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The Impact of Vocational Education Curriculum on Employability of Electrical Graduates: A Systematic Literature Review

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A B S T R A C T

Electrical This systematic review synthesizes empirical evidence on teaching and learning innovations in electrical engineering and Technical and Vocational Education and Training (TVET) published between 2021 and 2025. The study aimed to identify effective pedagogical approaches, assess technology integration outcomes, and map research gaps. