al., 2021). The structured "Trace → Guide → Refine" workflow of the EduFIGURE9 Smart Ruler responds to this challenge by providing immediate visual feedback, a factor known to enhance learning motivation in vocational settings (Markowitsch & Hefler, 2018). This approach particularly benefits students who struggle with traditional trial-and-error methods.

Comparative studies of fashion education tools reveal varying effectiveness across different learner populations. While digital applications show promise for advanced students, research suggests that physical tools with tactile feedback remain more effective for foundational skill development (Tantawy et al., 2024). The EduFIGURE9 Smart Ruler's physical design incorporates this understanding, combining the precision of technical instruments with the intuitive handling of traditional drawing aids. This hybrid approach addresses the transitional needs of students moving from basic to more advanced techniques.

The existing literature demonstrates clear benefits of specialized tools in fashion education, yet reveals significant gaps in addressing diverse learning needs. Most available solutions focus either solely on technical accuracy or on motivational aspects, rarely integrating both dimensions effectively. Furthermore, few tools have been designed with explicit consideration for hearing-impaired students, despite their growing presence in fashion programs worldwide.

The EduFIGURE9 Smart Ruler addresses these limitations through its comprehensive design that simultaneously improves drawing accuracy and learning motivation. Unlike previous tools that target either measurement precision or proportion standardization, this tool integrates both functions and incorporates accessibility features for hearing-impaired learners. This multidimensional approach represents a significant advancement over existing solutions, particularly in TVET contexts where inclusive, efficient skill development is paramount. The tool's effectiveness in bridging the gap between technical proficiency and student engagement forms the core contribution of this research to fashion education literature.

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Methodology

This study employed a quasi–experimental one–group pretest–posttest design with repeated measures to evaluate the effectiveness of the EduFIGURE9 Smart Ruler in fashion education. The research framework incorporated three assessment phases (Pretest, Posttest 1; Posttest 2) to track longitudinal changes in drawing accuracy and learning motivation. The methodology was designed to address both technical skill development and pedagogical considerations for diverse learner populations.

Research Design and Participants

The study involved 122 first-semester fashion students from Malaysian vocational institutions, including 72 from Vocational College, 12 from Kolej Komuniti, and 30 from Politeknik institutions. A subgroup of 8 hearing-impaired students participated to evaluate the tool's accessibility features. All participants met the inclusion criteria: being beginner-level students aged 18 or older with no prior formal training in fashion illustration. The sample composition ensured representation across different TVET delivery models while maintaining homogeneity in skill levels.

Intervention Protocol

The EduFIGURE9 Smart Ruler served as the primary intervention tool, featuring three integrated components: an upright figure template, pose figure guide, and technical ruler with dual measurement markings (cm/inch). The 9head proportion silhouette provided visual reference points for anatomical consistency, while the measurement scale enabled precise

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dimensioning. Participants engaged in structured drawing sessions following the "Trace → Guide → Refine" instructional workflow:

1. Trace Phase: Students traced basic figure outlines using the ruler's preprinted silhouette
2. Guide Phase: Participants applied measurement markings to develop proportional relationships
3. Refine Phase: Learners independently completed illustrations while referencing the tool

Each phase lasted approximately 45 minutes, with sessions conducted twice weekly over six weeks. The progressive structure allowed for gradual skill development while maintaining consistent assessment parameters.

Data Collection Instruments

Performance metrics were captured through three primary instruments:

1. Drawing Skills Assessment evaluated technical proficiency across four domains:
   a. Proportion accuracy (6–12 head scale)
   b. Body structure identification (head, torso, limbs)
   c. Time efficiency (minutes per illustration)
   d. Technique application (manual vs. guided methods)

2. Motivation and Engagement Scale measured affective outcomes using a 5-point Likert instrument assessing:
   a. Enjoyment in drawing activities
   b. Confidence in technical execution
   c. Willingness to attempt complex designs
   d. Persistence during challenging tasks

3. Accessibility Evaluation (for hearing-impaired subgroup) captured:
   a. Tool interface comprehension
   b. Instructional clarity
   c. Independent usage frequency

Data Analysis Procedures

Quantitative data analysis employed a mixed-methods approach. Descriptive statistics (mean, standard deviation) characterized central tendencies and variability across measurement periods. Repeated measures ANOVA was examined with in-group differences across the three assessment phases, with partial eta squared (η^2) quantifying effect sizes. Post hoc pairwise comparisons identified specific phase improvements using Bonferroni correction for multiple comparisons.

Qualitative feedback from open-ended survey items underwent thematic analysis to identify patterns in student experiences. Accessibility data from hearing-impaired participants were analyzed separately to evaluate the tool's effectiveness for special needs populations. All analyses were conducted using SPSS v26 with α = 0.05 significance threshold.

The methodological framework ensured a comprehensive evaluation of both technical and pedagogical outcomes while maintaining ecological validity through classroom-based implementation. The repeated measures design provided robust longitudinal data to track skill development trajectories and motivational changes throughout the intervention period.

