

The Impact of Laboratory and Workshop Equipment Availability on Quality Management System Implementation in Public TVET Colleges: Evidence from North Wollo and Waghimra Zones, Ethiopia

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Research Article

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**Laboratory and Workshop Equipment Adequacy and Quality Management
System Implementation in Public TVET Colleges: Evidence from North Wollo
and Waghimra Zones, Ethiopia**

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Abstract

This study investigated laboratory and workshop resource adequacy and Quality Management System (QMS) implementation across eight public Technical and Vocational Education and Training (TVET) colleges in the post-conflict North Wollo and Waghimra Zones, Ethiopia. Employing a convergent mixed-methods design, quantitative and qualitative data were concurrently gathered from 341 stakeholders (256 trainees and 85 trainers) through structured surveys, interviews, and facility observations. Quantitative results show that the physical resource scarcities, with mean scores for computer availability ($M = 2.37$), laboratory sufficiency ($M = 2.45$), workshop adequacy ($M = 2.54$), and preventative maintenance ($M = 2.62$) falling below acceptable operational thresholds. Multiple linear regression confirmed that resource adequacy significantly predicts perceived quality improvement for both trainees ($R^2 = .985$) and trainers ($R^2 = .991$). Qualitative analysis identified additional challenges, including mismatched student enrollment and workstation capacity, post-conflict infrastructure issues, and absent preventive maintenance systems. The study concludes that acute physical resource shortages bottleneck systematic quality assurance, hindering the practical operationalization of Plan-Do-Check-Act (PDCA) cycles.

Keywords: Education, TVET Colleges, Quality Management System, Laboratory facility, Workshop facility, Resource Adequacy, Post-Conflict.

1. Introduction

Education is widely recognized as a fundamental driver of socioeconomic and political development (Barseguyan et al., 2024). Ensuring access to quality education is essential for achieving Sustainable Development Goal 4 (SDG 4), which promotes inclusive and equitable education and lifelong learning opportunities for all (Smith et al., 2024). Without education that imparts relevant knowledge, skills, and attitudes, sustainable development across economic and social sectors remains unattainable (Carvalho et al., 2024; Goshu & Woldeamanuel, 2019).

In Ethiopia, Technical and Vocational Education and Training (TVET) colleges play a crucial role in national development by equipping students with practical, industry-relevant skills, enabling them to enter the workforce and contribute effectively to various economic sectors (Teferi et al., 2025; Thapa, 2024). TVET programs provide a practical pathway to employment in areas such as IT, electrical and mechanical professions, industrial trades, and other fields, helping students competencies for success in the labor market (Nkunya & Mwila, 2024; Worku, 2025).

The effectiveness of TVET colleges depends not only on the availability of competent trainers and relevant curricula but also on robust institutional frameworks, such as QMS. A QMS provides a structured approach to planning, implementing, and evaluating training programs insuring that teaching, learning, and assessment processes meet national standards and labour market requirements (Cabreros & Barbacena, 2024; Jocson & Subia, 2025; Yirga & Beshir, 2025). When integrated into an institution's management structure, a QMS enhances accountability, supports continuous improvement, and strengthens confidence among students, employers, policymakers, and the wider community (Odjo et al., 2024b; Patmawati et al., 2022). The QMS operates through a structured framework that begins with inputs, continues through well-defined processes, and produces measurable outputs, outcomes, and long-term s, as illustrated in Figure 1. In TVET colleges, QMS fosters alliance with industry and the community, providing students with opportunities to apply theoretical knowledge in practical settings, and improving workforce readiness.

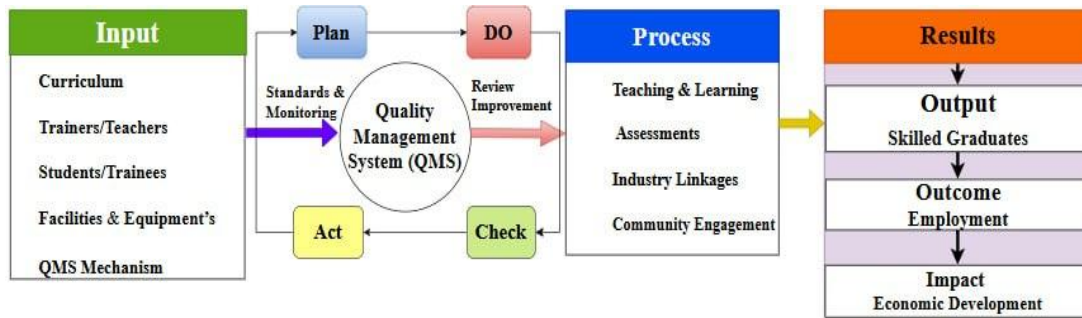


Figure 1: Results Based Formwork for QMS Implementation in TVET Colleges (Girmanová et al., 2022; Patmawati et al., 2022)

Despite extensive national policy reforms designed to embed standardized quality assurance mechanisms across Ethiopian TVET colleges, severe geographic and environmental disparities persist in resource allocation, facility modernization, and technical functionality (Sharma, 2021; Tanasiichuk et al., 2023; Wang & Xia, 2025). These structural imbalances are severely magnified in post-conflict regions, where widespread infrastructure damage, resource pillaging, and administrative capacity strains leave colleges poorly equipped to operationalize quality benchmarks (Gugssa, 2025; Regassa & Desissa, 2025). This study directly addresses this empirical gap by examining laboratory and workshop equipment adequacy and Quality Management System implementation in public TVET colleges across the post-conflict environments of North Wollo and Waghimra Zones, Ethiopia. Specifically, the study investigates the extent to which laboratory and workshop resource adequacy affects the implementation QMS practices and identifies the major challenges hindering effective QMS implementation in public TVET colleges affected by post-conflict conditions in the selected study areas.

To assess Laboratory and Workshop equipment adequacy, and challenges associated with QMS implementation; the study addressed the following research questions:

1. To what extent are laboratory, workshop, and ICT resources adequate and functional in public post-conflict TVET colleges in the North Wollo and Waghimra Zones?
2. How do trainers and trainees perceive the baseline implementation and effectiveness of Quality Management Systems within these sampled colleges?

3. Is there a statistically significant difference between the perceptions of trainers and trainees regarding resource adequacy and quality implementation?
4. What systemic administrative and environmental challenges constrain the effective implementation of QMS practice in post conflict TVET colleges?

2. Literature Review

2.1. General Concept on TVET College in Ethiopia

In Ethiopia, TVET colleges form a key part of the national education system as they incorporate both theoretical education and practical skills to prepare individuals for specific occupations and trades (UNESCO, 2015). The policy under which TVET colleges are run is the Ministry of Labor and Skills with the responsibility of the TVET bureaus, which monitors and ensures the quality at the regional level. Upon final grade 12, students are taking the Ethiopia higher education entrance certificate examination that defines how they are placed in various post-secondary tracks. The students can be enrolled in TVET programs, diploma programs or University degree programs depending on their results in their examinations and the set cut-off scores that are nationally determined. The TVET colleges programs have developed their training program from Level I to Level V according to the national requirements of admission and competency-based standards.

