

Competency Gaps in Automotive Air Conditioning Training in Nigerian TVET Institutions: A Systematic Review and Implications For Curriculum Reform

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ABSTRACT

This study presents a systematic review of literature examining competency gaps and occupational skill deficiencies in Automotive Air-Conditioning (AAC) training within Nigerian Technical and Vocational Education and Training (TVET) institutions. Guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework, the review identified, screened, and synthesised relevant empirical studies to examine competency requirements, curriculum challenges, and factors influencing skill development in AAC training. A structured search was conducted across Google Scholar and Scopus-indexed databases, covering studies published between 2019 and 2026. The eligible studies were analysed using thematic synthesis to identify recurring patterns related to occupational competencies, curriculum relevance, training resources, and industry alignment. The findings reveal multidimensional competency gaps affecting AAC training, particularly in system diagnosis, refrigerant management, fault detection, and the application of modern diagnostic technologies. The review further identifies a persistent mismatch between TVET training outcomes and industry expectations, resulting from outdated curricula, inadequate practical facilities, limited access to industry-standard equipment, insufficient instructor capacity, and weak industry-institution collaboration. The findings demonstrate that improving AAC training requires a coordinated reform approach involving competency-based curriculum development, modernised training infrastructure, continuous instructor professional development, and stronger partnerships between TVET institutions and the automotive industry. This review provides evidence-based insights for curriculum developers, policymakers, and educators seeking to enhance graduate employability and strengthen the alignment between AAC training and contemporary automotive industry requirements.

Keywords: Automotive air conditioning, TVET, occupational skill deficiencies, Curriculum reform, Systematic review, Automotive Training, Occupational skill deficiencies.

INTRODUCTION

Technical and Vocational Education and Training (TVET) is widely recognised as a critical driver of human capital development, industrialisation, technological innovation, and sustainable economic growth. Globally, TVET systems are expected to equip learners with the knowledge, skills, and competencies required to meet the evolving demands of the labour market and support national development agendas. (UNESCO, 2021); International Labour Organisation (Stamov Roßnagel et al., 2021). In developing countries such as Nigeria, TVET serves as an important mechanism for addressing youth unemployment, fostering entrepreneurship, enhancing workforce productivity, and promoting socio-economic development. (Chukwutem et al., 2025; Obadia et al., 2026). Despite these expectations, concerns remain regarding the extent to which graduates of TVET institutions possess the occupational competencies required to perform effectively in contemporary workplaces, particularly within automotive-related occupations. The automotive industry has experienced rapid technological advancements over the past decade, resulting in significant changes in vehicle design, operation, and maintenance requirements. Modern vehicles increasingly incorporate sophisticated automotive air conditioning (AAC) (Eniekenemi, 2021). These technological developments have transformed the competencies

required of automotive technicians, necessitating proficiency in system diagnostics, refrigerant handling and recovery, fault detection, preventive maintenance, servicing procedures, and the operation of advanced digital diagnostic equipment. (Shehu, 2024). Consequently, AAC training has become an essential component of automotive technology programmes offered in Technical and Vocational Education and Training institutions.