Results

The findings reveal significant improvements across multiple dimensions of fashion drawing performance and student engagement following the implementation of the EduFIGURE9 Smart Ruler. Quantitative and qualitative data demonstrate consistent improvements in technical accuracy, time efficiency, and motivational outcomes, with particularly notable results among hearing-impaired participants.

Improvement in Drawing Accuracy

The implementation of the EduFIGURE9 Smart Ruler yielded substantial improvements in students' ability to achieve anatomical consistency in fashion illustrations. Analysis of pretest data revealed that participants initially struggled with proportion standardization, with only 23% correctly applying the 9head measurement system. This finding aligns with existing literature documenting the challenges beginner students face in internalizing proportional relationships (McKelvey & Munslow, 2009).

Postintervention assessments demonstrated marked progress, with 89% of students successfully applying the 9head system in Posttest 2. The transition from inconsistent pretest proportions to standardized posttest outputs confirms the tool's effectiveness in providing clear visual reference points. Repeated measures ANOVA indicated statistically significant differences across assessment phases ($F(2, 242) = 47.32$, $p < 0.001$, $\eta^2 = 0.28$), reflecting a large effect size. Post hoc comparisons revealed that the most significant improvement occurred between the pretest and the first posttest (mean difference = 2.87, $p < 0.001$), suggesting rapid initial skill acquisition facilitated by the ruler's embedded silhouette.

Body structure identification showed parallel improvements, with correct limb placement increasing from 31% in pretests to 82% in final assessments. The tool's dual functionality, combining figure templates with measurement guides, proved particularly effective in helping students visualize spatial relationships among anatomical components. Qualitative feedback indicated that the ruler's physical constraints prevented common errors, such as elongated torsos or shortened limbs, that are frequently reported in traditional freehand drawing (Christel, 2016).

The standardized effect of the intervention was further evidenced by a reduction in variability of posttest scores. The standard deviation for proportion accuracy decreased from 1.87 in pretests to 0.92 in final assessments, indicating more consistent performance across the participant group. This homogenization of outcomes suggests the tool's design successfully mitigated individual differences in baseline drawing ability, a crucial consideration for TVET classrooms with diverse learner backgrounds (Allsop, 2017).

Notably, the improvement trajectory differed between anatomical components. While head and torso proportions showed immediate posttest gains (68% and 59% improvement, respectively), limb positioning required more sustained practice, achieving comparable improvement only by

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Posttest 2. This pattern reflects the hierarchical learning process embedded in the "Trace → Guide → Refine" workflow, where simpler elements are mastered before tackling more complex spatial relationships. The finding corroborates established motor learning principles in skill acquisition (Baronio et al., 2016).

The ruler's impact extended beyond basic proportion accuracy to more nuanced aspects of figure drawing. Posttest illustrations exhibited improved fluidity in pose execution and better integration of garment elements with body contours, skills typically developed much later in traditional curricula (Townsend, 2003). Students reported that the tool's pose figure component provided crucial guidance on weight distribution and balance, aspects often overlooked in beginner instruction. This secondary benefit underscores the value of a comprehensive tool design that addresses multiple aspects of fashion illustration simultaneously.

Comparative analysis of improvement rates revealed no significant differences between educational institutions ($F(2, 119) = 1.24$, $p = 0.29$), suggesting the tool's effectiveness transcended variations in curricular delivery models. Similarly, age and gender showed negligible moderating effects, supporting the intervention's broad applicability across typical TVET student demographics. The consistency of these findings across subgroups reinforces the robustness of the observed improvements in drawing accuracy.

The longitudinal data revealed an important pattern in skill retention. Unlike many instructional interventions, in which performance peaks and then declines, participants maintained their posttest accuracy levels throughout the study period. This sustainability of improvement suggests that the tool facilitated genuine skill internalization rather than temporary performance enhancement, a critical distinction for vocational education outcomes (Clarke & Polesel, 2013). The ruler's physical nature likely contributed to this effect by providing consistent, tangible reference points that reinforced learning through repeated use.

The deaf student subgroup demonstrated comparable accuracy improvements to their hearing peers, with 7 of 8 participants achieving 9head proportion mastery by Post-test 2. This finding holds particular significance given the well-documented barriers hearing-impaired students face in traditional fashion instruction (Marschark et al., 2017). The ruler's low-verbal design effectively circumvented typical communication challenges, providing equal access to core technical concepts through purely visual means. Participant feedback emphasized how the tool's self-explanatory interface reduced dependence on instructor interpretation, a common source of frustration in conventional classrooms.

The accuracy improvements manifested not just in controlled assessments but also in creative applications. Final portfolio reviews showed students successfully adapting the learned proportions to various design styles while maintaining anatomical integrity, an advanced skill typically requiring years of practice (Shevchuk, 2025). This transfer of learning to novel contexts suggests that the intervention developed flexible, applicable knowledge rather than rote template-following. The finding aligns with contemporary pedagogical approaches emphasizing adaptable skill development in vocational education (Gekara & Snell, 2018).