In the recent years, the Ethiopian government has undertaken some reforms focused on enhancing the quality and relevance of TVET education such as curriculum revision, occupational standards development, accreditation systems, and the introduction of QMS (Yirga & Beshir, 2025). However, empirical studies show that many colleges face challenges in relevance, infrastructure, and quality assurance, including inadequate laboratory and workshop facilities, outdated equipment, limited industry collaboration, and uneven implementation of quality assurance mechanisms, particularly in post-conflict and resource-constrained regions (Dehnie, 2024; Tanasiichuk et al., 2023). Researcher further indicates that teacher's preparation and quality assurance systems are insufficiently developed hindering effective implementation (Kebede & Asgedom, 2024).

2.2. Theoretical Framework

This study conceptualizes QMS implementation through dimensions such as monitoring, continuous improvement, documentation, stakeholder feedback, and quality assurance practices, while laboratory and workshop resource adequacy is treated as a supporting institutional factor influencing these processes (Sawant et al., 2018). Additionally, the study was conceptually grounded in the principles of International Organization Standards (ISO) 9001 quality management and the PDCA framework. Within this framework, laboratory and workshop resources were conceptualized as institutional inputs supporting QMS processes, including instructional monitoring, documentation practices, corrective action procedures, customer satisfaction, and continuous quality improvement (Wang & Chen, 2025, Kiarie, 2020).

Practical studies indicate that effective QMS implementation can significantly enhance institutional performance and adherence to quality goals when leadership dedication, sufficient resources, and staff capacity are appropriately mobilized (Mislam & Azha, 2025). In vocational and technical education contexts further demonstrates that the application of ISO 9001:2015 principle contributes to improved institutional performance and higher satisfaction level among both learners and employers (Erwin et al., 2022). However, the implementation of QMS in resource constrained environments such as public TVET colleges in North Wollo and Waghimra Zones of Ethiopia faces substantial contextual challenges. Evidence from developing country TVET Colleges shows that inadequate instructional resources, limited technical capacity, weak leadership, and insufficient institutional support mechanisms constrain the effective operationalization of QMS frameworks, thereby reducing their potential on training quality and graduate competence (Mutebi & Ferej, 2023).

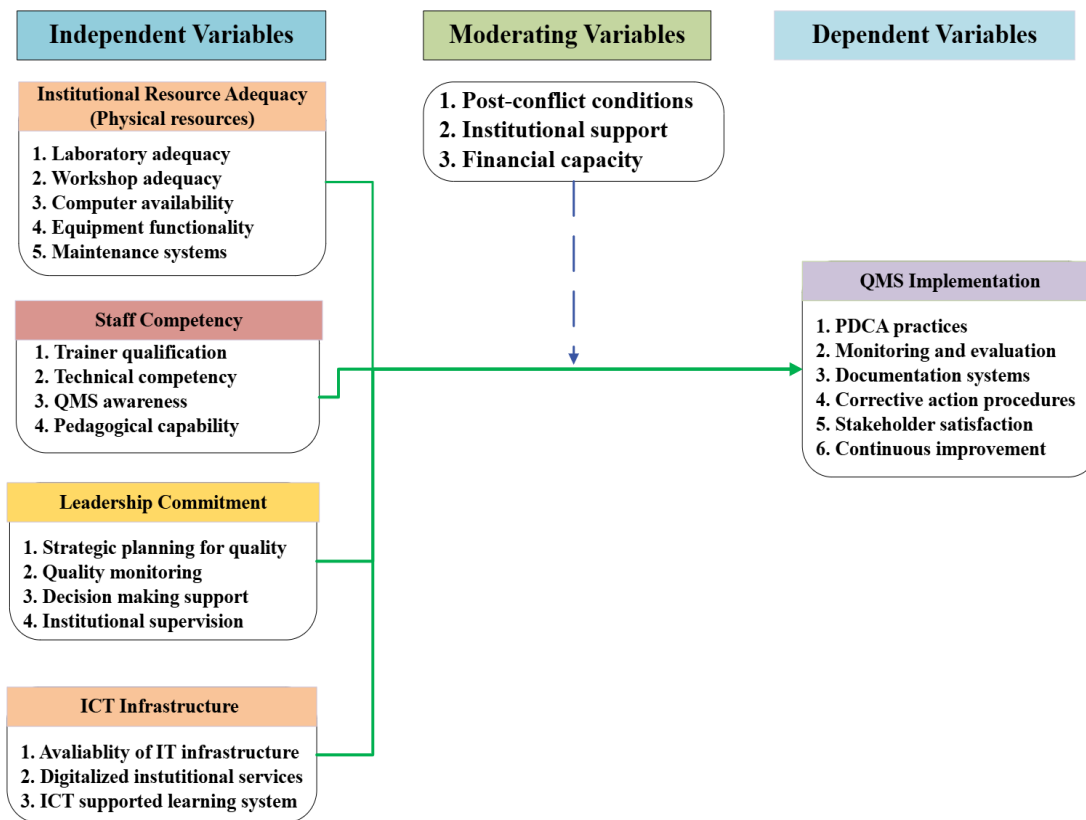


Figure 2: Conceptual framework

Although previous studies have examined TVET quality assurance and institutional performance in developing countries, limited empirical evidence exists regarding how laboratory and workshop resource adequacy relates to QMS implementation within post-conflict colleges in Ethiopia. Furthermore, this study seeks to fill existing gaps in understanding by assessing the challenges faced by TVET colleges in achieving their strategic and operational goals, particularly concerning the adequacy of instructional materials and tools (Duangapinun et al., 2025; Fantaye, 2019).

2.3. Laboratory and Workshop resources in TVET College

The availability of functional laboratory and workshop resources is a critical determinant of both instructional quality and effective QMS implementation in TVET colleges. Laboratories and workshops provide essential environments for skill-based training, enabling students to apply theoretical knowledge, develop

technical competencies, and practice skills aligned with industry standards (Mohd Raffi et al., 2025). Moreover, the availability and quality of equipment directly influenced key QMS processes such as practical assessments, safety management, equipment maintenance, and continuous improvement (Kiptoo & Kipngetich, 2025; Odjo et al., 2024a). empirical evidence indicates that insufficient laboratory and workshop facilities constrain practical instruction, reduce student engagement, and compromise graduates' readiness for the labour market (Mutale Mulenga & Chileshe, 2020). Such constraints ultimately deny the implementation of standards aligned practical training and limit institutional capacity to deliver competitive vocational education and training programs (Rajamanickam et al., 2025).

The study is further supported by systems theory, which conceptualizes educational colleges as interdependent systems in which instructional resources, institutional management, human capacity, and quality assurance mechanisms interact to influence organizational performance. Within this perspective, laboratory and workshop facilities constitute essential institutional inputs necessary for effective implementation of QMS processes and continuous improvement practices.

2.4. Implementation of QMS in TVET Colleges

The implementation of QMS in TVET colleges involves the systematic incorporation of quality assurance principles, processes, and continuous improvement practices. It ensures that the institution operations, instructional delivery, and stakeholder performance expectations are achieved effectively, efficiently, and relevancy (Mislam & Azha, 2025). Total Quality Management (TQM) dimensions like leadership and customer focus have a positive and significant relationship with innovation performance (Yirga & Beshir, 2025). Additionally, research on quality management practices in TVET colleges in Kenya demonstrated that management commitment, employee involvement, and customer focus are positively correlated with improved student performance and institutional outcomes (Magut & Kihara, 2019). QMS implementation in TVET colleges is not solely a procedural necessity but a strategic mechanism that facilitates quality assurance and institutional

innovation and stakeholder outcomes supported by effective leadership, proper resources and enabling organizational cultures.

2.5. Post-Conflict Educational Context

Post-conflict environments present unique challenges for TVET colleges particularly that depend heavily on physical infrastructure and practical training facilities. TVET colleges are especially vulnerable because their effectiveness relies on functional laboratories, workshops, equipment, and continuous maintenance systems. Conflict-related disturbances often result in damaged infrastructure, loss of instructional equipment, interruptions in educational services, and reduced institutional capacity for quality assurance and continuous improvement (Choi, 2021),(Abu Naim & Rohanai, 2025).

Previous studies have shown that educational colleges operating in post-conflict settings frequently experience difficulties in restoring learning environments, maintaining educational quality, and implementing institutional management systems. Resource shortages, weakened administrative capacity, and financial constraints can significantly affect implementation of QMS, which require adequate infrastructure, systematic monitoring, stakeholder engagement, and continuous improvement mechanisms. In vocational education colleges, these challenges may be more pronounced because practical training depends directly on the availability and functionality of laboratory and workshop facilities (Grundall & Mack, 2023).

In Ethiopia, conflict-affected areas have experienced substantial challenges related to infrastructure rehabilitation, equipment replacement, and restoration of educational services. Although previous studies have examined quality assurance practices, institutional performance, and resource management in TVET colleges, limited empirical research has investigated the relationship between laboratory and workshop resource adequacy and QMS implementation within post-conflict educational context. Furthermore, evidence from Ethiopian TVET colleges remains scarce, particularly in conflict-affected regions where infrastructure interruption and resource shortages may influence institutional quality performance.

3. Materials and Methods

Research Design and Approach

This study adopted a convergent mixed-methods design to achieve a comprehensive understanding of institutional resource environments and quality management processes. Within this framework, a quantitative cross-sectional survey was concurrently deployed alongside qualitative interviews and field observations. Quantitative and qualitative data were collected simultaneously, analyzed independently, and subsequently integrated during the interpretation phase to triangulate findings and contextualize descriptive trends.

Population and Sample of the Study

Eight public TVET colleges were purposively selected because they were located in conflict-affected areas of the North Wollo and Waghimra Zones and had resumed educational operations after the conflict. First, eight public TVET colleges were purposively selected based on their post-conflict context. Second, the target population was stratified into trainers and trainees. Third, proportional allocation was applied to determine the number of respondents from each stratum. Fourth, The sample size was calculated using Yamane's formula (Heng et al., 2025) at a 95% confidence level and 5% margin of error, resulting in a finalized sample size of 341 total respondents (256 trainees and 85 trainers) from the targeted total population.

Data Collection Instruments

In this study, QMS implementation was operationalized through four interrelated dimensions adapted from the literature on TVET quality assurance, ISO 9001 principles, and continuous improvement frameworks. These dimensions included: (1) Customer Satisfaction, reflecting stakeholder feedback mechanisms and service quality; (2) Learning and Teaching Activities, representing the effectiveness of practical training delivery and instructional processes; (3) Learning Resource Facilities, assessing the adequacy, functionality, and maintenance of laboratories, workshops, and equipment; and (4) Quality Improvement Practices, encompassing institutional monitoring, adherence to quality standards, quality documentation, and

continuous improvement efforts. Together, these dimensions provide a multidimensional assessment of perceived QMS implementation within public post conflict TVET colleges.

Validity and Reliability

To secure robust construct and content validity, the survey questionnaire was adapted from validated metrics aligned with ISO 9001:2015 principles, the PDCA framework, and regional TVET quality frameworks. Following expert refinement, a pilot study was conducted with 30 independent respondents (comprising institutional management, trainers, and trainees) at Woldia TVET College to evaluate field comprehensibility and structural stability. Internal consistency reliability was calculated using Cronbach’s alpha coefficients, computed strictly and independently for both the trainer (n = 85) and trainee (n = 256) cohorts across all targeted subscales as shown table 1.

Table 1: Reliability statistics of the QMS instrument

Item Statement	Number of Items	Trainers		Trainees	
		N	Cronbach's alpha	N	Cronbach's alpha
Customer Satisfaction (CS)	7	85	.993	256	.988
Learning and Teaching (LT)	8	85	.993	256	.990
Learning Resource Facility (LRF)	7	85	.996	256	.989
Quality Improvement (QI)	7	85	.992	256	.986
Overall Instrument	29	85	.996	256	.996

The psychometric assessment yielded exceptional internal consistency reliability. The subscale alpha coefficients ranged from .992 to .996 for trainers, and from .986 to .990 for trainees. These metrics comfortably surpass the standard academic threshold of ≥ 0.70 for acceptable research instruments and meet the criterion for high-precision multi-group comparisons. The uniformity of these exceptionally high

coefficients indicates a highly stable, coherent conceptual structure across both respondent profiles.

Data Collection Procedure

Data was collected using structured questionnaires, semi-structured interviews and observation checklists. The questionnaire was composed of four sections. The first section was about respondent's demographics, the second section was QMS related elements, such as customer satisfactions, the third section was teaching and learning activities, the fourth was resource management, and the last section was quality improvement procedures (Hiruy & Mengistie, 2022). The closed-ended questions including Likert-scale items for quantitative analysis, and open-ended questions captured additional qualitative approaches. The observation checklist and interview guide were developed to complement the survey by systematically exploring the experiences and TVET practices of the participants.

Data Analysis Procedure

Quantitative data were analyzed using SPSS version 25. Descriptive statistics (frequencies, percentages, mean scores (M), and standard deviations (SD)), Pearson correlation analysis, multiple linear regression analysis, and independent-samples t-tests were conducted across all Likert-scale items to mathematically evaluate whether statistically significant differences exist between the operational perceptions of trainers and trainees. Correlation and regression analyses were conducted separately for trainers and trainees to account for their distinct institutional roles and perspectives. Qualitative data were analyzed thematically and integrated with the quantitative findings.

Ethical Considerations

Ethical approval was obtained from the appropriate research ethics committee of Woldia University Research, Publication, Ethics, and System Directorate. The principals of the TVET offices granted written permission to collect data on their premises for each of the selected post-conflict TVET colleges. The research was

conducted in full compliance with the ethical principles. All participants gave their written informed consent after having been fully informed about the purpose, procedures and their right to withdraw at any time without any consequences. Privacy of the participants and confidentiality were strictly maintained and all the data collected were anonymized.

4. Results and Findings

4.1. Demographic characteristics of the respondents

Gender distribution of respondents

Table 2 below presents the gender distribution of respondents across the sampled TVET colleges. Among those colleges, the total respondents, 239 (70.09%) were male and 102 (29.91%) were female, indicating a substantial gender imbalance within the TVET Colleges. Woldia TVET College recorded the largest number of respondents ($n = 80$), with males accounting for 83.8% and females 16.3%. Similarly, Kobo TVET College demonstrated a high male dominance (83.3%). In contrast, Kone TVET College showed a relatively balanced gender distribution, with males representing 54.0% and females 46.0%.

Table 2: TVET College gender demographic details of the total participants

No	TVET College	Male	Female	Total	% Male	% Female
1	Woldia	67	13	80	83.8%	16.3%
2	Kone	27	23	50	54.0%	46.0%
3	Kobo	10	2	12	83.3%	16.7%
4	Lalibela	41	32	73	56.2%	43.8%
5	Muja	11	3	14	78.6%	21.4%
6	Sekota	46	18	64	71.9%	28.1%
7	Amdework	28	8	36	77.8%	22.2%
8	Asketema	9	3	12	75.0%	25.0%
Total		239	102	341	70.09%	29.91%

Age distribution of respondents

In Figure 3 shown below, age distribution analysis demonstrated clear demographic differences between trainees and trainers. Most trainee respondents were concentrated within the 19-24 age categories, particularly in Woldia, Sekota, and Kone TVET colleges. In contrast, trainers were primarily distributed within the 26-40 age range. The relatively youthful trainee population suggests increasing demand for technologically supported teaching and learning systems.

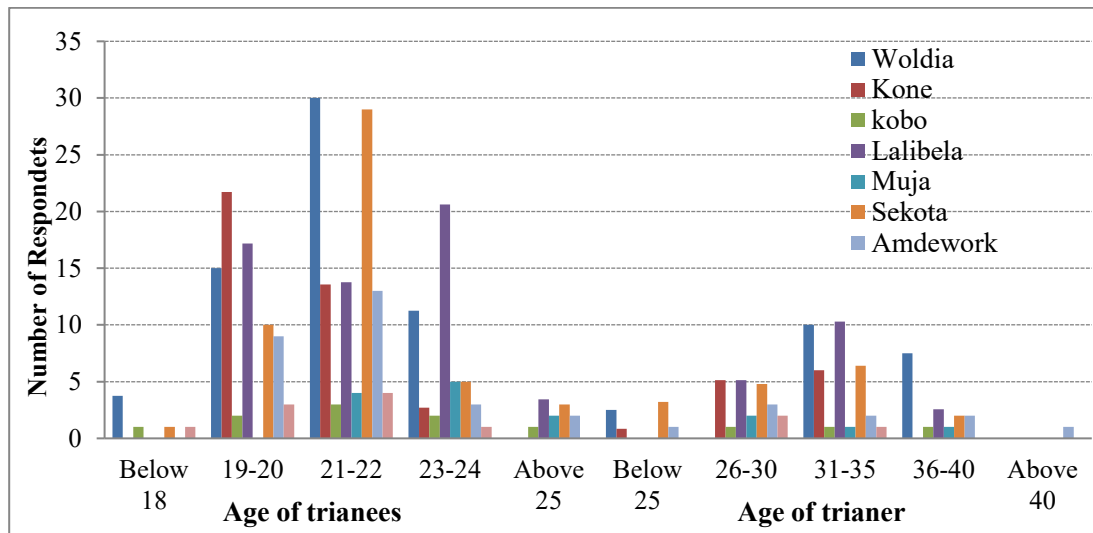


Figure 3: Distribution of age of trainees and trainer across TVET colleges

Educational level and professional profiles

Figure 4 presents the distribution of trainee respondents by educational level across the sampled TVET colleges. The highest concentrations of trainees were observed at Levels 3 and 4 across most colleges. Woldia, Sekota, and Lalibela TVET colleges recorded the largest numbers of trainees at these levels. In contrast, Kobo, Amdework, and Asketema TVET colleges reported comparatively lower enrolment at advanced training levels. Across all participating colleges, the number of trainees decreased at Level 5 compared with Levels 3 and 4.

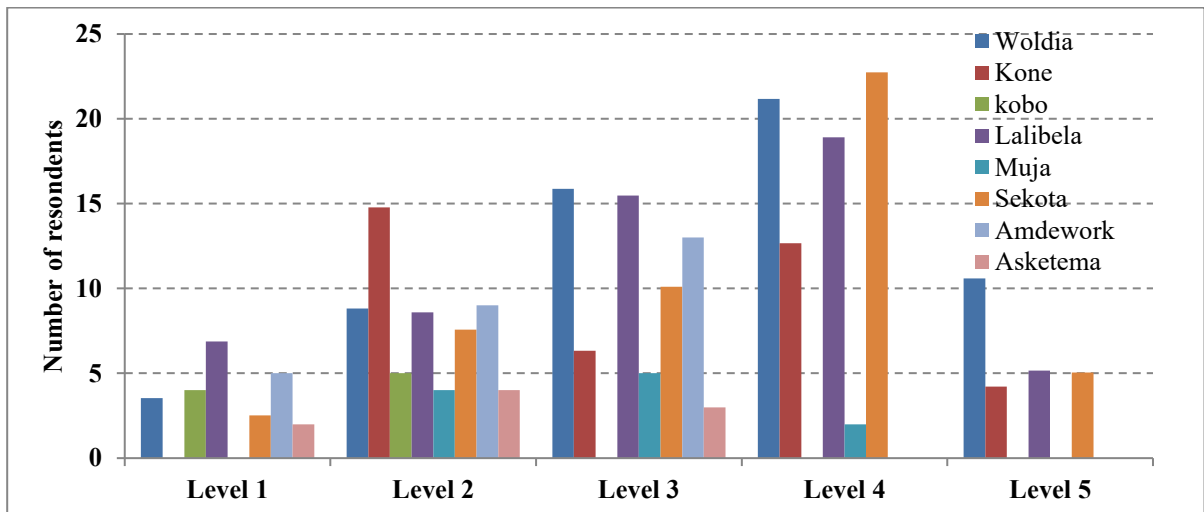


Figure 4: Distribution of trainee's respondents by grade level across TVET colleges

Figure 5 shows educational experience of trainers revealed that most instructors held BA/BSc degrees, mainly in Woldia and Kone TVET colleges. A smaller number of trainers possessed MA/MSc qualifications, mainly in Woldia and Lalibela colleges.

