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Organizational, Pedagogical, and Technological Requirements in Sewing Education: A Situated Learning Approach

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Abstract: This study explores the organizational, pedagogical, technological, and managerial dimensions of equipping sewing training workshops in vocational education institutions, grounded in situated learning theory and competency-based education principles. The research examines how physical infrastructure, equipment standardization, workshop ergonomics, safety compliance, and material flow management directly influence the quality of competency-based education in the sewing and garment production sector. Employing a mixed-methods approach, this study conducted observations in fifteen vocational institutions across Uzbekistan over a six-month period (January-June 2024), involving structured observations, instructor interviews, and student performance assessments. Data analysis revealed that modern, well-equipped workshops following situated learning principles significantly improve students' professional readiness ($p<0.05$), operational accuracy, and adaptability to real industrial environments. The findings confirm a strong positive correlation between workshop infrastructure quality and student competency development ($r=0.78$), with students in well-equipped facilities demonstrating 34% higher skill mastery rates compared to those in traditional workshops. Furthermore, the study proposes a comprehensive situated learning-based model for optimizing workshop infrastructure and pedagogical processes in sewing education, emphasizing the integration of authentic learning activities, cognitive apprenticeship, and community of practice development

Keyword : vocational education, sewing workshops, material management, workshop equipment, situated learning, competency-based education, cognitive apprenticeship, garment technology, occupational safety

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INTRODUCTION

Background and Relevance

The rapid transformation of global and national economies has placed an increasing emphasis on developing skilled human capital capable of responding to changing labor market demands. In developing and transitioning economies, vocational education plays a pivotal role in bridging the gap between theoretical knowledge and practical competence (Lucas, Spencer, & Claxton, 2022). Among the most significant sectors requiring continuous vocational support is the textile and garment industry, which forms a substantial part of industrial production and small-scale entrepreneurship, contributing approximately 2.1 million jobs globally in the fashion technology sector alone (WorldSkills, 2024).

Sewing and garment manufacturing enterprises, ranging from large industrial factories to private tailoring studios and micro-enterprises, contribute not only to meeting consumer demand for clothing but also to employment generation and poverty reduction. According to recent data from the Global Textile Academy (2024), the textile and clothing sector generates significant employment and income along the entire value chain, particularly in developing regions. Therefore, preparing competent specialists for this sector requires an educational environment that replicates real production conditions and integrates modern technological advancements.

The core of effective vocational training in sewing lies in the proper organization of training workshops based on situated learning principles. Lave and Wenger (1991) emphasized that learning is fundamentally situated in authentic contexts and social interactions, arguing that knowledge cannot be separated from the contexts in which it is used. These workshops serve as experimental and practical platforms where students acquire hands-on skills through legitimate peripheral participation, understand workflow systems, and develop professional discipline within a community of practice. The quality of equipment, layout design, safety standards, and material supply mechanisms directly determines the effectiveness of learning outcomes and students' readiness for employment in real industrial settings.

Theoretical Framework: Situated Learning and Competency-Based Education

This research is underpinned by two complementary theoretical frameworks: situated learning theory and competency-based education (CBE). Situated learning theory, as articulated by Lave and Wenger (1991), posits that learning is inherently social and occurs through participation in authentic activities within communities of practice. In the context of vocational education, this theory emphasizes that

knowledge and skills must be learned in contexts that reflect how they are obtained and applied in everyday workplace situations (Billett, 1993). The theory comprises four essential elements: learning is grounded in actions of everyday situations, knowledge is acquired situationally, learning is a social process encompassing ways of thinking and problem-solving, and learning exists in robust social environments made up of actors, actions, and situations.

Collins, Brown, and Newman (1989) extended this concept through cognitive apprenticeship, which emphasizes making thinking visible through modeling, coaching, scaffolding, and fading. In sewing education, this translates to instructors demonstrating techniques, providing guided practice, supporting learners as they develop independence, and gradually withdrawing support as competence increases. This approach bridges traditional apprenticeship methods with contemporary educational needs, ensuring that learners not only acquire procedural skills but also develop conceptual understanding and strategic thinking abilities essential in modern garment production.

Complementing situated learning, competency-based education (CBE) provides a structured framework for defining, teaching, and assessing specific skills required in professional contexts (Mulder, 2017). Unlike traditional time-based education, CBE focuses on what learners can demonstrate they know and can do, allowing students to advance upon mastering specific competencies regardless of time spent (UNESCO-UNEVOC, 2022). In vocational sewing education, this approach enables precise identification of required skills including pattern making, cutting techniques, machine operation, quality control, and finishing procedures, ensuring that graduates possess industry-relevant capabilities.

The integration of these frameworks creates a powerful pedagogical approach where authentic workplace contexts (situated learning) meet systematic skill development (CBE). This synthesis addresses the primary challenge in vocational education: ensuring that theoretical knowledge translates into practical competence within real-world production environments. Research demonstrates that combining situated learning with competency-based approaches significantly enhances learning motivation and achievement in vocational contexts (Huang et al., 2016), particularly when supported by appropriate infrastructure and equipment that mirror industry standards.

Problem Statement

Despite the recognized importance of workshop infrastructure in vocational education, many institutions face persistent challenges that undermine learning effectiveness.

Observational studies conducted in vocational institutions across Uzbekistan reveal that approximately 62% of sewing workshops operate with outdated equipment purchased over a decade ago, while 48% lack adequate spatial organization following ergonomic principles. These infrastructure deficiencies directly contradict the principles of situated learning, which requires authentic environments that mirror real workplace conditions.

Furthermore, inefficient material utilization remains a critical concern, with preliminary assessments indicating that traditional workshop management approaches result in material wastage rates exceeding 25%, significantly impacting both educational budgets and environmental sustainability. Poor ergonomic design contributes to student fatigue and reduced learning efficiency, while insufficient integration of modern technologies creates a disconnect between educational outcomes and industry requirements. Recent consultations with garment industry representatives revealed that 57% of vocational graduates require additional on-the-job training to meet industry standards, suggesting fundamental gaps in workshop-based preparation.

These limitations collectively impede the implementation of effective situated learning and competency-based education, negatively impacting learning efficiency, increasing resource wastage, and ultimately reducing graduates' competitiveness in the labor market. The absence of standardized frameworks for workshop organization exacerbates these challenges, creating inconsistent learning experiences across institutions and hindering systematic quality improvement efforts.

Research Purpose and Objectives

The primary purpose of this study is to develop a comprehensive situated learning-based framework for equipping sewing training workshops and optimizing the utilization of raw materials and auxiliary resources in vocational education settings. This framework integrates theoretical principles from situated learning and competency-based education with practical requirements of contemporary garment production.

The specific research objectives are as follows. First, to analyze international and national standards and requirements for sewing workshop infrastructure and equipment, establishing benchmarks for optimal learning environments. Second, to examine strategies for efficient management of raw materials and consumables within the context of sustainable vocational education practices. Third, to assess the pedagogical impact of workshop organization on student learning outcomes, with particular attention to situated learning principles and competency development. Fourth, to

investigate the relationship between workshop infrastructure quality and students' professional readiness for industrial employment. Finally, to propose an integrated model for sustainable workshop development that synthesizes situated learning theory, competency-based education, and industry best practices, providing actionable guidelines for vocational institutions seeking to modernize their sewing education programs.

METHODS

Research Design and Theoretical Positioning

This study employed a convergent mixed-methods research design, integrating qualitative and quantitative approaches to provide a comprehensive understanding of workshop infrastructure and its impact on vocational education outcomes. The research framework was explicitly grounded in situated learning theory (Lave & Wenger, 1991) and competency-based education principles (Mulder, 2017), positioning workshop environments as authentic learning contexts where students engage in legitimate peripheral participation within communities of practice.

The qualitative component focused on understanding the contextual factors, pedagogical practices, and social dynamics within sewing workshops, while the quantitative component measured infrastructure quality, student performance metrics, and learning outcome correlations. This dual approach aligns with recommendations for vocational education research, which emphasizes the importance of capturing both measurable outcomes and the nuanced social processes underlying skill development (Lucas, 2022). The research design deliberately positions workshops as sites of situated cognition, where learning emerges through the dynamic interaction between individuals, tools, and authentic tasks reflecting real-world garment production scenarios.

Sampling Strategy and Research Context

The research was conducted across fifteen vocational education institutions in Uzbekistan, selected through purposive stratified sampling to ensure representation of diverse institutional contexts. The sampling criteria included institutional accreditation status, student enrollment capacity ranging from 200 to 800 students, availability of dedicated sewing/garment production programs, and geographic diversity representing urban, peri-urban, and rural locations across five regions (Tashkent, Samarkand, Bukhara, Fergana, and Andijan).

The selected institutions comprised eight professional colleges (lycees), five technical training centers, and two higher education institutions offering vocational programs. Within

these institutions, the study focused on 45 sewing workshops of varying equipment levels, categorized as traditional (equipment older than 10 years, n=18), transitional (mixed equipment ages 5-10 years, n=17), and modern (equipment less than 5 years old with digital integration, n=10). This categorization enabled comparative analysis of infrastructure impact on learning outcomes across different modernization stages.

The participant sample included 420 second and third-year vocational students (aged 17-22, mean age 19.3 years) enrolled in sewing and garment technology programs, 45 workshop instructors with teaching experience ranging from 5 to 28 years (mean 14.6 years), and 12 workshop supervisors/administrators responsible for facility management and equipment procurement. Student selection employed random sampling within each institution, ensuring balanced representation across program levels and workshop categories. All participants provided informed consent, and the study received ethical approval from the Chirchik State Pedagogical University Research Ethics Committee (Approval No. CSPU-2023-147).

Data Collection Instruments and Procedures

Data collection occurred over six months (January-June 2024) employing multiple instruments to ensure triangulation and comprehensive coverage of research objectives. First, structured observation protocols were developed based on situated learning principles and vocational education standards, documenting workshop spatial organization, equipment availability and functionality, material flow systems, instructor-student interactions, and authenticity of learning activities. Each workshop was observed for a minimum of 12 hours across different class sessions, with observations recorded using standardized checklists and field notes capturing contextual details and emergent themes.

Second, infrastructure quality assessments utilized a validated Workshop Infrastructure Quality Index (WIQI) developed specifically for this study. The WIQI comprised 47 items across five dimensions: spatial organization and ergonomics (12 items), equipment quality and diversity (15 items), safety and compliance standards (8 items), material management systems (7 items), and technological integration (5 items). Each item was rated on a five-point scale, with total scores ranging from 47 to 235, categorized as poor (47-94), fair (95-141), good (142-188), and excellent (189-235). The instrument demonstrated high internal consistency reliability (Cronbach's alpha = 0.91) and content validity as confirmed by a panel of five vocational education experts and three industry specialists.

Third, student competency assessments measured practical skill

development using performance-based evaluations aligned with national vocational qualification standards. Assessments occurred at the beginning (baseline) and end (endpoint) of the study period, evaluating eight core competencies: pattern interpretation and layout, fabric cutting accuracy, machine operation proficiency, seam construction quality, pressing and finishing techniques, quality control and defect identification, time management and workflow organization, and problem-solving in production scenarios. Each competency was scored using detailed rubrics developed through expert consultation, with possible scores ranging from 0-100 for each competency area. Assessment reliability was established through inter-rater agreement (Cohen's kappa = 0.84) involving two independent expert evaluators.

Fourth, semi-structured interviews were conducted with instructors and supervisors to understand pedagogical practices, resource management challenges, and perspectives on situated learning implementation. Interview protocols explored themes including instructional strategies for skill development, integration of authentic tasks and industry connections, material procurement and waste management approaches, challenges in equipment maintenance and technology adoption, and observations regarding student engagement and learning progression. Interviews were audio-recorded with permission, transcribed verbatim, and analyzed using thematic coding procedures.

Finally, material utilization tracking involved systematic documentation of fabric consumption, waste generation, and resource efficiency across selected workshops over a three-month period. This quantitative measure provided objective data on the economic and environmental sustainability dimensions of workshop operations.

Data Analysis Procedures

Quantitative data analysis employed descriptive and inferential statistical procedures using SPSS 27.0 software. Descriptive statistics (means, standard deviations, frequencies) characterized workshop infrastructure quality, student competency levels, and material utilization patterns. Pearson correlation analysis examined relationships between infrastructure quality scores and student competency development, while independent samples t-tests and one-way ANOVA compared student outcomes across workshop categories (traditional, transitional, modern). Multiple regression analysis identified specific infrastructure factors most strongly predicting student competency gains, controlling for potential confounding variables including prior educational background and instructor experience.

Qualitative data analysis followed Braun and Clarke's (2006) thematic analysis approach, involving

familiarization with data through repeated reading of transcripts and observation notes, generation of initial codes capturing semantic and latent meanings, searching for themes by collating codes into potential patterns, reviewing themes to ensure coherence and distinctiveness, defining and naming themes with clear descriptions of their essence, and producing the final analysis integrating themes with quantitative findings. Analysis was supported by NVivo 14 software for coding management and theme visualization. To ensure analytical rigor, two researchers independently coded a subset of data, discussing discrepancies until consensus was reached, achieving an inter-coder reliability of 89%.

Integration of quantitative and qualitative findings occurred through a convergent analysis approach, where results were compared, contrasted, and synthesized to develop comprehensive understanding of how workshop infrastructure shapes learning experiences and outcomes. Contradictions or complementarities between data sources were explored to deepen interpretive insights, with particular attention to how situated learning principles manifested in workshop practices and their measurable impacts on competency development.

Validity, Reliability, and Ethical Considerations

Multiple strategies ensured research validity and reliability. Construct validity of measurement instruments was established through expert review panels and pilot testing in two institutions not included in the main study. Concurrent validity of the WIQI was verified through correlation with external auditor ratings of workshop quality ($r=0.76$, $p<0.01$). Internal consistency reliability of all quantitative instruments exceeded the 0.70 threshold considered acceptable for research purposes. Inter-rater reliability for performance assessments was established through joint evaluation sessions and regular calibration meetings among assessors.

Qualitative research credibility was enhanced through prolonged engagement in research sites, persistent observation across diverse contexts and time periods, triangulation of multiple data sources and methods, member checking procedures where participants reviewed interpreted findings, and maintenance of an audit trail documenting analytical decisions. Transferability was supported through thick description providing detailed contextual information enabling readers to assess applicability to their settings.

Ethical considerations received careful attention throughout the research process. All participants provided voluntary informed consent after receiving clear explanations of

research purposes, procedures, potential risks and benefits, and their rights to withdraw without penalty. Student performance data were de-identified to protect privacy, and institutional identities were anonymized in reporting. The study posed minimal risk to participants, with the primary concern being time demands, which were minimized through efficient scheduling. Findings are being shared with participating institutions to support their improvement efforts, fulfilling the research's commitment to reciprocal benefit.

RESULTS AND DISCUSSION

Workshop Infrastructure Quality and Spatial Organization

Analysis of workshop infrastructure using the Workshop Infrastructure Quality Index (WIQI) revealed substantial variation across the fifteen institutions studied. Mean WIQI scores ranged from 89 (poor category) to 198 (excellent category), with an overall sample mean of 151.3 (SD=34.7), placing most workshops in the good category. Modern workshops (n=10) demonstrated significantly higher infrastructure quality (M=187.4, SD=18.2) compared to transitional workshops (M=147.8, SD=22.6) and traditional workshops (M=119.5, SD=25.4), $F(2,42)=38.67$, $p<0.001$, eta-squared=0.65, indicating a large effect size.

Spatial organization emerged as a critical dimension of workshop quality. Effective workshops demonstrated the following quantifiable characteristics based on observational assessments and measurements. Adequate floor space allocation averaged 4.2 square meters per student workstation in modern workshops compared to 2.8 square meters in traditional facilities, with European vocational standards recommending minimum 3.5 square meters per station. Proper functional zoning was evident in 80% of modern workshops, with clearly demarcated areas for cutting operations, sewing stations, pressing and finishing, quality inspection, and material storage, compared to only 35% of traditional workshops exhibiting clear zoning patterns.

Workstation layout followed ergonomic principles in 72% of modern facilities, featuring adjustable-height work surfaces, appropriate lighting levels exceeding 500 lux at task surfaces, and strategic equipment placement minimizing repetitive reaching or twisting motions. Traditional workshops demonstrated ergonomic design in only 28% of observed stations, contributing to student reports of physical fatigue and discomfort during extended practice sessions.

Lighting quality assessments revealed that modern workshops maintained average illumination levels of 620 lux at sewing stations and 780 lux at cutting tables, meeting or exceeding international standards for precision

textile work. Traditional workshops averaged 310 lux at sewing stations, falling significantly below recommended levels and potentially impeding accurate seam work and quality assessment. Natural lighting integration through appropriately positioned windows supplemented artificial lighting in 60% of modern facilities compared to 25% of traditional workshops.

Ventilation and climate control systems were functional in 90% of modern workshops, maintaining temperatures between 20-24°C and relative humidity at 40-60%, optimal ranges for textile handling and worker comfort. Traditional facilities showed inadequate climate control, with 65% lacking mechanical ventilation systems and experiencing temperature fluctuations between 15-32°C depending on season, negatively impacting material behavior and student concentration levels.

Table 1. Recommended Spatial Standards for Sewing Workshops Based on International Best Practices and Study Findings

Infrastructure Element	Recommended Standard	Modern Workshops (M±SD)	Traditional Workshops (M±SD)
Floor space per student	3.5-4.5 m²	4.2±0.6 m²	2.8±0.8 m²
Ceiling height	Minimum 3.0 m	3.4±0.3 m	2.9±0.4 m
Lighting at sewing stations	500-750 lux	620±95 lux	310±120 lux
Lighting at cutting tables	750-1000 lux	780±110 lux	340±150 lux
Temperature range	20-24°C	22.1±1.3°C	18.5±4.2°C
Relative humidity	40-60%	52±6%	38±15%
Ventilation rate	6-8 air changes/hour	7.2±1.1	3.1±1.8

Equipment Quality, Diversity, and Technological Integration

Equipment analysis revealed significant disparities in machinery availability, functionality, and technological sophistication across workshop categories. Modern workshops maintained comprehensive equipment inventories averaging 24.3 functional machines per 20-student capacity workshop (ranging from 20-28 machines), ensuring adequate machine-to-student ratios of approximately 1.2:1 allowing for individual practice and small group collaborative work. Traditional workshops averaged 14.7 machines per equivalent capacity (ranging from 10-18 machines), resulting in ratios of 0.74:1 requiring extensive rotation schedules that reduced actual practice time per student.

Equipment diversity assessment examined the presence of essential machine types required for comprehensive garment production training. Modern workshops demonstrated superior diversity, maintaining the following equipment categories with specific quantities per 20-student workshop capacity. Industrial lockstitch straight-stitch machines numbered 8-10 units, representing the fundamental tool for basic seam construction and accounting for approximately 60% of garment assembly operations. Single-needle and multi-needle overlock machines totaled 4-6 units, essential for seam finishing and preventing fabric fraying,

particularly critical for knit fabric handling. Coverstitch and flatlock machines numbered 2-3 units, enabling professional hem finishing and decorative topstitching techniques increasingly demanded in contemporary fashion. Heavy-duty machines for thick fabrics and special materials included 1-2 units designed for outerwear, upholstery, and technical textile applications, expanding student competency beyond basic apparel. Computer-controlled pattern-making and cutting systems were present in 70% of modern workshops, including CAD software for digital pattern development and automated cutting equipment improving accuracy and material efficiency.

Traditional workshops showed significant equipment gaps, with 67% lacking coverstitch machines, 83% lacking computer-aided design systems, and 45% relying exclusively on domestic-grade sewing machines inadequate for developing industrial production competencies. Equipment condition assessments revealed that modern workshops maintained 94% functional equipment status through regular maintenance protocols, while traditional workshops showed only 68% functional status, with broken or poorly-maintained machines creating safety hazards and impeding learning progression.

Auxiliary equipment and tools demonstrated similar disparities. Modern workshops provided comprehensive tool sets including rotary cutters and self-healing cutting mats, professional steam pressing systems maintaining consistent temperature and pressure, dress forms in multiple size ranges for fitting assessment, specialized presser feet enabling diverse sewing techniques, and comprehensive measuring and marking tools ensuring precision throughout the production process. Traditional workshops showed limited auxiliary equipment, with students often sharing basic tools and lacking specialized implements for advanced techniques, constraining their ability to execute complex garment construction tasks matching industry standards.

Table 2. Equipment Inventory and Technological Integration Across Workshop Categories

Equipment Category	Modern Workshops (%)	Transitional Workshops (%)	Traditional Workshops (%)
Lockstitch machines (adequate quantity)	100%	88%	72%
Overlock machines (adequate quantity)	100%	82%	56%
Coverstitch/Flatlock machines	100%	59%	33%
Heavy-duty specialized machines	80%	47%	22%
CAD pattern-making software	70%	35%	17%
Automated cutting systems	60%	24%	11%
Professional pressing equipment	100%	76%	50%
Digital projection/demonstration systems	80%	41%	17%
Overall equipment functionality rate	94%	81%	68%

Material Management Systems and Resource Efficiency Outcomes

Material management analysis revealed substantial differences in procurement procedures, inventory tracking systems, and resource

utilization efficiency across workshop categories, directly impacting both educational budgets and environmental sustainability. Modern workshops implementing systematic material management demonstrated material wastage rates averaging 8.3% (SD=2.1%), significantly lower than traditional workshops averaging 26.7% (SD=5.8%), $t(25)=11.45$, $p<0.001$, Cohen's $d=4.31$, representing a very large effect size. This 18.4 percentage point difference translates to substantial cost savings and environmental benefits over an academic year.

Inventory tracking systems showed marked variation in sophistication and effectiveness. Modern workshops employed digital inventory management systems utilizing barcode scanning or RFID technology in 70% of cases, enabling real-time tracking of fabric stocks, consumables, and finished products. These systems automatically generated procurement alerts when supplies approached reorder points, maintained usage histories facilitating accurate budget forecasting, and produced detailed reports on material consumption patterns identifying inefficiencies. Traditional workshops relied predominantly on manual record-keeping (89%), resulting in frequent stockouts of essential materials, overordering of slow-moving items, and limited visibility into actual consumption patterns hindering informed decision-making.

Standardized procurement procedures were documented and consistently followed in 90% of modern workshops compared to 45% of traditional facilities. Modern workshops demonstrated systematic approaches including needs assessment based on curriculum requirements and enrollment projections, competitive supplier solicitation ensuring quality and cost-effectiveness, quality inspection protocols upon material receipt, and centralized storage with controlled access preventing unauthorized use or pilferage. These structured procedures contributed to improved material quality consistency, reduced procurement costs through volume purchasing and supplier relationships, and better alignment between material availability and instructional schedules.

Waste minimization strategies varied substantially across workshop categories. Modern workshops implemented comprehensive approaches achieving superior resource efficiency. Pattern layout optimization using CAD software improved marker efficiency, increasing fabric utilization from typical 72-78% to 83-87%, representing 5-15% material savings per garment. Systematic fabric remnant management involved categorizing and storing usable scraps for future projects, creating opportunities for teaching creative design using leftover materials and preventing premature disposal of

valuable resources. Student training in precise cutting techniques emphasized accuracy and material conservation, with competency assessments including efficiency metrics alongside quality measures. Some modern workshops (40%) established recycling partnerships with textile recycling facilities, diverting non-usable fabric waste from landfills and demonstrating environmental stewardship.

Traditional workshops showed limited waste minimization efforts, with fabric cutting performed primarily manually without layout optimization, remnant materials often discarded rather than systematically preserved, and minimal emphasis on conservation in instruction focusing predominantly on technique mastery. Observations revealed that inadequate cutting tools, poor workspace organization, and insufficient instructor supervision of material handling contributed to elevated wastage in traditional settings.

Table 3. Material Management Practices and Efficiency Outcomes Across Workshop Categories

Management Practice/Outcome	Modern Workshops	Transitional Workshops	Traditional Workshops
Material wastage rate (M±SD)	8.3±2.1%	15.4±3.7%	26.7±5.8%
Digital inventory system usage	70%	35%	11%
Standardized procurement procedures	90%	65%	45%
Pattern optimization software usage	70%	29%	6%
Fabric utilization efficiency	83-87%	76-80%	72-78%
Systematic remnant management	90%	53%	22%
Recycling program implementation	40%	18%	6%

Student Competency Development and Learning Outcomes

Student competency assessments revealed significant differences in skill development trajectories based on workshop infrastructure quality and pedagogical practices. Baseline assessments conducted at study commencement showed no significant differences in initial competency levels across workshop categories, $F(2,417)=1.83$, $p=0.162$, confirming comparable starting points and enabling valid comparison of learning gains.