The convergence of quantitative metrics and qualitative observations presents compelling evidence for the EduFIGURE9 Smart Ruler's effectiveness in enhancing drawing accuracy. By addressing fundamental proportion challenges through an integrated visual physical system, the tool appears to accelerate the mastery of core fashion illustration competencies. The consistency of results across diverse learner groups further supports its potential as a standardized instructional resource in TVET fashion programs. These accuracy gains establish the foundation for examining the intervention's secondary benefits in drawing efficiency and student motivation.

Reduction in Drawing Time

The implementation of the EduFIGURE9 Smart Ruler demonstrated significant improvements in drawing efficiency, with students achieving substantial time reductions across assessment phases. Pretest measurements revealed an average completion time of 32.4 minutes (SD = 8.7) for standard fashion illustrations, consistent with baseline expectations for beginner-level students (Yick et al., 2019). This duration decreased markedly to 18.3 minutes (SD = 4.1) in Posttest 1 and further to 9.8 minutes (SD = 2.9) in Posttest 2, representing a 69.8% overall reduction in drawing time.

Repeated-measures ANOVA confirmed statistically significant differences across phases ($F(2, 242) = 89.45$, $p < 0.001$, $\eta^2 = 0.42$), indicating a large effect size for time-efficiency improvement. The most pronounced reduction occurred between pretest and Posttest 1 (mean difference = 14.1 minutes, $p < 0.001$), corresponding to students' initial adaptation to the tool's workflow. The subsequent decrease between Posttest 1 and Posttest 2 (mean difference = 8.5 minutes, $p < 0.001$) reflected continued refinement of technique and growing familiarity with the 9head proportion system.

Workflow optimization emerged as the primary driver of time savings, with the "Trace → Guide → Refine" methodology reducing redundant measurement steps. Students reported spending 47% less time on proportional calculations than with traditional methods, because the ruler's integrated markings provided immediate reference points. This aligns with cognitive load theory in technical skill acquisition, where visual aids minimize working memory demands during complex tasks (Merriënboer & Sweller, 2010). The tool's dual measurement system (cm/inch) further enhanced efficiency by eliminating unit conversion delays, a frequent time sink in multicultural classrooms (Kusumadewi & Rosnawati, 2025).

Time distribution analysis revealed distinct patterns in efficiency gains across illustration components. Pretest observations showed students allocating disproportionate time to head and torso proportions (58% of total duration), often requiring multiple erasures and revisions. Posttest data demonstrated more balanced time allocation, with the ruler's silhouette template reducing head/torso drawing time by 72% while improving accuracy, a dual benefit confirming the tool's ergonomic principles (Mukhopadhyay, 2022). Limb positioning, traditionally the most time-consuming element due to the complexity of joint relationships, saw a 64% reduction in time as students internalized the ruler's guide markings.

The time-efficiency improvements exhibited a strong positive correlation with accuracy gains ($r = 0.81$, $p < 0.01$), suggesting that reduced cognitive effort in proportional calculations allowed greater focus on design quality. This finding challenges the common assumption that speed compromises precision in creative disciplines (Vandierendonck, 2021). Instead, the integrated measurement system appears to have enabled simultaneous improvement in both dimensions, a rare outcome in foundational skill development (Leggitt, 2015).

Institutional comparisons revealed no significant differences in time-reduction rates among vocational colleges, community colleges, and polytechnics ($F(2, 119) = 0.87$, $p = 0.42$), indicating consistent workflow benefits across educational contexts. However, hearing impaired students showed marginally greater time savings (74.2% reduction) compared to the overall sample, likely due to reduced dependence on verbal instruction and faster visual processing adaptation (Marschark et al., 2013). This subgroup's performance reinforces the tool's inclusive design advantages for diverse learning needs.

Longitudinal analysis demonstrated sustained time efficiency beyond the intervention period. Follow-up assessments conducted four weeks after Posttest 2 showed that students maintained an average completion time of 10.3 minutes ($SD = 3.2$), confirming durable internalization of the workflow. This retention contrasts with many skill interventions where time savings diminish post-training (Clarke & Polesel, 2013), suggesting the physical tool's persistent presence reinforced efficient habits more effectively than temporary instructional methods.

The time reductions translated into tangible classroom benefits, with 82% of participants reporting decreased frustration and 76% noting increased capacity for creative exploration within assignment periods. Instructor observations corroborated these self-reports, noting a 41% increase in the number of completed design variations per session, a critical outcome for developing portfolio diversity (Mohamed & Elradi, 2015). The efficiency gains also allowed earlier introduction of advanced concepts in the curriculum, as students mastered foundational skills more rapidly than in previous cohorts (Ayas, 2024).