The increasing integration of advanced automotive technologies, particularly Automotive Air Conditioning (AAC) systems, has intensified the demand for technicians with specialised occupational competencies in installation, servicing, maintenance, diagnostics, and troubleshooting (Muoghalu & Ahmad, 2025; Shehu, 2024). However, evidence from the literature indicates a persistent mismatch between the competencies expected by the automotive industry and those acquired by graduates of technical and vocational education and training (TVET) institutions in Nigeria. (Ayonmike & Okeke, 2016; Chinyere Shirley et al., 2015; Okolie et al., 2021). This competency mismatch has become a major concern as modern vehicle air conditioning systems increasingly incorporate electronic controls, environmental refrigerant regulations, and advanced diagnostic technologies that require updated technical knowledge and practical skills. Several studies have attributed the competency gaps among TVET graduates to inadequate workshop facilities, obsolete training equipment, insufficient industrial exposure, and curricula that are not adequately aligned with contemporary industry requirements. (Elijah & Ezeife, 2020; Okolie et al., 2020). In addition, deficiencies in instructional resources, limited technological infrastructure, and weak collaboration between educational institutions and industry stakeholders have been reported as factors constraining the development of industry-relevant competencies among learners. (Okolie et al., 2021; Oviawe et al., 2017; Chukwutem et al., 2025). These challenges are particularly significant in AAC training, where practical competence, diagnostic skills, and familiarity with emerging technologies are essential for effective workplace performance. The problem of competency mismatch is not limited to AAC training but reflects broader challenges within the Nigerian TVET system. Previous studies have consistently reported gaps between institutional training outcomes and workplace expectations, manifested through inadequate practical skills, limited problem-solving abilities, insufficient technological competencies, and reduced employability among graduates. (Ayonmike & Okeke, 2016; Okolie et al., 2020). To address these challenges, scholars have emphasised the need for competency-based curricula, stronger industry partnerships, modernised training facilities, and learner-centred instructional approaches that promote active engagement and workplace readiness. (UNESCO, 2021; Stamov Roßnagel et al., 2021).

Despite the growing body of literature on automotive technology education and vocational skills development, empirical evidence on competency gaps in automotive air-conditioning training remains scattered and fragmented. Existing studies tend to focus on broader automotive technology programmes or general vocational skills development, offering limited synthesis of the occupational competencies required for effective AAC servicing, maintenance, fault diagnosis, and system performance evaluation. Consequently, there is a lack of comprehensive evidence to guide curriculum improvement, instructional enhancement, and workforce development initiatives in this specialised area. Against this background, the present study conducts a systematic review of the empirical literature on competency gaps in automotive air-conditioning training within Nigerian TVET institutions. Specifically, the review synthesises evidence on the occupational competencies required in AAC training, identifies prevailing competency gaps and instructional challenges, and examines curriculum-related issues that affect the development of industry-relevant skills among learners. By consolidating findings from previous studies, the review provides evidence-based recommendations for curriculum reform, instructional improvement, industry collaboration, and workforce development. Furthermore, the findings offer valuable insights for integrating instructional design frameworks, particularly the ADDIE Model and Needham's Five Phases Constructivist Model, to enhance competency-based automotive air-conditioning training and improve graduate preparedness for contemporary automotive workplaces.

Several studies have reported competency deficiencies among automotive technology graduates in Nigeria, particularly in practical skills, diagnostic procedures, and emerging vehicle technologies. (And et al., 2020; Emmanuel & Victor, 2022). Recent evidence further indicates that curriculum misalignment, inadequate training facilities, and weak industry collaboration continue to hinder effective competency development. (Muoghalu & Ahmad, 2025; Ugochukwu & Esther, 2026). Despite increasing attention to skills development in TVET, there remains a limited synthesis of evidence specifically addressing competency gaps in Automotive Air

Conditioning training. Consequently, a systematic review is required to consolidate existing evidence and identify implications for curriculum reform