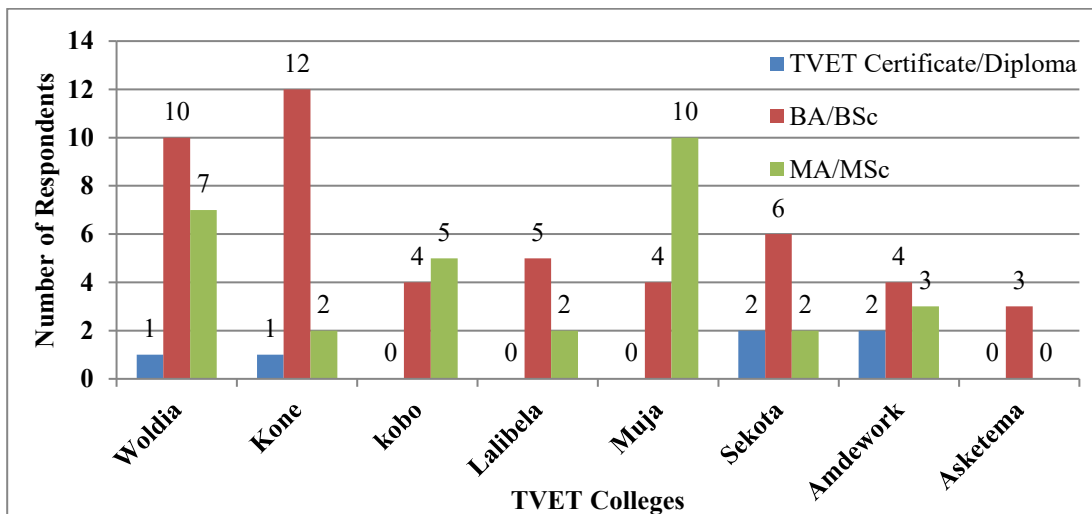


Figure 5: Distribution of trainer education level across TVET colleges

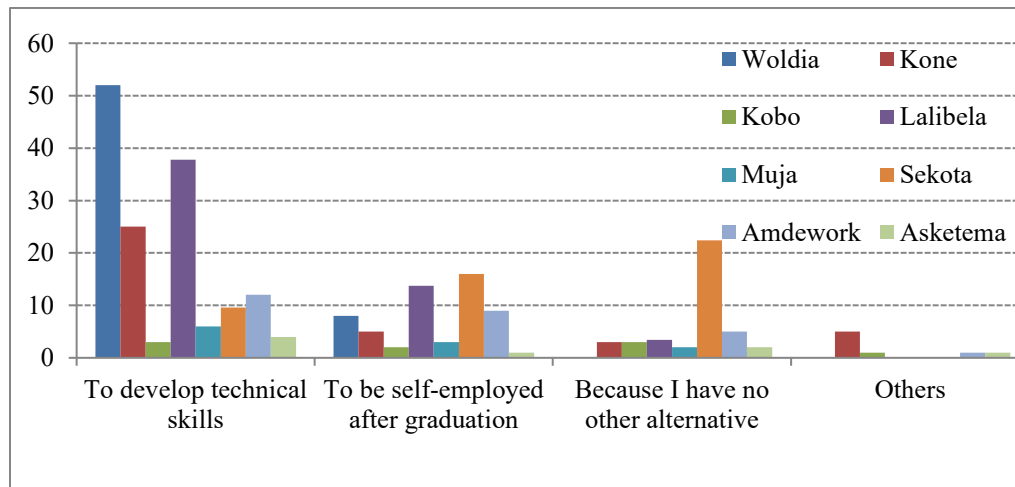
In table 3 shows that, most trainers had between 3 and 8 years of professional experience, indicating the presence of a relatively experienced mid-career workforce. Woldia TVET College had the highest number of trainers with more than 12 years of service, suggesting stronger institutional continuity and accumulated organizational knowledge. However; Kobo, Muja, and Asketema lacked experienced trainers, which may limit institutional capacity for sustaining QMS implementation.

Table 3: Distribution of trainer professional experience

TVET College	0-2 Years	3-5 Years	6-8 Years	9-11 Years	Above 12 Years
Woldia	0	5	3	3	10
Kone	1	3	3	5	0
Kobo	1	0	2	0	0
Lalibela	0	5	7	2	5
Muja	1	2	1	0	0
Sekota	0	5	5	5	2
Amdework	2	4	2	1	0
Asketema	1	1	1	0	0
Total	6	24	23	16	16

4.2. Customer satisfaction and institutional communication

Figure 6 presents the primary reasons reported by trainees for enrolling in TVET colleges. The majority of respondents indicated that acquiring technical skills was their main motivation for joining TVET programs. Woldia TVET College recorded highest number of respondents reporting this reason, followed by Lalibela College.

**Figure 6:** Distribution of trainer reason for joining across TVET colleges

Customer satisfaction was examined through respondents' perceptions regarding institutional communication, trainee feedback, customer service, and management commitment to quality improvement. The results are presented in Table 4.

Table 4: Customer satisfaction respondent's response of the TVET College

Item Code	Item Statement			Trainers			Trainees		
				N	Mean	Std. Dev.	N	Mean	Std. Dev.
CS1	TVET College provides feedback on trainees' performance			85	3.92	1.408	256	3.42	1.003
CS2	Trainees are satisfied with practical work			85	4.00	1.512	256	3.44	1.016
CS3	Mission and vision are clearly communicated			85	4.08	1.365	256	3.46	.957
CS4	Top management ensures customer service quality			85	3.47	1.428	256	3.13	1.042
CS5	Top management regularly checks workshop/laboratory quality			85	3.56	1.569	256	2.95	1.135
CS6	TVET college builds relationships with local enterprises and industry			85	3.47	1.428	256	3.11	1.059
CS7	Trainees are given the opportunity to do practical work in local enterprises and industries.			85	3.55	1.435	256	3.16	1.017
Average Mean				3.72			3.24		

Among trainers, mean scores ranged from 3.47 to 4.08 on a five-point Likert scale. The highest-rated item was the communication of the institution's mission and vision ($M = 4.08$, $SD = 1.365$), followed by trainee satisfaction with their practical work ($M = 4.00$, $SD = 1.512$). The lowest rated items were management efforts to ensure customer service quality ($M = 3.47$, $SD = 1.428$) and the institutional relationships with local enterprises and industries ($M = 3.47$, $SD = 1.428$). The overall mean score for trainers was 3.72.

Among trainees, mean scores ranged from 2.95 to 3.46. The highest-rated item was again related to institutional visibility, namely TVET college's mission and vision ($M = 3.46$, $SD = 0.957$). The lowest-rated item management monitoring of laboratory and workshop quality systems ($M = 2.95$, $SD = 1.135$).

4.3. Learning resources and facilities

The adequacy of laboratory and workshop resources was assessed using indicators related to equipment functionality, laboratory sufficiency, workshop availability, computer access, maintenance systems, and workshop layout organization.