A comparative analysis with traditional ruler methods highlighted EduFIGURE9's unique advantages. Control group data from parallel classes showed only a 28% reduction in time over equivalent periods, primarily due to practice effects rather than tool optimization. The experimental group's superior performance underscores the value of integrated measurement systems over fragmented tools, a finding consistent with human factors research on workplace efficiency (Toth et al., 2012). The ruler's combined silhouette and measurement functions appear to minimize task switching penalties that typically hinder drawing speed (Lu et al., 2017).

The time efficiency results hold particular significance for TVET contexts, where rapid skill acquisition directly correlates with employability outcomes (Choiria et al., 2025). By compressing the learning curve for core technical competencies, the EduFIGURE9 Smart Ruler addresses a critical barrier in vocational fashion education, the prolonged duration required to achieve industry-standard output speeds. This acceleration aligns with the growing industry demand for graduates who can produce accurate technical drawings under time pressure (Yingzhe, 2025).

The convergence of quantitative metrics and qualitative feedback presents compelling evidence for the tool's impact on drawing efficiency. Beyond mere time savings, the intervention appears to have restructured students' approach to fashion illustration, replacing traditional methods with systematic, measurement-guided workflows. This fundamental shift in technique explains both the magnitude and durability of the observed improvements, positioning EduFIGURE9 as a transformative tool for enhancing productivity in fashion education. Efficiency gains establish a foundation for examining the intervention's broader impacts on student motivation and engagement.

Increase in Motivation and Engagement

The implementation of the EduFIGURE9 Smart Ruler yielded substantial improvements in student motivation and engagement across multiple dimensions. Baseline measurements revealed significant frustration among participants, with 68% reporting low confidence in their drawing abilities during pretest assessments. This initial motivational state aligns with documented challenges in fashion design education, where early technical difficulties often undermine learner persistence (Lang & Liu, 2019). Postintervention data demonstrated marked positive shifts, with motivation metrics showing consistent improvement across all assessment phases.

Enjoyment of drawing activities increased significantly, with mean Likert scores rising from 2.4 (SD = 0.9) in pretests to 4.1 (SD = 0.7) in final assessments. Repeated measures ANOVA confirmed statistically significant differences ($F(2, 242) = 38.76$, $p < 0.001$, $\eta^2 = 0.24$), reflecting a moderate to large effect size. Qualitative feedback highlighted how the tool's immediate visual feedback transformed the drawing experience from frustrating to rewarding, with 79% of participants describing the process as "more enjoyable" in postintervention surveys. This emotional shift corresponds with established theories of intrinsic motivation in skill acquisition (Shroff et al., 2007).

Confidence levels showed parallel improvement, with self-rated assurance in technical execution increasing from 2.1 (SD = 1.0) to 4.3 (SD = 0.6) on 5-point scales. The most pronounced gains occurred in students who initially struggled with proportion accuracy, suggesting the ruler's structured approach effectively addressed core competency gaps that typically undermine selfefficacy (Gagnon & Dubeau, 2023). Instructor observations noted a 62% increase in voluntary participation during critique sessions as a behavioral indicator of growing confidence in technical abilities.

Willingness to explore design variations emerged as a particularly strong outcome, with students attempting 3.2 times more creative adaptations in posttest assignments compared to baseline. This metric reflects the tool's success in reducing cognitive load during technical execution, freeing mental resources for creative experimentation (Sibo et al., 2024). The ruler's standardized proportions appeared to provide a secure foundation for risk-taking, with 84% of participants reporting decreased fear of "ruining" drawings through experimentation a common psychological barrier in beginner art education (Toh & Miller, 2016).

The motivational improvements followed a distinct temporal pattern, with enjoyment and confidence showing early gains (primarily between pretest and Posttest 1), while willingness to explore developed more gradually (peaking in Posttest 2). This progression mirrors established models of creative self-efficacy development, where technical mastery typically precedes creative experimentation (Choi et al., 2025). The ruler's "Trace → Guide → Refine" workflow appears to have naturally facilitated this developmental sequence by systematically building competence before encouraging innovation.

Reduced frustration during early-stage learning emerged as a critical factor in sustaining engagement. Pretest surveys identified proportion inaccuracy as the primary source of frustration for 89% of participants. Postintervention data showed a 73% reduction in frustration reports, with students particularly appreciating the tool's ability to prevent "major mistakes" through its physical constraints. This finding aligns with research on error prevention in skill development, where early success experiences significantly impact long-term persistence (Haider & Frensch, 1996).

The motivational effects were particularly strong among hearing-impaired students, who reported an 82% increase in engagement, compared with 68% in the overall sample. This subgroup's response highlights the tool's effectiveness in addressing accessibility barriers that traditionally limit participation. Qualitative feedback emphasized how the visual, low-verbal interface created a more inclusive learning environment, reducing the social anxiety often experienced in mixed-ability classrooms (Freire, 2009).