Endpoint assessments conducted after six months of instruction revealed substantial differences in overall competency development. Students in modern workshops achieved mean total competency scores of 78.4 out of 100 (SD=8.6), significantly higher than transitional workshop students averaging 68.7 (SD=10.3) and traditional workshop students averaging 58.5 (SD=12.1), $F(2,417)=89.34$, $p<0.001$, partial eta-squared=0.30. Post-hoc Tukey tests confirmed significant differences between all three categories ($p<0.001$ for all pairwise comparisons), demonstrating that workshop infrastructure quality substantially impacts learning outcomes across the competency spectrum.

Analysis of mean competency gain scores from baseline to endpoint further illuminated differential learning rates. Modern workshop

students demonstrated average gains of 34.2 points (SD=7.8), compared to 24.6 points (SD=8.9) for transitional workshop students and 19.3 points (SD=9.7) for traditional workshop students, $F(2,417)=67.12$, $p<0.001$, partial eta-squared=0.24. These findings indicate that students in modern facilities not only achieve higher absolute competency levels but also learn more rapidly and efficiently, likely reflecting the combined influences of better equipment, enhanced pedagogical practices, and more authentic learning environments aligned with situated learning principles.

Disaggregated analysis of specific competency domains revealed patterns of differential impact. Modern workshop students showed particularly strong advantages in technical skill areas directly dependent on equipment quality and technology integration. Machine operation proficiency scores averaged 81.3 in modern workshops compared to 64.7 in traditional settings, representing a 25.6% performance gap. Quality control and defect identification showed modern workshop means of 76.9 versus traditional means of 55.8, a 37.8% performance difference, potentially reflecting better lighting, magnification tools, and systematic quality standards in modern facilities. Pattern interpretation and layout demonstrated modern means of 79.5 compared to traditional means of 60.2, a 32.1% gap, likely influenced by CAD technology exposure in modern workshops enhancing spatial visualization and technical drawing skills.

Competency areas less directly dependent on equipment showed smaller but still significant advantages for modern workshop students. Problem-solving in production scenarios showed modern means of 75.6 versus traditional means of 63.2, a 19.6% difference, suggesting that authentic learning environments with diverse challenges foster superior adaptive thinking. Time management and workflow organization demonstrated modern means of 77.8 compared to traditional means of 67.1, a 15.9% gap, potentially reflecting better workspace organization and material flow systems enabling students to develop efficient work habits.

Correlation analysis examining relationships between workshop infrastructure quality and student outcomes revealed strong positive associations. Overall WIQI scores correlated significantly with total competency scores, $r=0.78$, $p<0.001$, indicating that approximately 61% of variance in student competency could be explained by workshop infrastructure quality, a substantial proportion suggesting infrastructure as a critical determinant of learning success. Specific infrastructure dimensions showed varying correlation strengths with competency outcomes, with equipment quality

showing the strongest association (r=0.74), followed by technological integration (r=0.69), spatial organization (r=0.62), material management systems (r=0.58), and safety standards (r=0.51), all significant at p<0.001 level.

Multiple regression analysis controlling for potential confounding variables including student prior achievement, instructor experience, class size, and instructional hours confirmed that workshop infrastructure quality remained a significant predictor of competency gains (β=0.64, p<0.001) even after accounting for these factors, demonstrating robust infrastructure effects independent of other educational inputs.

Table 4. Student Competency Development Outcomes by Workshop Category (N=420)

Competency Domain	Modern (M±SD)	Transitional (M±SD)	Traditional (M±SD)
Pattern interpretation & layout	79.5±7.8	71.2±9.3	60.2±11.5
Fabric cutting accuracy	80.2±7.2	69.8±9.7	57.9±12.3
Machine operation proficiency	81.3±6.9	72.4±8.8	64.7±10.6
Seam construction quality	78.9±8.1	68.9±10.2	58.3±11.9
Pressing & finishing techniques	77.6±8.5	67.3±10.5	56.1±12.7
Quality control & defect ID	76.9±9.1	65.8±11.2	55.8±13.2
Time management & workflow	77.8±8.3	69.7±9.8	67.1±10.9
Production problem-solving	75.6±9.4	68.1±10.7	63.2±11.8
Overall Total Competency	78.4±8.6**	68.7±10.3*	58.5±12.1

*Note: Scores range from 0-100. **p<0.001 compared to traditional; *p<0.001 compared to traditional.*

Pedagogical Organization and Situated Learning Implementation

Qualitative analysis of instructional practices revealed substantial variation in pedagogical approaches aligned with situated learning principles across workshop categories. Modern workshops demonstrated significantly greater implementation of authentic learning activities, cognitive apprenticeship techniques, and community of practice development compared to traditional facilities.

Authentic task integration, central to situated learning theory, was systematically observed in modern workshops where 82% of instructional time involved students working on realistic garment production projects mirroring industry practices, including complete garment construction from pattern to finished product, quality standards matching commercial production expectations, and time constraints reflecting real workplace pressures. Instructors in these settings deliberately designed projects requiring students to navigate typical production challenges such as fabric variations, equipment malfunctions, and design modifications, fostering problem-solving capabilities transferable to actual employment contexts. Traditional workshops showed only 43% of instructional time devoted to complete authentic projects, with remaining time focused on isolated skill practice divorced from meaningful production contexts.

Cognitive apprenticeship elements, particularly modeling and coaching, were prominently featured in modern workshops. Instructors routinely demonstrated techniques while articulating their thinking processes, making expert decision-making visible to novice learners. Following demonstrations, instructors provided intensive one-on-one coaching, observing students' work closely and offering immediate corrective feedback tailored to individual needs. As students developed proficiency, instructors gradually reduced support intensity (fading), encouraging independent problem-solving and self-assessment. Traditional workshop instructors relied more heavily on verbal explanations without demonstrations, provided less individualized attention due to larger effective class sizes from inadequate equipment, and maintained high support levels throughout instruction rather than strategically fading to promote autonomy.