Table 5: Learning resources and facilities in TVET College

Item Code	Item Statement	Trainers			Trainees		
		N	Mean	Std. Dev.	N	Mean	Std. Dev.
LRF1	Tools and equipment are fully functional	85	3.49	1.525	256	2.80	1.103
LRF2	Laboratory/workshop rooms are attractive and comfortable	85	3.27	1.349	256	2.69	1.108
LRF3	Sufficient laboratory facilities are available	85	3.31	1.380	256	2.45	1.105
LRF4	Sufficient workshop facilities are available	85	3.35	1.420	256	2.54	1.098
LRF5	Enough computers are available for trainees	85	3.34	1.410	256	2.37	1.113
LRF6	Equipment maintenance is conducted on time	85	3.35	1.420	256	2.62	1.227
LRF7	Laboratory/Workshop plant layouts (Kaizen) are advantageous	85	3.64	1.534	256	3.09	1.050
Average Mean			3.39			2.65	

The findings in Table 5 indicate that respondents generally expressed dissatisfaction regarding the adequacy of physical learning resources, with most indicators recording mean scores below the neutral midpoint threshold of 3.0. Trainees highlighted acute systemic constraints, identifying computer availability ($M = 2.37$, $SD = 1.113$), laboratory resource sufficiency ($M = 2.45$, $SD = 1.105$), and workshop

adequacy ($M = 2.54$, $SD = 1.098$) as primary functional deficits. Furthermore, equipment maintenance practices received low baseline marks from trainees ($M = 2.62$, $SD = 1.227$), highlighting significant institutional difficulties in preserving laboratory and workshop operational functionality in a post-conflict environment. In contrast, workshop plant layouts and Kaizen organizational practices received comparatively higher ratings from both trainers ($M = 3.64$, $SD = 1.534$) and trainees ($M = 3.09$, $SD = 1.050$), indicating that several colleges achieved internal structural space improvements despite severe underlying equipment limitations.

4.4. Learning and Teaching activities

Learning and teaching activities were assessed using indicators related to practical instruction, instructional effectiveness, trainee engagement, academic support, training completion, teacher-student ratios, and trainer qualifications.

Table 6: Learning and teaching activities respondent's response of TVET College

Item Code	Item Statement	Trainers			Trainees		
		N	Mean	Std. Dev.	N	Mean	Std. Dev.
LT1	Important skills and knowledge are taught through practical work	85	4.26	1.135	256	3.69	.901
LT2	Teaching and learning through laboratory and workshop activities are delivered effectively	85	3.84	1.396	256	3.35	1.033
LT3	Trainees investigate new ideas while working in practical settings	85	3.61	1.520	256	3.11	1.075
LT4	Trainees receive continuous support during practical work	85	3.78	1.366	256	3.28	1.020
LT5	Trainees complete training according to the academic calendar	85	3.88	1.491	256	3.12	1.080
LT6	Trainers focus on practical work rather than theoretical instruction	85	4.12	1.375	256	3.41	1.077
LT7	There is an appropriate teacher-	85	3.94	1.672	256	3.26	1.098

Item Code	Item Statement	Trainers			Trainees		
		N	Mean	Std. Dev.	N	Mean	Std. Dev.
	student ratio in workshop classes						
LT8	Qualified trainers are available in various occupational fields	85	4.14	1.329	256	3.42	.971
	Average Mean		3.95			3.33	

The findings presented in Table 6 reveal that respondents were generally dissatisfied with the adequacy of physical learning resources, as this dimension received the lowest ratings among all assessed constructs. Among trainers, mean scores ranged from 3.27 to 3.64. The highest-rated item was laboratory and workshop layout organization ($M = 3.64$, $SD = 1.534$), whereas the lowest-rated item was the attractiveness and comfort of laboratory and workshop rooms ($M = 3.27$, $SD = 1.35$). The overall mean score for trainers was 3.39.

According to the trainees' responses, mean scores ranged from 2.37 to 3.09. The lowest-rated item was the availability of computer for trainees ($Mean = 2.37$, $SD = 1.113$), indicating severe shortages of ICT infrastructure across the sampled colleges. Similarly, respondents reported insufficient laboratory facilities ($Mean = 2.45$, $SD = 1.105$) and workshop facilities ($Mean = 2.54$, $SD = 1.098$). The relatively highest score was obtained by the item assessing workshop and laboratory layout (Kaizen) practices ($M = 3.09$, $SD = 1.050$), indicating that some colleges had implemented organizational improvements despite resource limitations.

4.5 Quality improvement and QMS practices

Figure 7 presents respondents' perception regarding of QMS implementation on the teaching and learning process. The majority of respondents (60.4%; $n = 206$) indicated that the effectiveness of the teaching and learning process had increased following QMS implementation. In contrast, 26.7% ($n = 91$) reported a decrease, while 12.9% ($n = 44$) perceived no change.

In your opinion, what has been the impact of QMS implementation in laboratories and workshops on the effectiveness of the teaching and learning process?

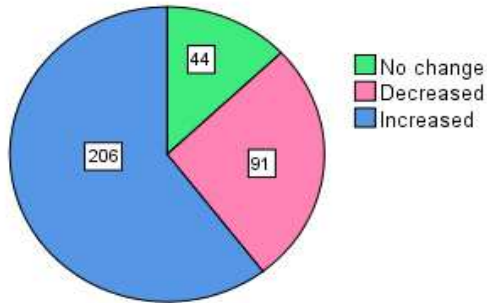


Figure 7: Respondents' perception of QMS implementation

The implementation of a Quality Management System (QMS) in laboratories/workshops improves the quality of TVET college training

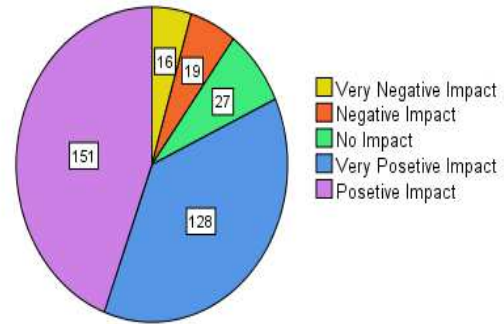


Figure 8: Respondents' Perceptions of QMS Implementation Outcomes

Figure

8 shows that, the majority of respondents perceive the implementation of a Quality Management System (QMS) in laboratories and workshops as having a beneficial effect on TVET quality. Specifically, 37.5% of respondents reported a very positive, while 44.3% indicated a positive. In contrast, 7.9% reported no, whereas 10.3% (5.6% negative and 4.7% very negative) perceived a negative.

Implementation of QMS was further assessed using the results presented in Table 7.