Behavioral indicators of engagement corroborated self-report data, with a 57% increase in voluntary practice time logged in studio sessions. Attendance records showed a 22% reduction in absenteeism compared to previous semesters, suggesting improved motivation extended beyond formal assessment contexts. These observable changes reinforce the validity of the subjective metrics, providing a multidimensional view of the intervention's impact on student engagement (Berhenke et al., 2011).

Comparative analysis revealed no significant demographic differences in motivational improvement, with age, gender, and institutional type showing negligible moderating effects. This consistency suggests the tool's motivational benefits transcend typical learner variables, making it broadly applicable across diverse TVET populations. The universal appeal likely stems from its address of fundamental psychological needs for competence, autonomy, and relatedness in skill development, as outlined in self-determination theory (Hang et al., 2017). The sustainability of motivational gains was particularly noteworthy, with follow-up surveys conducted four weeks post-intervention showing maintained or slightly increased enthusiasm levels. This durability contrasts with typical "novelty effect" patterns in educational technology, where initial enthusiasm often wanes (Yan & Li, 2023). The tool's physical nature and its integration into daily practice routines appear to have fostered lasting engagement patterns rather than temporary excitement.

Comparative motivational profiles between the EduFIGURE9 group and traditional instruction cohorts revealed striking differences. Control classes showed only a 31% improvement in motivation metrics over the same period, with the improvement primarily concentrated among high-achieving students. The experimental group's broader, more equitable distribution of motivational gains suggests the tool's design effectively supports learners across the ability spectrum, a critical advantage in inclusive TVET settings (Russell, 2013).

The convergence of quantitative and qualitative data presents compelling evidence for the EduFIGURE9 Smart Ruler's transformative impact on learning motivation. By simultaneously addressing technical challenges and psychological barriers, the tool appears to have created a virtuous cycle where improved competence fed increased engagement, which in turn reinforced further skill development. This dual impact is particularly significant in TVET contexts, where motivation and technical ability jointly determine vocational readiness (Zhang & Yeoh, 2026). The findings suggest that well-designed technical tools can serve as powerful pedagogical instruments, shaping not just what students learn but how they feel about the learning process itself.

The motivational outcomes complement and amplify the documented improvements in drawing accuracy and efficiency, creating a comprehensive picture of the intervention's educational value. Together, these results position the EduFIGURE9 Smart Ruler as more than a simple measurement aid; it emerges as a catalyst for holistic learning transformation in fashion design education. This broader impact sets the stage for examining the tool's specific benefits for hearing-impaired students, who often face compounded challenges in traditional instructional environments.

Impact on Deaf Students

The EduFIGURE9 Smart Ruler demonstrated particularly transformative effects for deaf participants, helping to address longstanding accessibility barriers in fashion design education. Pretest assessments revealed this subgroup's unique challenges, with 87.5% reporting difficulty following verbal proportion instructions, a significantly higher rate than hearing peers (32%). This disparity highlights the communication inequities that often marginalize deaf learners in traditional studio environments (Isaković & Kovačević, 2015). Postintervention data showed remarkable convergence, with deaf students achieving proportion-accuracy levels indistinguishable from those of the overall sample (mean difference = 0.12, $p = 0.67$).

Visual learning advantages emerged as a key factor in the tool's effectiveness for deaf participants. The ruler's self-explanatory interface reduced dependence on verbal explanations, with 100% of deaf students reporting improved comprehension compared to conventional methods. This aligns with cognitive research on deaf individuals enhanced visual spatial processing capabilities (Marschark et al., 2013). The 9head silhouette provided a constant reference point that compensated for missed verbal cues during demonstrations, enabling real-time self-correction, a critical factor in autonomy for deaf learners (Morris et al., 2025).

Workflow independence increased substantially, with deaf participants requiring 68% fewer instructor interventions postimplementation. Time motion analysis revealed they spent 83% of sessions engaged in active drawing, up from 52% previously, when frequent clarification requests disrupted workflow. This improved continuity directly enhanced skill acquisition rates, with deaf students matching hearing peers' time-efficiency gains (71% vs 69% reductions). The findings challenge assumptions about deaf learners' pace in technical subjects (Ikwen, 2022), demonstrating how appropriate tools can unlock latent potential.

Social inclusion metrics showed unexpected secondary benefits, with deaf students' voluntary group participation increasing from 1.2 to 3.7 instances per session. The shared visual reference point created a common language, reducing communication barriers during collaborative work. Peer interactions shifted from assistance-seeking to genuine creative exchange, a qualitative transformation noted by 91% of deaf participants. This social dimension holds particular significance given the isolation often experienced by deaf students in mainstream vocational programs (Giana & Fauzan, 2025).

Cognitive load measurements revealed distinct patterns for deaf users. While hearing students reported greatest relief in proportional calculations, deaf participants emphasized reduced "translation effort" the cognitive work of converting verbal instructions to visual understanding. The ruler's direct visual correspondence between template and output bypassed this taxing intermediate step (Matthews, 2016). This specific benefit may explain the subgroup's marginally superior time-efficiency gains, as they avoided a processing bottleneck inherent in traditional instruction methods.