Community of practice development varied notably across settings. Modern workshops fostered collaborative learning environments where students worked in production teams, engaged in peer assessment and feedback exchanges, and participated in collective problem-solving discussions. Some modern facilities (30%) established formal connections with local garment enterprises, enabling guest expert demonstrations, student internship placements, and industry feedback on student work, all elements strengthening the authenticity and legitimacy of the learning community. Traditional workshops exhibited more individualistic learning orientations with limited structured peer interaction and minimal industry connections, reducing opportunities for social learning processes central to situated cognition.

Assessment practices showed pedagogical sophistication differences across categories. Modern workshops employed predominantly performance-based assessments evaluating students' actual garment production capabilities under realistic conditions, utilized detailed rubrics providing clear competency standards and transparent evaluation criteria, incorporated both formative assessments throughout learning progressions and summative evaluations at key milestones, and included student self-assessment and peer assessment activities developing metacognitive skills. Traditional workshops relied more heavily on written examinations testing theoretical knowledge without corresponding skill demonstration requirements, providing less detailed feedback to guide improvement, and employing primarily summative assessments at course conclusions offering limited opportunities for ongoing learning refinement.

DISCUSSION

Theoretical Implications: Validating Situated Learning in Vocational Contexts

The findings of this study provide robust empirical support for situated learning theory's applicability to vocational education, particularly in technical domains requiring integrated cognitive and psychomotor skill development. The strong positive correlation (r=0.78) between workshop infrastructure quality and student competency outcomes substantiates Lave and Wenger's (1991) assertion that learning environments authentically reflecting target practice contexts significantly enhance skill acquisition and transfer. Workshops equipped with industry-standard machinery, organized according to professional workflow patterns, and implementing materials management systems mirroring actual production facilities created what Lave and Wenger term legitimate peripheral participation opportunities, enabling students to gradually assume fuller roles within communities of practice.

The differential impact of infrastructure quality on various competency domains offers nuanced insights into how environmental authenticity shapes learning processes. Technical competencies most directly dependent on equipment quality and technological tools, such as machine operation proficiency and computer-aided pattern development, showed the largest performance gaps between modern and traditional workshop students, 25.6% and 32.1% respectively. This pattern suggests that certain forms of vocational knowledge are indeed highly situated in specific technological contexts and cannot be effectively developed through abstract instruction or inferior substitutes, supporting situated cognition perspectives emphasizing tool-mediated learning.

However, the finding that problem-solving and adaptive thinking competencies, while showing significant advantages for modern workshop students, demonstrated smaller performance gaps (19.6%) suggests that these more transferable capabilities may develop through multiple pathways beyond purely material infrastructure. This partial independence from immediate environmental features aligns with critiques of strong situated cognition views, suggesting that while context matters substantially, some forms of knowledge possess greater abstraction and transferability than strict situatedness perspectives might predict. The implication for vocational education theory is that an optimal pedagogical framework must balance situated, context-specific learning with opportunities to develop generalizable problem-solving capacities applicable across diverse settings.

The pedagogical practices observed in higher-performing workshops operationalized cognitive apprenticeship principles articulated by Collins, Brown, and Newman

(1989), particularly through systematic modeling of expert performance, intensive coaching during student practice, strategic scaffolding of increasing task complexity, and gradual fading of instructor support as competence developed. The positive learning outcomes associated with these practices validate cognitive apprenticeship as an effective instructional model for vocational domains, bridging traditional apprenticeship wisdom with contemporary educational psychology insights. The explicit emphasis on making tacit expert knowledge visible through think-aloud demonstrations and articulated reasoning proved particularly valuable, addressing a longstanding challenge in vocational education where master practitioners often struggle to explain their intuitive expertise to novices.

The integration of competency-based education frameworks with situated learning principles demonstrated in effective workshops represents a productive synthesis addressing complementary aspects of vocational preparation. CBE provides the structure of defining, teaching, and assessing specific skills required for professional practice, ensuring comprehensive coverage of requisite competencies and transparent standards for learner progression. Situated learning provides the authentic context ensuring these competencies develop in meaningful application scenarios rather than as decontextualized skill fragments. Together, these frameworks created learning environments where students systematically developed well-defined capabilities while simultaneously gaining the contextual understanding, adaptive flexibility, and professional identity formation essential for successful workplace integration.

Practical Implications for Workshop Modernization and Pedagogical Practice

The research findings carry significant implications for vocational education administrators, policymakers, and instructional personnel seeking to enhance sewing and garment technology training effectiveness. The documented strong relationship between infrastructure quality and student outcomes provides compelling justification for institutional investments in workshop modernization, demonstrating that enhanced facilities yield substantial educational returns rather than constituting mere cosmetic improvements.

Priority investment areas emerge clearly from the data. Equipment modernization should emphasize acquiring diverse, industry-standard machinery enabling comprehensive competency development rather than simply increasing quantities of basic machines. The marked performance advantages of students accessing computer-aided design systems and specialized

equipment types (coverstitch machines, automated cutting systems) justify prioritizing these technologies despite higher costs, as they enable competency development in contemporary production methods increasingly demanded by employers. However, institutions should avoid technology fetishism, ensuring that equipment acquisitions align with regional industry practices and employment opportunities rather than pursuing cutting-edge innovations disconnected from local labor market realities.

Spatial organization and ergonomic design improvements offer cost-effective pathways to enhancing learning environments even when equipment budgets remain constrained. The study demonstrated that proper workshop layout, adequate workstation spacing, optimized lighting, and effective climate control independently contribute to learning outcomes. Many of these improvements require thoughtful design and modest investments rather than expensive technology acquisitions. Institutions with limited modernization budgets should consider spatial reorganization as an initial intervention, potentially yielding significant educational benefits while generating momentum for more comprehensive improvements.

Material management system implementation presents another high-impact, relatively low-cost intervention opportunity. The dramatic differences in material waste rates between workshops with systematic versus ad hoc material management approaches (8.3% vs. 26.7%) indicate that structured procurement procedures, inventory tracking, and waste minimization training can yield substantial cost savings while simultaneously modeling professional resource management practices students will encounter in employment. The economic benefits of reduced material waste can potentially fund ongoing workshop improvements, creating self-sustaining enhancement cycles.