METHODOLOGY

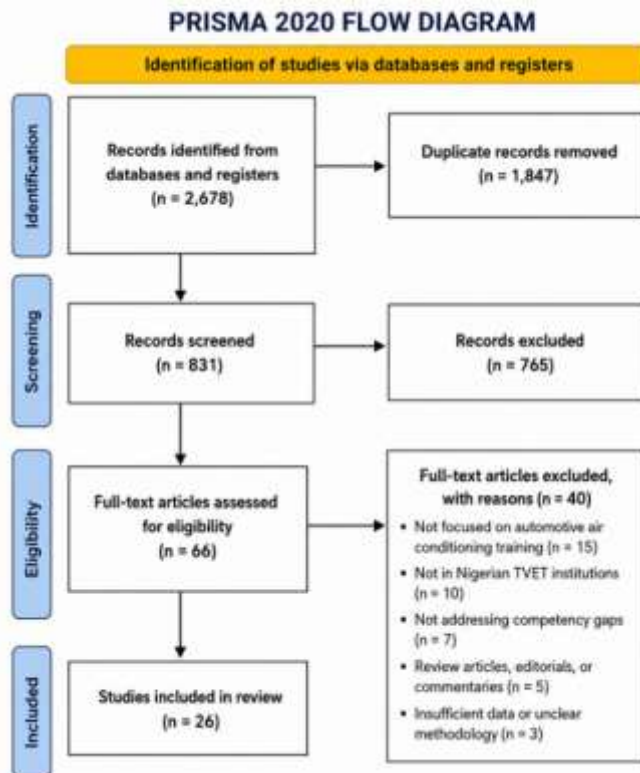


Figure 1: PRISMA FRAMEWORK

Note: The PRISMA flow diagram illustrates the study identification, screening, eligibility assessment, and inclusion process used in this systematic review.

Research Design

This study adopted a systematic literature review (SLR) approach to examine competency gaps in Automotive Air Conditioning (AAC) training within Technical and Vocational Education and Training (TVET) institutions and to identify implications for curriculum reform. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines to ensure transparency, rigour, and reproducibility throughout the review process. (Matthew et al., 2021). The systematic review approach was considered appropriate because it enables the identification, appraisal, synthesis, and interpretation of existing empirical evidence related to competency development, curriculum implementation, industry requirements, employability skills, and emerging technological competencies within automotive education. By systematically analysing relevant studies, the review provides a comprehensive understanding of the factors contributing to competency gaps in automotive air-conditioning training and offers evidence-based recommendations for curriculum improvement. Figure 1. PRISMA 2020 flow diagram showing the identification, screening, eligibility assessment, and inclusion of studies examining competency gaps in automotive air-conditioning training and related TVET disciplines between 2019 and 2026.

Data Sources and Search Strategy

A comprehensive literature search was conducted across five major academic databases: Google Scholar, Scopus, Web of Science, ERIC (Education Resources Information Centre) and ScienceDirect. These databases were selected because they provide extensive coverage of vocational education, technical education, engineering education, automotive technology, workforce development, and curriculum studies. The search covered

publications published between 2019 and 2026. The search strategy combined keywords and Boolean operators related to automotive air-conditioning training, competency development, skills gaps, curriculum issues, and TVET. The primary search terms included: “Air Conditioning Training”. “Competence Gap in Automobile”, “TVET Training”, “Curriculum” OR “Automotive Air Conditioning”, “Competency Gap”, “Skills Gap”

The search strings were refined using Boolean operators (AND, OR) to maximise the retrieval of relevant studies. An example of the search string is presented below: ("Automotive Air Conditioning" OR "Air Conditioning Training" OR "Automobile Air Conditioning") AND ("Competency Gap" OR "Skills Gap" OR "Competence Gap in Automobile") AND ("TVET" OR "Technical and Vocational Education and Training" OR "TVET Training") AND ("Curriculum" OR "Employability" OR "Industry Needs"). The search process yielded a total of 2,678 records across all databases.

Inclusion and Exclusion Criteria

To ensure the relevance and quality of the studies included in the review, predefined inclusion and exclusion criteria were established.

Inclusion Criteria

Studies were included if they were published between 2019 and 2026. If they were peer-reviewed journal articles and published in English. Focused on Technical and Vocational Education and Training (TVET), addressed automotive technology, automobile mechanics, automotive air-conditioning, employability skills, competency development, skills gaps, curriculum issues, teacher competencies, industry collaboration, and workforce readiness. Reported empirical findings or systematic review evidence relevant to competency development.

Exclusion Criteria

Studies were excluded if they were conference abstracts, editorials, commentaries, dissertations, or unpublished reports. If they were not published in English. If they did not focus on TVET or vocational education contexts. Unrelated to automotive education, technical competencies, skills development, or curriculum issues. If they were duplicate records identified during the screening process, and lacked sufficient methodological information or relevant findings.