Table 7: Quality improvement and QMS practices in TVET College

Item Code	Item Statement	Trainers			Trainees		
		N	Mean	Std. Dev.	N	Mean	Std. Dev.
QI1	Internal and external quality duties are integrated	85	3.59	1.188	256	3.11	.945
QI2	TVET colleges follow ISO standards	85	3.35	1.420	256	2.70	1.040
QI3	Service quality has improved	85	3.64	1.132	256	3.10	.957
QI4	Teaching staff are of high quality	85	3.91	1.324	256	3.50	.974
QI5	QMS implementation is encouraged by future benefits	85	3.69	1.291	256	3.16	1.046
QI6	Top management monitors laboratories/workshops	85	3.35	1.420	256	2.97	1.047
QI7	Quality manuals are established and maintained	85	3.40	1.457	256	2.93	1.153

Item Code	Item Statement	Trainers			Trainees		
		N	Mean	Std. Dev.	N	Mean	Std. Dev.
Average Mean			3.56			3.08	

The highest-rated item among trainers was the statement indicating that teaching staff in TVET colleges are of high quality ($M = 3.91$, $SD = 1.324$). In contrast, lower mean scores were recorded for institutional monitoring and adherence to ISO standards ($M = 3.35$, $SD = 1.420$). For trainee respondents, the highest-rated item similarly related to teaching staff quality ($M = 3.50$, $SD = 0.974$), while the lowest-rated item concerned compliance with ISO standards in laboratory and workshop operations ($M = 2.70$, $SD = 1.040$). Relatively low ratings were also reported for the availability of quality manuals ($M = 2.93$, $SD = 1.153$) and the effectiveness of management monitoring of laboratory and workshop quality systems ($M = 2.97$, $SD = 1.047$).

4.6. Comparison of major study dimensions between Trainers and Trainees

Table 8 presents the mean scores of trainers and trainees across the four major study dimensions. Trainers reported higher mean scores than trainees in all statement. The weighted grand mean was calculated based on the total sample size of 341 respondents, including both trainers and trainees.

Table 8: Comparison of mean scores between Trainers and Trainees

Item Code	Item Statement	Trainers Mean	Trainees Mean	Mean Difference	Interpretation
CS	Customer Satisfaction	3.72	3.24	0.48	Moderate difference
LT	Learning and Teaching	3.95	3.33	0.62	Moderate difference
LFR	Learning Resource Facilities	3.39	2.65	0.74	High difference
QI	Quality Improvement	3.56	3.08	0.48	Moderate difference

The largest difference was observed for Learning Resources and Facilities (LRF), where trainers indicated a mean score of 3.39 compared with 2.65 for trainees,

resulting in a mean difference of 0.74. Learning and Teaching (LT) observed a mean difference of 0.62. Customer Satisfaction (CS) and Quality Improvement (QI) each obtained a mean difference of 0.48. Overall, the findings demonstrated that trainers showed more favorable perceptions than trainees regarding customer satisfaction, learning and teaching activities, learning resources and facilities, and quality improvement practices.

4.7. Correlation Analysis

Pearson correlation analyses were conducted to examine the relationships among customer satisfaction, learning and teaching, learning resource facility, and quality improvement. These analyses were performed separately for trainees and trainers, as presented in Tables 9 and 10.

Table 9: Pearson correlation matrix for trainees

		Customer Satisfaction (CS)	Learning and Teaching (LT)	Learning and Resource Facility (LRF)	Quality improvement (QI)
Customer Satisfaction (CS)	Pearson Correlation	1	.988**	.956**	.991**
	Sig. (2-tailed)		.000	.000	.000
	N	256	256	256	256
Learning and Teaching (LT)	Pearson Correlation	.988**	1	.954**	.979**
	Sig. (2-tailed)	.000		.000	.000
	N	256	256	256	256
Learning and Resource Facility (LRF)	Pearson Correlation	.956**	.954**	1	.966**
	Sig. (2-tailed)	.000	.000		.000
	N	256	256	256	256
Quality improvement (QI)	Pearson Correlation	.991**	.979**	.966**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	256	256	256	256

** . Correlation is significant at the 0.01 level (2-tailed).

The results revealed statistically significant and positive correlations among all study variables. Quality improvement exhibited the strongest association with customer satisfaction ($r = .991$, $p < .001$), followed by learning and teaching ($r = .979$, $p < .001$) and learning resource facility ($r = .966$, $p < .001$).

Table 10: Pearson correlation matrix for trainers

		Customer Satisfaction (CS)	Learning and Teaching (LT)	Learning and Resource Facility (LRF)	Quality improvement (QI)
Customer Satisfaction (CS)	Pearson Correlation	1	.995**	.988**	.992**
	Sig. (2-tailed)		.000	.000	.000
	N	85	85	85	85
Learning and Teaching (LT)	Pearson Correlation	.995**	1	.980**	.982**
	Sig. (2-tailed)	.000		.000	.000
	N	85	85	85	85
Learning and Resource Facility (LRF)	Pearson Correlation	.988**	.980**	1	.991**
	Sig. (2-tailed)	.000	.000		.000
	N	85	85	85	85
Quality improvement (QI)	Pearson Correlation	.992**	.982**	.991**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	85	85	85	85

** . Correlation is significant at the 0.01 level (2-tailed).

Similarly, among trainers, all QMS dimensions were positively and significantly correlated. Quality Improvement showed very strong relationships with Customer Satisfaction ($r = .992$, $p < .001$) and learning resource facility ($r = .991$, $p < .001$). The exceptionally high correlations observed among several dimensions may reflect conceptual overlap among respondents' perceptions of institutional quality and should therefore be interpreted with caution.

4.8. Regression Analysis

Multiple linear regression analysis was performed to determine the extent to which customer satisfaction, learning and teaching, and learning resource facility significantly predicted quality improvement shown in Table 11-Table 16.

Table 11: Multiple regression results for Trainees

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.059	.032		1.846	.066
	Customer Satisfaction (CS)	.848	.051	.859	16.739	.000
	Learning and Teaching (LT)	-.085	.049	-.086	-1.722	.086
	Learning and Resource Facility (LRF)	.207	.024	.227	8.600	.000

Table 12: ANOVA^a results for Trainees

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	243.623	3	81.208	5685.984	.000 ^b
	Residual	3.599	252	.014		
	Total	247.222	255			

a. Dependent Variable: Quality improvement (QI)

b. Predictors: (Constant), Learning and Resource Facility (LRF), Learning and Teaching (LT), Customer Satisfaction (CS)

Table 13: Regression Model Summary for Trainees

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.993 ^a	.985	.985	.11951

a. Predictors: (Constant), Learning and Resource Facility (LRF), Learning and Teaching (LT), Customer Satisfaction (CS)

The regression model was statistically significant and explained 98.5% of the variance in quality improvement ($R^2 = .985$). Customer satisfaction emerged as the strongest predictor of quality improvement ($\beta = .859$, $p < .001$), followed by learning resource facility ($\beta = .227$, $p < .001$). In contrast, learning and teaching did not significantly predict quality improvement ($\beta = -.086$, $p = .086$).