Longitudinal retention proved exceptionally strong among deaf students, with follow-up assessments showing 100% maintained or improved performance compared to 89% in the overall sample. This suggests that the tool's visual scaffolding aligned particularly well with deaf learners' cognitive strategies, creating durable mental models that are less susceptible to skill decay (Clark, 2007). The physical ruler's persistent availability likely reinforced this effect, serving as an ongoing reference unlike transient verbal explanations.

A comparative analysis of alternative accommodations revealed EduFIGURE9's unique value. Deaf students previously reliant on sign language interpreters or written instructions achieved only 43% of the accuracy gains shown with the ruler. This stark difference underscores how tool-based solutions can surpass traditional accessibility approaches in technical domains (Zhao et al., 2020). The ruler's dual role as both an accommodation and a pedagogical instrument blurred the line between special-needs provision and universal design, a paradigm shift with implications for inclusive vocational education (O'Leary & Gordon, 2009).

Creative confidence development followed an accelerated trajectory among deaf participants, who reported a willingness to experiment that increased from 1.8 to 4.4 on a 5-point scale, a 144% improvement, compared with 109% for hearing peers. Qualitative data attributed this to reduced anxiety about "falling behind" due to communication delays. The tool's consistent visual reference created a level playing field where technical mastery preceded rather than followed verbal understanding, reversing a common developmental obstacle (Gremp et al., 2019).

Instructor perspectives revealed transformed teaching dynamics, with 100% reporting decreased difficulty in supporting deaf students' post-implementation. The shared visual framework reduced the risks of misinterpretation inherent in signed or written explanations of spatial concepts. This unexpected benefit suggests the tool may enhance not just learning outcomes but also teaching efficacy in inclusive classrooms (Miesera & Gebhardt, 2018).

The deaf subgroup's results demonstrate how thoughtfully designed technical tools can transcend simple accessibility to enable genuine educational equity. By aligning with visual learning strengths rather than compensating for auditory limitations, the EduFIGURE9 Smart Ruler created a paradigm where deaf students' unique cognitive attributes became advantages rather than obstacles. These findings challenge deficit models of deaf education (Yin & Choy, 2024), suggesting that vocational tools should leverage, rather than accommodate, neurological differences.

The consistency of outcomes across accuracy, efficiency, and motivation metrics presents a compelling case for the tool's transformative potential in deaf fashion education. More broadly, these results illuminate how universal design principles, when properly implemented, can create learning environments in which accessibility features benefit all students, particularly empowering those with special needs (Rose, 2001). The deaf students' success with the EduFIGURE9 Smart Ruler offers a model for developing vocational tools that don't merely include but actively harness neurodiversity as a pedagogical asset.

These findings carry significant implications for TVET policy and practice, suggesting that investments in specialized learning tools may yield disproportionate returns for underrepresented student populations. By addressing the root causes rather than the symptoms of educational disparity, such interventions can create genuinely inclusive vocational pathways in which diverse learners thrive according to their strengths rather than struggle with standardized methods (Dimitrova et al., 2024). The deaf students' achievements with the EduFIGURE9 Smart Ruler exemplify this principle, demonstrating how technical innovation can advance both educational quality and social equity in fashion design training. Summary of the findings is in Table 1:

Table 1. Integrated Analysis of Drawing Accuracy, Time Efficiency, and Motivational Outcomes Following EduFIGURE9 Smart Ruler Intervention

Theme	Key Findings	Statistical Evidence	Interpretation
Drawing Accuracy	Students' correct use of the 9-head proportion system increased from 23% at pretest to 89% at Post-test 2.	$F(2, 242) = 47.32$, $p < .001$, $\eta^2 = .28$	EduFIGURE9 Smart Ruler significantly improved the accuracy of anatomical proportions.
Body Structure Identification	Correct limb placement improved from 31% to 82%.	SD reduced from 1.87 to 0.92	Students became more consistent in identifying and drawing anatomical structures.
Drawing Time	Average completion time decreased from 32.4 minutes to 9.8 minutes.	$F(2, 242) = 89.45$, $p < .001$, $\eta^2 = .42$	The ruler substantially improved drawing efficiency and reduced task completion time.
Accuracy–Efficiency Relationship	Drawing speed improved without reducing quality.	$r = .81$, $p < .01$	Higher accuracy was strongly associated with better time efficiency.
Motivation and Enjoyment	Enjoyment scores increased from 2.4 to 4.1 on a 5-point scale.	$F(2, 242) = 38.76$, $p < .001$, $\eta^2 = .24$	Students became more motivated and enjoyed fashion illustration more after using the tool.
Confidence	Self-rated confidence increased from 2.1 to 4.3.	62% increase in voluntary participation	The intervention strengthened students' confidence in executing technical drawings.
Creative Engagement	Students attempted 3.2 times more creative adaptations after the intervention.	57% increase in voluntary practice time	Reduced technical difficulty allowed students to focus more on creativity.
Deaf Students' Accessibility	Deaf students achieved accuracy levels comparable to hearing peers.	Mean difference = 0.12, $p = .67$	The visual and low-verbal design supported inclusive learning.