Study Selection Process

The study selection followed the PRISMA 2020 guidelines. Database searches across Google Scholar, Scopus, Web of Science, ERIC, and ScienceDirect identified 2,678 records. After removing 1,847 duplicate records, 831 unique records remained for title and abstract screening. Screening excluded 765 records that did not meet the predefined inclusion criteria, leaving 66 full-text articles for eligibility assessment. Of these, 40 articles were excluded for the following reasons: 15 did not focus on automotive air-conditioning training, 10 were not conducted within Nigerian TVET institutions, 7 did not address competency gaps, 5 were review articles, editorials, or commentaries, and 3 had insufficient methodological detail or unclear research methods. Consequently, 26 studies met all eligibility criteria and were included in the final qualitative synthesis. The complete study selection process is illustrated in Figure 1 (PRISMA 2020 flow diagram).

Quality Appraisal of Included Studies

To ensure methodological rigour and reliability, all included studies underwent quality appraisal before synthesis. The appraisal process was guided primarily by the Mixed Methods Appraisal Tool (MMAT, 2018) and supported by selected criteria adapted from the Critical Appraisal Skills Programme (CASP). The combined approach was considered appropriate because the review included quantitative, qualitative, mixed-methods, and review studies.

Each study was assessed based on the following criteria: Clarity of research, objectives; Appropriateness of research design; Adequacy of sampling procedures and participants; Reliability and validity of data collection instruments. Transparency and appropriateness of data analysis procedures; Consistency between findings and

conclusions; Relevance to automotive education, competency development, TVET, and curriculum reform. Studies that met the minimum quality requirements and demonstrated methodological soundness were retained for synthesis. The appraisal process helped ensure that only credible and relevant evidence informed the thematic analysis and subsequent recommendations for curriculum reform in automotive air-conditioning training within Nigerian TVET institutions.

Data Extraction and Synthesis (thematic synthesis)

A structured data extraction form was systematically developed to capture relevant information from each study. The extracted information included: Author(s) and year of publication; Research objectives; Methodology and research design; Key findings; Limitations and future research directions; Country of study. After extraction, thematic synthesis was used to analyse and integrate findings across the selected studies. Similar concepts and patterns were grouped into broader themes. The analysis yielded several major themes, including technical competency gaps, curriculum misalignment, inadequate facilities and infrastructure, teacher competency development, industry collaboration, employability challenges, and digital transformation in TVET. This thematic synthesis provided a comprehensive understanding of the factors influencing competency development in automotive air-conditioning training and formed a foundation for evidence-based curriculum reform recommendations.

Table 1 Theme Findings

Theme of the Study	T1 Technical & Occupational Competency Gaps	T2 Curriculum Misalignment & Reform	T3 Facilities & Infrastructure	T4 Teacher Competency Development	T5 Industry Collaboration & Work-Based Learning	T6 Employability & Workforce Readiness	T7 Digital Transformation & Emerging Technologies
Eniekene mi (2021)	✓	✓	✓		✓	✓	
Emmanuel & Victor (2022)	✓	✓				✓	
Obadiah et al. (2026)	✓			✓		✓	✓
Muoghalu & Ahmad (2025)	✓	✓	✓	✓	✓		✓
Egbunefu (2026)	✓	✓				✓	✓
Saue et al. (2024)	✓	✓	✓	✓		✓	✓
Munawar et al. (2024)	✓	✓		✓		✓	
Magaj, et al. (2023)	✓			✓			
Adegbenjo &			✓	✓		✓	

Busisiwe (2023)							
Ogbebor & Osuyi (2024)			✓	✓	✓	✓	
Ujevbe et al. (2020)	✓	✓	✓	✓	✓	✓	
Zheng et al. (2025)	✓	✓				✓	
Okeke & Odu (2024)			✓	✓			
Olowe (2024)		✓		✓		✓	
Zulkifli et al. (2025)			✓	✓			✓
Sultono et al. (2025)		✓	✓			✓	✓
Machaka & Singh-Pillay (2025)	✓			✓		✓	
Shehadeh (2025)	✓	✓				✓	✓
Emah et al. (2025)	✓					✓	
Ajuzieogu (2025)	✓	✓	✓	✓		✓	✓
Rabiu et al. (2025)		✓	✓	✓			✓
Onele (2025)		✓		✓			✓
Subagja et al. (2025)	✓	✓		✓	✓	✓	
Maksum et al. (2023)	✓	✓		✓		✓	✓

Note: The seven themes presented in this table were identified through thematic synthesis of the studies included in the systematic review. These themes represent the major competency gaps in automotive air conditioning training reported across Nigerian TVET institutions.

Data Analysis

Theme 1: Technical and Occupational Competency Gaps in TVET Programmes

This theme emerged from studies reporting deficiencies in the technical competencies required for successful workplace performance. Several studies revealed that graduates often lack the practical and occupational skills demanded by industry. Emmanuel & Victor (2022) identified competency gaps in auto-electricity and electronics, while reporting deficiencies in technical and occupational skills among automobile technology graduates. Yin

et al. (2021) Further, significant mismatches between graduate competencies and employer expectations. Similarly, Abdul & Ibrahim (2025) reported variations in students' technical competencies, particularly weaknesses in digital security competencies. These findings indicate persistent gaps between training outcomes and labour market requirements.

Sub-themes: Automotive technical competency deficiencies; Graduate-employer competency mismatch; Technical and occupational skill shortages; Automotive air-conditioning competency needs

Theme 2: Curriculum Misalignment and the Need for Curriculum Reform

This theme emerged strongly across the literature. Several studies highlighted the inability of existing curricula to respond adequately to emerging technologies and industry requirements. Muoghalu & Ahmad, (2025), reported curriculum misalignment with evolving automotive industry practices. Ugochukwu & Esther (2026), emphasised integrating computerised diagnostics, hybrid vehicle maintenance, and electronic system repair into curricula. Rabiou et al. (2025), Curriculum innovation to facilitate AI adoption, while Oluwadunmininu et al. (2025) Called for the integration of climate literacy into TVET curricula. Subagja et al. (2025) also demonstrated the superiority of integrated curriculum approaches for soft skill development. Collectively, these studies suggest that curriculum reform is essential for improving workforce readiness.

Sub-Themes: Outdated curriculum content; Emerging technology integration [Automotive air-conditioning curriculum enhancement; Soft skill integration and Environmental and sustainability education

Theme 3: Inadequate Facilities, Equipment, and Technological Infrastructure

Many studies identified inadequate facilities and technological infrastructure as barriers to competency development. Eniekenemi (2021). reported infrastructure deficiencies affecting TVET effectiveness, while Muoghalu & Ahmad (2025), highlighted shortages of modern equipment and learning resources. Barliana et al. (2025), found inadequate technological support and poor access to digital infrastructure despite high entrepreneurial readiness among students. Rabiou et al. (2025) Similarly, infrastructure deficits were identified as a major obstacle to AI implementation. These findings suggest that effective competency development depends heavily on access to modern training resources and technologies.

Sub-Themes: Inadequate workshop facilities; Outdated automotive equipment; Digital infrastructure deficits; Technology accessibility challenges

Theme 4: Teacher Competency and Professional Development Needs

Teacher competence emerged as one of the most dominant themes. Magaji, et al (2023) identified deficiencies in content knowledge and pedagogical competencies among lecturers. Busisiwe., (2023) reported inadequate workshop management competencies among technical teachers. Muoghalu & Ahmad, (2025)) highlighted limited technological expertise among instructors, while (Rabiou et al., 2025) identified lecturer competency as a barrier to AI integration. (Aida et al., 2025) similarly demonstrated that inadequate staff training undermines successful technology adoption. These findings suggest that professional development for teachers is essential for enhancing the quality of training. The findings suggest that professional development for teachers is essential to enhancing the quality of training.

Sub-themes: Pedagogical competency gaps; Technical competency gaps among instructors; Digital competency deficiencies; Professional development and retraining needs

Theme 5: Industry Collaboration and Work-Based Learning Challenges

Several studies emphasised the importance of industry partnerships in reducing competency gaps. Ogbebor, and Osuyi, (2024) reported inadequate collaboration between technical colleges and industries. Eniekenemi, (2021), identified industry partnership as a key success factor for employability outcomes. Subagja et al., (2025), found industry-academia collaboration to be crucial for competency development but noted substantial implementation

gaps. And et al., (2020) Also recommended stronger public-private partnerships and industrial attachment programmes. Ongoing weak engagement from the industry is limiting the acquisition of practical skills and hindering workplace readiness.