Table 14: Multiple regression results for Trainers

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	.416	.052		7.994	.000
	Customer Satisfaction (CS)	.847	.124	.930	6.806	.000
	Learning and Teaching (LT)	-.335	.100	-.359	-3.350	.001
	Learning and Resource Facility (LRF)	.387	.064	.425	6.100	.000

a. Dependent Variable: Quality improvement (QI)

Table 15: ANOVA^a results for Trainers

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	139.191	3	46.397	2913.816	.000 ^b
	Residual	1.290	81	.016		
	Total	140.481	84			

a. Dependent Variable: Quality improvement (QI)

b. Predictors: (Constant), Learning and Resource Facility (LRF), Learning and Teaching (LT), Customer Satisfaction (CS)

Table 16: Regression Model Summary for Trainers

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.995 ^a	.991	.990	.12619

a. Predictors: (Constant), Learning and Resource Facility (LRF), Learning and Teaching (LT), Customer Satisfaction (CS)

The regression model for trainers was statistically significant and explained 99.1% of the variance in quality improvement ($R^2 = .991$). Customer satisfaction ($\beta = .930$, $p < .001$) and learning resource facility ($\beta = .425$, $p < .001$) were positively associated with quality improvement, while learning and teaching exhibited a significant negative coefficient ($\beta = -.359$, $p = .001$).

4.9. Qualitative Findings

The qualitative interviews and observations on site revealed a huge gap between the official policies of the college and the actual situation in the workshops. High-level goals are posted on notice boards, but there are no functional systems for trainees to give feedback, and student complaints about poor workshop conditions are largely ignored. There is a big difference in the perception of quality of education among trainers and trainees. Trainers feel they're doing a great job; trainees find the sessions repetitive and really hamstrung by lack of tools.

Resource shortages were associated with conflict-related damage, supply-chain disruptions, and maintenance challenges, according to interview participants and observations. Instructors and administrators reported chronic shortages in basic tools, obsolete machinery, and a total absence of consumables for daily training. Observations showed widespread physical damage to facilities, broken or abandoned machinery, and crowded workbenches, all exacerbated by frequent power outages.

Ultimately, the findings indicate that some QMS activities were implemented mainly at the documentation level, with little evidence of systematic monitoring and continuous improvement practices. Quality frameworks exist on paper but laboratory monitoring in practice is irregular and left to the efforts of individual faculty rather than managed systematically by the institution. Field observations showed little evidence of fully operational PDCA cycles in several TVET colleges.

5. Discussion

The empirical results indicate that weakened supply chains, systematic equipment loss, disrupted maintenance frameworks, and direct post-conflict infrastructure damage are heavily linked to acute institutional resource constraints. These co-occurring operational circumstances have severely degraded the functional capacity of laboratory and workshop spaces across the sampled public TVET colleges, a trend clearly corroborated by interviewees and field observations. The qualitative evidence details a clear narrative of widespread equipment looting, long-term supply chain isolation, and physical facility degradation. Within a competency-based TVET

framework, operating without functional machinery fundamentally shifts the educational dynamic converting interactive, hands-on skill development into rigid, highly theoretical classroom instruction that fails to meet baseline national vocational benchmarks.

The findings also show that both trainers' and trainees' perceptions of quality improvement were strongly correlated with the sufficiency of learning resources. The results indicate that sufficient laboratory and workshop resources may be crucial in enabling successful QMS implementation, even though the study design does not allow for causal inference.

The perceptual gap between trainers and trainees serves as more evidence of this systemic vulnerability. In every research dimension, trainers consistently reported higher evaluations; this was especially true for learning resource facilities, where a significant mean difference was found ($M_{\text{trainers}} = 3.39$; $M_{\text{trainees}} = 2.65$). This result implies that trainee' perceptions of the suitability and functioning of laboratory and workshop materials may not be well captured by institutional assessments. Previous TVET quality assurance studies have documented similar discrepancies between staff and student perceptions, underscoring the significance of taking into account a variety of stakeholder viewpoints when assessing institutional quality.

Multiple linear regression modeling confirmed that learning resource facility adequacy serves as an exceptionally strong, statistically significant predictor of quality improvement for both trainees ($\beta = .227$, $p < .001$, $R^2 = .985$) and trainers ($\beta = .425$, $p < .001$, $R^2 = .991$). These results imply that while high trainer competence ($M_{\text{trainers}} = 3.91$; $M_{\text{trainees}} = 3.50$) is maintained across locations, human capital alone cannot compensate for empty workshops and broken tools. Consequently, physical resource adequacy remains a crucial baseline determinant for enabling successful QMS adoption and executing continuous quality cycles.

5. Conclusion

This study examined QMS implementation and the sufficiency of laboratory and workshop equipment in public TVET colleges in Ethiopia's North Wollo and

Waghimra Zones that are working under post-conflict recovery settings. The study obtained a comprehensive multi-stakeholder assessment of the significant operational gap between official quality assurance mandates and the reality of everyday resource-constrained contexts by employing a convergent mixed-methods methodology.

Although colleges have shown resilience by continuing educational activities and upholding distinct institutional objectives, the descriptive data and field observations show that severe physical resource deficiencies continue to significantly impede successful QMS execution. The biggest institutional obstacles to quality assurance are persistent shortages of computer workstations, inadequate lab space, under-equipped workshops, and postponed preventative maintenance schedules. Additionally, inferential analysis showed a substantial correlation between QMS implementation indicators and resource adequacy variables. In order to support sustainable quality assurance methods in post-conflict TVET environments, these findings emphasize the significance of bolstering institutional infrastructure and maintenance mechanisms.

6.1. Study Limitations and Recommendations

This study offers important data from the Waghimra and North Wollo Zones. We are aware of some restrictions on its application. First, since our data particularly reflects a post-conflict situation, the spatial focus may restrict the findings' external validity to more stable areas of Ethiopia. Second, the reduced percentage of trainers compared to trainees should be taken into consideration when assessing leadership-related results, even though the total sample size is statistically representative of the target population.

This study has the following recommendations:

- To promote competency-based training, laboratory and workshop facilities should be restored and upgraded as a top priority in post-conflict rehabilitation activities.

- Improving equipment inventory management procedures and preventative maintenance systems may be advantageous for TVET colleges.
- Regular chances for professional development pertaining to digital resource management, ISO-based quality assurance, and QMS implementation could improve institutional capability.
- Better resource mobilization and training relevance may result from increased cooperation between TVET colleges, business partners, and regional education authorities.
- Performance-based quality improvement techniques may be explored in future policy initiatives; however, more study is needed to ascertain their efficacy in the Ethiopian TVET colleges.

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Use of AI-assisted technologies

AI-assisted tools (Grammarly and QuillBot) were used solely for language editing and grammar refinement. They did not generate data, analysis, or substantive content. The authors take full responsibility for the intellectual content and conclusions.

Authors' contributions

Addis Goshe designed the study, coordinated the data collection, and drafted the manuscript. Shumye Girmay conducted the simulations, performed the data analysis, and contributed to the results interpretation. Both authors participated in the revision process, provided critical feedback, and have read and approved the final version of the manuscript.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Declarations**Ethical Approval**

Ethical approval was obtained from the appropriate research ethics committee of Woldia University Research, Publication, Ethics, and System Directorate.

Consent to participate

All respondents provided written informed consent before participation.

Consent to Publish

Informed consent was obtained from all individuals who participated in this study, including for the use of anonymized data in academic publication.

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