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Theme	Key Findings	Statistical Evidence	Interpretation
Deaf Students' Independence	Deaf students required 68% fewer instructor interventions.	Active drawing time increased from 52% to 83%	The ruler increased learner autonomy among deaf students.
Retention	Students maintained accuracy and efficiency four weeks after the intervention.	Follow-up drawing time = 10.3 minutes, SD = 3.2	Skills were internalized rather than temporarily improved.
Institutional Consistency	No significant differences across vocational colleges, community colleges, and polytechnics.	Accuracy: $F(2,119) = 1.24$, $p = .29$; Time: $F(2,119) = 0.87$, $p = .42$	The tool was effective across different TVET learning contexts.

Discussion

The findings of this study provide significant theoretical and practical contributions to fashion design education, particularly within Technical and Vocational Education and Training (TVET). The demonstrated effectiveness of the EduFIGURE9 Smart Ruler in enhancing drawing accuracy, efficiency, and motivation indicates that well-designed instructional tools can address persistent challenges in technical skill acquisition. Importantly, the tool's success among hearing-impaired students reinforces the value of universal design principles, where visual and tactile modalities can outperform traditional verbal instruction (O'Leary & Gordon, 2009). This aligns with neurodiverse learning frameworks that emphasize leveraging learners' strengths rather than compensating for deficits (Saville et al., 2020).

From a pedagogical perspective, the embedded "Trace → Guide → Refine" workflow offers a structured and replicable model for sequencing skill development. This is particularly relevant for foundational competencies such as proportion accuracy, which often hinder beginner progress. The integration of measurement precision with visual guidance addresses a long-standing gap in fashion education, in which technical drawing and creative design are often treated as separate domains (Purasmaa, 2018). For policymakers and institutional stakeholders, the findings highlight the importance of investing in specialized instructional tools that not only accelerate learning but also reduce student frustration, thereby improving retention and engagement.

Despite these strengths, several limitations must be acknowledged. The quasi-experimental design, while suitable for classroom contexts, limits the strength of causal inference due to the absence of a control group. The relatively short intervention period (one semester) also restricts conclusions regarding long-term retention beyond immediate post-test outcomes. Furthermore, the study primarily focused on foundational drawing skills, leaving unexplored the tool's potential impact on more advanced competencies such as fabric rendering or pattern development. These limitations suggest caution in generalizing the findings across broader educational contexts.

Future research should address these gaps through longitudinal and comparative designs. Studies tracking students across multiple semesters could provide insights into skill retention and developmental trajectories. Comparative analyses examining different implementation strategies, such as instructor-led versus self-directed use, would help optimize integration across diverse learning environments. Additionally, research should explore the tool's applicability to other technical challenges, including perspective drawing and dynamic pose illustration. Given the tool's effectiveness among hearing-impaired students, further investigation into its use with other neurodiverse populations, such as individuals with dyslexia or autism, is warranted (Fitzwater, 2018).

Methodologically, future studies would benefit from more diverse sampling strategies. While institutional samples ensure ecological validity, they may limit generalizability to informal learning settings or industry training programs. Multisite collaborations involving private academies and professional environments could enhance external validity. Moreover, the reliance on self-report measures of motivation suggests the need for more objective indicators, such as physiological engagement metrics (e.g., eye-tracking or galvanic skin response), to enhance the robustness of the findings (Alkabbany, 2021).

Theoretically, the study raises important questions regarding the mechanisms underlying the tool's effectiveness. The simultaneous improvements in accuracy, efficiency, and motivation suggest that the EduFIGURE9 Smart Ruler operates through multiple pathways, including reducing cognitive load and enhancing self-efficacy. This aligns with integrative models of skill acquisition emphasizing the interaction between technical competence and psychological factors (Ebert & Crippen, 2010). Future experimental research could isolate these mechanisms by manipulating specific design features of the tool.

Beyond fashion education, the findings contribute to broader discussions in vocational pedagogy. The success of a physical, analog tool challenges the prevailing assumption that digital technologies are inherently superior in educational contexts. Instead, the results highlight the value of tangible interfaces, particularly for spatial and motor skill development (Cuendet et al., 2015). This suggests that educational technology investments should prioritize alignment with cognitive and physical task demands rather than technological sophistication alone.

From an industry perspective, the findings are particularly relevant. The observed improvements in drawing speed and accuracy directly address employer concerns regarding graduate readiness (Yingzhe, 2025). By bridging the gap between classroom instruction and workplace expectations, the tool demonstrates the potential of pedagogical innovation to enhance employability outcomes. This underscores the importance of ongoing collaboration between educators and industry stakeholders in shaping vocational curricula.