Sub-themes: Weak industry partnerships; Limited industrial attachment opportunities; Inadequate workplace learning experiences; Industry-academia collaboration gaps

Theme 6: Employability, Workforce Readiness, and Skills Mismatch

Employability emerged as a major concern across the studies. Eniekenemi, (2021) found that effective TVET programmes improved employment outcomes, while Ugochukwu & Esther, (2026) Linked technical competencies to job creation and self-reliance. Yin et al., (2021) identified significant differences between employer expectations and graduate competencies. Ajuzieogu, (2025), further revealed broader labour market challenges, including skills shortages, teacher deficits, and curriculum-industry misalignment. These studies collectively suggest that competency gaps significantly affect graduate employability and workforce readiness.

Sub-themes: Graduate employability challenges; Labour market mismatch; Workforce readiness deficits; Entrepreneurship and self-employment skills.

Theme 7: Digital Transformation, Artificial Intelligence, and Emerging Technologies

This theme is particularly important for modern automotive training and emerged from several recent studies. Zulkifli et al. (2025) highlighted the importance of digital skills development for successful digitisation. Shehadeh (2025) emphasised digital competencies among students, while Rabiou et al. (2025) examined opportunities and challenges associated with AI integration in TVET institutions. (Barliana et al., 2025) Further highlighted deficiencies in digital infrastructure despite increasing demand for technology-driven learning. These studies indicate that future TVET curricula must incorporate digital literacy, AI applications, and emerging automotive technologies.

Sub-themes: Digital competency development; Artificial intelligence integration; Technology-enhanced learning; Digital infrastructure readiness.

Ethical Considerations

Since this study utilised secondary data obtained from published literature, no human participants were directly involved. Consequently, ethical approval and informed consent were not required. Nevertheless, the review adhered to accepted principles of research integrity by ensuring accurate citation, proper acknowledgement of original authors, transparency in study selection, and objective reporting of findings. The review process was conducted in accordance with academic ethical standards to minimise bias, maintain transparency, and ensure the credibility and trustworthiness of the findings.

Thematic Findings

Technical and Occupational Competency Gaps in Automotive Training

The most prominent theme identified across the reviewed studies is the persistent deficiency in the technical and occupational competencies required for effective performance in contemporary automotive industries. Evidence consistently indicates that students, graduates, lecturers, and practising technicians experience competency gaps, highlighting a systemic mismatch between TVET training outcomes and evolving workplace requirements (Kanife et al., 2022; Ujevbe et al., 2020; Zheng et al., 2025).

Within the Nigerian context, studies on automobile technology, auto-electricity, electronics, and automotive servicing consistently reported inadequate practical competencies among both learners and instructors. Kanife

et al. (2022) identified deficiencies in essential auto-electricity and electronics competencies required for workplace performance, while Ujevbe et al. (2020) found that many automobile technology graduates lacked the occupational competencies needed for effective employment. Similarly, Magaji et al. (2023) reported substantial competency development needs among lecturers responsible for teaching automotive fuel and air-conditioning systems. These findings are particularly relevant to Automotive Air-Conditioning (AAC) training because contemporary AAC systems increasingly rely on electronic control units, computerised diagnostics, sensors, and hybrid-electric technologies.

Comparable patterns were reported internationally. Zheng et al. (2025) found a significant mismatch between employer expectations and graduates' competencies, indicating that vocational graduates often overestimate their workplace readiness. Likewise, Shehadeh (2025) reported deficiencies in digital competencies required for modern automotive occupations, while Emah et al. (2025) highlighted competency disparities associated with occupational specialisation and changing industry expectations. Collectively, these findings demonstrate that competency gaps represent a global challenge rather than an issue confined to a single educational system.

Overall, the reviewed evidence suggests that competency deficiencies extend beyond technical knowledge to include diagnostic, digital, cognitive, and workplace competencies required in modern automotive service environments. In AAC training, these deficiencies are reflected in limited proficiency in diagnosing electronically controlled systems, ineffective troubleshooting of advanced air-conditioning technologies, and inadequate adaptation to emerging automotive innovations. These findings underscore the need for curriculum reform that aligns competency standards, instructional practices, and practical training with current industry requirements, thereby enhancing graduate employability and workforce readiness.