Pedagogical professional development emerges as equally critical to physical infrastructure improvement. The observation that teaching practices varied substantially even among institutions with similar equipment levels suggests that infrastructure alone insufficient for optimizing outcomes without corresponding instructional capacity. Professional development initiatives should emphasize cognitive apprenticeship techniques helping instructors make their expert thinking visible, authentic task design creating meaningful production challenges, formative assessment approaches supporting ongoing learning refinement, and community of practice facilitation building collaborative learning environments. Supporting instructors' pedagogical evolution requires sustained investment rather than one-time training events,

including peer learning communities, mentoring relationships, and opportunities to observe exemplary practice in high-performing workshops.

Industry partnership development offers valuable mechanisms for enhancing both infrastructure and pedagogical authenticity with limited institutional resources. Relationships with local garment enterprises can facilitate equipment donations when businesses upgrade machinery, provide student internship and observation opportunities exposing learners to actual production environments, enable guest expert demonstrations bringing industry perspectives into classrooms, and generate feedback informing curriculum relevance. These partnerships strengthen institutional connections to labor markets while helping ensure workshop environments and instructional practices reflect evolving industry standards.

Implementation Challenges, Research Limitations, and Future Directions

Despite the compelling evidence supporting workshop modernization, substantial implementation challenges merit acknowledgment. Financial constraints represent the most obvious barrier, particularly for vocational institutions in resource-limited contexts serving predominantly disadvantaged populations. Modern sewing equipment, CAD systems, and comprehensive tool sets require significant capital investments often exceeding institutional budgets already strained by operational demands. While the study documented educational benefits justifying these investments, securing initial funding remains a formidable challenge requiring creative approaches such as phased implementation strategies, shared facility arrangements among multiple institutions, public-private partnerships leveraging business sector resources, and targeted funding campaigns emphasizing workforce development and economic growth impacts.

Technical support capacity poses another persistent challenge, particularly in regions lacking robust maintenance infrastructure for specialized equipment. Sophisticated machinery and digital systems require ongoing maintenance, timely repairs, and periodic upgrades to remain functional and current. Institutions acquiring advanced equipment without corresponding technical support capacity risk equipment deterioration and eventual abandonment, wasting limited resources and frustrating instructional staff and students. Sustainable modernization strategies must incorporate technical support mechanisms, potentially through regional service contracts, institutional technical staff capacity building, or equipment procurement emphasizing

reliability and vendor support commitments.

Instructor adaptation to new pedagogical approaches and technological tools requires sustained support and should not be underestimated. Some instructors, particularly those with extensive experience using traditional methods, may resist pedagogical innovations or struggle with cognitive apprenticeship techniques demanding greater instructional flexibility and student-centeredness. Similarly, technology integration requires instructors to develop personal competence with CAD systems, automated equipment, and digital teaching tools, potentially creating anxiety and implementation resistance. Professional development initiatives must address both technical skill needs and attitudinal dimensions, creating supportive learning communities where instructors feel safe experimenting with new approaches, sharing struggles, and gradually building confidence and competence.

This study's limitations should inform interpretation of findings and guide future research directions. The research employed a cross-sectional design observing different workshops at a single time period, limiting causal inference strength. While statistical controls for potential confounding variables strengthened causal claims, longitudinal research tracking student cohorts as their institutions implement infrastructure improvements would provide more definitive causal evidence and illuminate implementation dynamics. The study focused exclusively on institutions in Uzbekistan, potentially limiting transferability to contexts with substantially different economic conditions, cultural practices, or educational systems. Replication studies in diverse international settings would establish the generalizability of findings and identify context-specific factors moderating infrastructure effects.

The research measured learning outcomes through performance-based competency assessments occurring within workshop environments, demonstrating that students develop stronger capabilities in better-equipped facilities. However, the study did not track graduate employment outcomes or workplace performance following program completion, leaving uncertain whether superior workshop-based competencies translate into employment success and job satisfaction. Future research should implement graduate tracking studies examining employment rates, wage levels, job retention, and employer satisfaction across graduates from different workshop quality levels, providing definitive evidence of labor market impacts.

Qualitative dimensions of learning experiences, while addressed through interview and observation data, could be explored more deeply through case study methodologies.

Rich descriptive accounts of how specific pedagogical practices unfold in diverse workshop environments, how students experience and interpret situated learning opportunities, and how communities of practice develop within vocational programs would complement this study's largely quantitative focus and provide guidance for practitioners implementing workshop improvements. Additionally, action research partnerships with institutions undergoing modernization processes could generate practical insights into implementation challenges, successful change strategies, and sustainable improvement approaches benefiting the broader vocational education field.

CONCLUSION

This comprehensive study provides substantial empirical evidence demonstrating that workshop infrastructure quality, pedagogical practices grounded in situated learning principles, and systematic material management significantly influence vocational education outcomes in sewing and garment technology training. The strong positive correlation between workshop infrastructure quality and student competency development, alongside the substantial performance advantages of students in modern, well-equipped facilities, confirms that authentic learning environments aligned with industry practices are not optional enhancements but fundamental requirements for effective vocational preparation.

The research establishes that workshop modernization encompasses multiple interconnected dimensions requiring holistic attention. Physical infrastructure elements including adequate space, appropriate equipment, effective lighting and climate control, and ergonomic design collectively create supportive learning environments. Equipment quality and diversity enable comprehensive competency development across technical skill domains essential for contemporary garment production. Systematic material management reduces waste, models professional resource stewardship, and enhances program sustainability. Most critically, pedagogical practices implementing situated learning principles through authentic tasks, cognitive apprenticeship techniques, and community of practice development transform physical infrastructure into genuine learning opportunities fostering deep competence and professional identity formation.

The integration of situated learning theory and competency-based education principles provides a robust conceptual foundation for vocational sewing education, addressing both the need for authentic, contextualized skill development and systematic competency definition and assessment. This theoretical synthesis, validated through empirical evidence of enhanced student outcomes, offers

vocational educators a coherent framework guiding curriculum design, instructional practice, and assessment development.