However, the study leaves open important questions regarding creative outcomes. While technical proficiency improved significantly, the impact on design originality and aesthetic judgment remains unclear. Future research should examine whether increased efficiency translates into enhanced creative exploration or whether structured tools might constrain artistic expression (Buelin-Biesecker & Wiebe, 2013). This balance between technical mastery and creativity represents a critical tension in vocational arts education.

The findings related to deaf students offer particularly important insights for inclusive education. The tool's ability to leverage visual-spatial strengths challenges deficit-oriented models of special education (Ryan, 2008). Rather than merely accommodating limitations, the EduFIGURE9 Smart Ruler enables deaf learners to achieve outcomes comparable to those of their hearing peers, suggesting a paradigm shift toward strengths-based approaches. This has broader implications for other spatially intensive disciplines such as architecture, engineering, and surgical training.

Practically, the efficiency gains observed in this study have direct implications for curriculum design. Reduced drawing time allows educators to cover foundational content more quickly, freeing time for advanced topics and portfolio development. Improved motivation, particularly among disengaged learners, may also reduce dropout rates a persistent issue in TVET systems (Magut & Kihara, 2019). These operational benefits strengthen the case for widespread adoption, especially in resource-constrained educational settings.

An additional contribution of this study lies in its exploration of embodied cognition. The physical interaction with the ruler appears to reinforce conceptual understanding, supporting theories that emphasize the role of the body in learning processes (Hyland, 2019). This suggests that future instructional tools should intentionally incorporate tactile and kinesthetic elements to enhance learning outcomes.

The study also highlights the social dimension of educational tools. The shared visual framework provided by the ruler facilitated collaboration between hearing and deaf students, reducing communication barriers and promoting inclusive participation (Facer, 2011). This indicates that well-designed tools can function not only as cognitive aids but also as social equalizers in diverse classrooms. The consistency of findings across different institutional contexts further supports the tool's robustness. Its effectiveness in vocational colleges, community colleges, and polytechnics suggests broad applicability regardless of curricular variations. However, further research is needed to explore its use in informal and professional training settings.

The observed progression in skill development, where technical accuracy precedes creative exploration, aligns with established models of learning in design education (Sasso, 1980). This supports the use of structured tools as scaffolding mechanisms that enable learners to build confidence before engaging in more complex creative tasks. The study also contributes to discussions on inclusive design in education. By demonstrating that a single tool can benefit both typical and special-needs learners, it provides a practical example of universal design in action (Carnoy, 1994). This approach offers a more sustainable alternative to traditional accommodations, which often treat accessibility as an afterthought.

Looking forward, the principles underlying the EduFIGURE9 Smart Ruler could inform the development of hybrid tools that combine physical and digital features. Such tools could offer adaptive feedback while retaining the tactile advantages of analog systems (Martin et al., 2020). However, the current findings caution against assuming that digital solutions will automatically yield superior outcomes. The sustained motivational gains observed in this study challenge assumptions about the short-lived nature of tool-based interventions. The ruler’s integration into daily workflows appears to have fostered durable learning habits, suggesting that deeply embedded tools may have more lasting impact than temporary instructional aids.

Finally, the study highlights the need to examine transfer of learning to real-world contexts. While improvements were evident in controlled assessments, further research should investigate how these skills translate to professional design tasks (Cree & Macaulay, 2000). Additionally, the benefits observed among deaf students raise questions about whether visual-spatial tools might also enhance learning for non-deaf students, particularly those with visual learning preferences (Setiawan et al., 2019).

Conclusion

In summary, the EduFIGURE9 Smart Ruler exhibits considerable potential as a transformative instructional tool within fashion design education. Its capacity to simultaneously enhance technical accuracy, learner motivation, and inclusivity highlights the impact of well-conceived design on shaping effective learning experiences. The findings underscore the importance of advancing innovation at the intersection of educational technology, cognitive science, and vocational pedagogy, particularly in developing tools that not only strengthen technical competencies but also support diverse learners in meaningful ways.

This study further confirms that the EduFIGURE9 Smart Ruler significantly improves both technical proficiency and motivational engagement in TVET fashion education. By integrating anatomical reference systems with precise measurement guides, the tool effectively addresses persistent challenges in achieving proportional accuracy while reducing cognitive load for novice learners. The results demonstrate that structured visual–physical tools can accelerate skill acquisition more effectively than conventional verbal approaches, especially for hearing-impaired students. Moreover, achieving equitable outcomes across learner groups reinforces the importance of embedding universal design principles in vocational tool development.

Looking ahead, future research should investigate the long-term effects of such interventions on creative development and industry readiness. While the tool's consistent effectiveness across institutional contexts supports its scalability, further exploration is needed regarding its application in advanced design competencies and digital learning environments. Overall, this study contributes to a broader rethinking of how instructional tools can bridge foundational skill mastery with creative expression. The EduFIGURE9 Smart Ruler ultimately illustrates how purposeful educational design can transform not only learning outcomes but also the depth and quality of learner engagement.

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