Curriculum Misalignment and the Need for Curriculum Reform

A second major theme identified across the reviewed studies is the misalignment between existing TVET curricula and the rapidly evolving requirements of the automotive industry. The evidence indicates that many vocational programmes continue to emphasise conventional mechanical systems while providing insufficient coverage of emerging automotive technologies, thereby limiting graduates' readiness for contemporary workplaces (Muoghalu & Ahmad, 2025; Ujevbe et al., 2020). Within the Nigerian context, Muoghalu and Ahmad (2025) identified significant curriculum deficiencies in Motor Vehicle Mechanic programmes, particularly in auto-electricity and electronics. Similarly, Egbunefu (2026) advocated the integration of computerised diagnostics, hybrid and electric vehicle technologies, and electronic control systems into vocational curricula. Ujevbe et al. (2020) further demonstrated that outdated curricular structures contribute directly to graduates' competency deficiencies and reduced employability.

These shortcomings are particularly evident in Automotive Air-Conditioning (AAC) training. Contemporary AAC systems have evolved beyond conventional refrigeration principles to incorporate electronic climate control, computerised diagnostics, thermal management for hybrid and electric vehicles, and environmentally sustainable refrigerant technologies. However, the reviewed studies indicate that these technological advancements remain inadequately represented in many TVET curricula. Beyond technical knowledge, the literature consistently emphasises the need to integrate digital literacy, entrepreneurial competencies, environmental sustainability, and employability skills into vocational education. Studies by Subagja et al. (2025), Sultono et al. (2025), and Onele (2025) collectively demonstrate that effective curriculum reform requires a holistic, industry-responsive approach that combines updated technical content with competency-based instruction, authentic assessment, stronger industry collaboration, and continuous curriculum review to

Inadequate Facilities, Equipment, and Technological Infrastructure

Another recurring theme concerns the inadequacy of training facilities, obsolete equipment, and limited technological infrastructure within TVET institutions. The reviewed studies consistently indicate that these deficiencies restrict practical skills acquisition and reduce learners' exposure to industry-standard technologies,

thereby widening the gap between institutional training and workplace expectations (Eniekenemi, 2021; Muoghalu & Ahmad, 2025; Ujevbe et al., 2020).

Several studies reported persistent shortages of modern laboratories, workshop facilities, and instructional equipment required for effective automotive training. Okeke and Odu (2024) further identified infrastructural limitations that continue to constrain the quality of technical education delivery. More recent studies on digital transformation in TVET (Rabiu et al., 2025; Sultono et al., 2025; Zulkifli et al., 2025) likewise revealed insufficient digital infrastructure and technology integration, limiting institutions' capacity to prepare learners for increasingly digitalised automotive workplaces.

The implications for Automotive Air-Conditioning (AAC) training are particularly significant because competency development depends heavily on practical experience with industry-standard equipment. Effective training requires access to computerised diagnostic scanners, refrigerant recovery and recycling machines, electronic leak detection equipment, pressure testing instruments, hybrid and electric vehicle climate-control systems, and simulation technologies that replicate real workplace conditions. Without such facilities, students have limited opportunities to develop the diagnostic, technical, and problem-solving competencies expected by employers.

Overall, the reviewed evidence demonstrates that curriculum reform alone is insufficient to address competency gaps. Sustainable improvement in AAC training requires complementary investment in modern laboratories, smart workshops, digital learning technologies, and industry-standard equipment. Strengthening technological infrastructure should therefore be regarded as a fundamental component of competency-based TVET reform and an essential condition for improving graduate employability.

DISCUSSION

This systematic review demonstrates that competency gaps in Automotive Air-Conditioning (AAC) training within Nigerian Technical and Vocational Education and Training (TVET) institutions are multidimensional and interconnected. The findings indicate that deficiencies in technical competencies, curriculum relevance, training infrastructure, instructor preparedness, and industry engagement collectively contribute to the limited workplace readiness of graduates. The identified competency deficiencies extend beyond theoretical understanding to include practical diagnostic abilities, fault identification, refrigerant management, and the application of modern automotive service technologies.