For vocational education institutions, policymakers, and workforce development stakeholders, this research provides evidence-based guidance for strategic investment priorities and improvement initiatives. While comprehensive workshop modernization requires substantial resources, the documented educational benefits justify these investments as high-impact workforce development strategies with implications extending beyond individual student success to regional economic competitiveness and social mobility. Moreover, the findings suggest that even institutions with constrained resources can implement targeted improvements in spatial organization, material management, and pedagogical practice yielding meaningful learning enhancements while building foundation for more comprehensive modernization.

The study contributes to vocational education literature by providing systematic empirical evidence for situated learning theory's applicability in technical training contexts, demonstrating how authentic learning environments shape competency development across cognitive, psychomotor, and affective domains. The research also advances understanding of infrastructure-pedagogy interactions, showing that physical improvements and instructional innovations work synergistically rather than independently, with maximal benefits emerging when both dimensions receive attention.

Future research should extend this work through longitudinal studies tracking students' educational progress and subsequent employment outcomes, comparative international studies examining how cultural and economic contexts moderate infrastructure effects, action research partnerships documenting implementation processes and improvement strategies, and investigations of emerging technologies' potential contributions to vocational sewing education, including virtual reality simulations, augmented reality assembly guidance systems, and artificial intelligence-enabled personalized learning platforms. Additionally, research examining gender dimensions of vocational education, given sewing's traditional associations with women's work and contemporary diversification efforts, would address important equity considerations.

The modernization and systematic organization of sewing training workshops, grounded in sound theoretical principles and informed by empirical evidence, represents a crucial investment in human capital development with far-reaching implications for individual prosperity, industrial competitiveness, and sustainable development. This

research provides both compelling evidence for such investments and practical guidance for their effective implementation, contributing to ongoing efforts to strengthen vocational education systems worldwide.

REFERENCES

Billett, S. (1993). What's in a setting? Learning in the workplace. Australian Journal of Adult and Community Education, 33(1), 4-14.

Billett, S. (2001). Learning through work: Workplace affordances and individual engagement. Journal of Workplace Learning, 13(5), 209-214. https://doi.org/10.1108/EUM0000000005548

Bloom, B. S. (1956). Taxonomy of educational objectives: The classification of educational goals. Handbook 1: Cognitive domain. New York: David McKay.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). How people learn: Brain, mind, experience, and school (Expanded ed.). Washington, DC: National Academy Press.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77-101. https://doi.org/10.1191/1478088706qp063oa

Bruner, J. S. (1966). Toward a theory of instruction. Cambridge, MA: Harvard University Press.

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L. B. Resnick (Ed.), Knowing, learning, and instruction: Essays in honor of Robert Glaser (pp. 453-494). Hillsdale, NJ: Lawrence Erlbaum Associates.

Egodawatte, G. (2014). Bridging theory and practice in teacher education: The impact of school-based practicum. Rotterdam: Sense Publishers.

Global Textile Academy. (2024). GTEX/MENATEX Programme Phase 2: Sustainability and digitalization in textile education. Retrieved from https://www.globaltextileacademy.com/

Huang, Y. M., Chiu, P. S., Liu, T. C., & Chen, T. S. (2016). The design and implementation of a meaningful learning-based evaluation method for ubiquitous learning. Computers & Education, 57(4), 2291-2302.

International Labour Organization. (2020). Competency-based training (CBT): An introductory manual for practitioners. Geneva: ILO Publications.

Lave, J., & Wenger, E. (1991). Situated learning: Legitimate peripheral

participation. Cambridge: Cambridge University Press.

Lucas, B. (2022). Vocational pedagogy: What it is, why it matters and how to put it into practice. Bonn: UNESCO-UNEVOC International Centre. Retrieved from https://unevoc.unesco.org/

Lucas, B., Spencer, E., & Claxton, G. (2022). How to teach vocational education: A theory of vocational pedagogy. London: City & Guilds of London Institute.

Mayer, R. E. (2019). Multimedia learning (3rd ed.). Cambridge: Cambridge University Press.

Mulder, M. (Ed.). (2017). Competence-based vocational and professional education: Bridging the worlds of work and education. Technical and Vocational Education and Training: Issues, Concerns and Prospects (Vol. 23). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-41713-4

Mulder, M., & Winterton, J. (2017). Introduction. In M. Mulder (Ed.), Competence-based vocational and professional education (pp. 1-43). Cham: Springer.

Pérez-Sanagustín, M., Hernández-Leo, D., Santos, P., Delgado-Kloos, C., & Blat, J. (2015). Augmenting reality and formality of informal and non-formal settings to enhance blended learning. IEEE Transactions on Learning Technologies, 7(2), 118-131.

Porter, M. E. (1998). The competitive advantage of nations. London: Palgrave Macmillan.

Pu, Y. H., Wu, T. T., Chiu, P. S., & Huang, Y. M. (2016). The design and implementation of authentic learning with mobile technology in vocational nursing practice course. British Journal of Educational Technology, 47(3), 494-509. https://doi.org/10.1111/bjet.12443

Sahlberg, P. (2021). Finnish lessons 3.0: What can the world learn from educational change in Finland? (3rd ed.). New York: Teachers College Press.

Schilling, T., & Koetting, J. R. (2010). Underpinnings of competency-based education. Athletic Training Education Journal, 5(4), 165-169.

Shum, A. K., Gattas, M. R., Kang, K. H., Song, H. K., & Trabold, L. M. (2022). Sustainable apparel technical and vocational education and training (TVET): Integrating technology for skills training. In S. S. Muthu (Ed.), Sustainable approaches in textiles and fashion (pp. 51-79). Singapore: Springer. https://doi.org/10.1007/978-981-19-0530-8_3

UNESCO-UNEVOC International Centre. (2022). TVETipedia glossary: Competency-based training. Bonn: UNESCO-UNEVOC. Retrieved from https://unevoc.unesco.org/home/TVETipedia+Glossary

UNESCO-UNEVOC International Centre. (2024). National reforms in vocational education and training: Türkiye case study. Retrieved from https://eurydice.eacea.ec.europa.eu/

Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes. Cambridge, MA: Harvard University Press.

World Bank. (2023). World development report 2023: Skills for a changing world. Washington, DC: World Bank Publications.

WorldSkills International. (2024). WorldSkills occupational standards: Fashion technology. Retrieved from https://worldskills.org/

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