These findings are consistent with previous studies that reported inadequate occupational competencies among vocational graduates due to limited practical exposure and insufficient alignment between institutional training and workplace expectations (Ujevbe et al., 2020; Kanife et al., 2022). In the context of AAC, these challenges are increasingly significant because contemporary systems require competence in electronic controls, computerised diagnostics, environmental regulations, and hybrid-electric vehicle technologies.

The review further reveals that curriculum limitations represent a major factor contributing to competency deficiencies. Although automotive technologies continue to advance rapidly, many TVET curricula remain focused on conventional mechanical systems and provide limited coverage of emerging technologies. This finding supports previous research emphasising the need for industry-responsive curricula that integrate digital competencies, sustainable practices, and competency-based assessment approaches (Muoghalu & Ahmad, 2025; Egbunefu, 2026). In addition, inadequate training facilities and obsolete equipment were identified as significant barriers to effective AAC competency development.

Practical competence in automotive servicing cannot be achieved through theoretical instruction alone; it requires continuous engagement with industry-relevant tools, diagnostic systems, and workplace simulations. Therefore, infrastructure limitations represent not only a resource challenge but also a direct constraint on the implementation of competency-based TVET.

IMPLICATIONS

Curriculum Implications

The findings indicate the need for comprehensive curriculum reform that moves beyond traditional content-based approaches towards competency-based and industry-responsive education. AAC curricula should incorporate emerging automotive technologies, including electronic climate control systems, computerised diagnostics, hybrid and electric vehicle thermal management, and sustainable refrigerant practices. Furthermore, curriculum revision should integrate digital literacy, problem-solving abilities, environmental awareness, and workplace competencies to ensure graduates possess the skills required in contemporary automotive industries.

Instructional Implications

The findings emphasise the need for a transformation in instructional practices within TVET institutions. Instructors should employ learner-centred strategies, including problem-based learning, simulation-based training, and authentic workplace tasks, to enhance practical competency development. Continuous professional development programmes are also essential to ensure instructors maintain current knowledge of rapidly changing automotive technologies and diagnostic procedures.

Institutional Implications

Institutions must invest in modern workshop facilities and diagnostic equipment. Strengthening partnerships with the automotive industries will also enhance students' exposure to real-life work environments through internships and industrial attachments.

Policy Implications

At the policy level, TVET development strategies should prioritise sustainable funding mechanisms for infrastructure modernisation, instructor development, and technology integration. Regulatory bodies should establish mechanisms for periodic curriculum review, competency standard updates, and stronger collaboration between educational institutions and industry stakeholders. These measures are necessary to ensure that AAC training systems remain responsive to technological advancement and labour market demands.

CONCLUSION

This systematic review demonstrates that competency gaps in Automotive Air-Conditioning (AAC) training within Nigerian Technical and Vocational Education and Training (TVET) institutions are complex and multidimensional, extending beyond technical skill deficiencies to encompass diagnostic capability, curriculum relevance, technological readiness, training capacity, infrastructure, institutional and industry alignment.

These findings indicate that improving AAC training requires a comprehensive reform approach that responds to the evolving demands of the automotive sector. Key priorities include competency-based curriculum reform, continuous enhancement of instructor capabilities, modernisation of training facilities and diagnostic technologies, and stronger engagement between TVET institutions and industry stakeholders.

The review further establishes that these challenges are interconnected rather than isolated, requiring coordinated efforts among policymakers, educators, curriculum developers, and industry partners. Addressing these issues will enhance the alignment between AAC training outcomes and workplace expectations, improve graduates' practical, digital, diagnostic, and occupational competencies, and contribute to the development of a more technically prepared automotive workforce. By synthesising existing evidence, this review provides an informed foundation for curriculum improvement, institutional planning, and future research aimed at strengthening AAC education within Nigerian TVET institutions.

The author declares no conflict of interest.

The data used in this study are derived from published literature and publicly available documents. All sources included in the systematic review are properly cited within the manuscript.

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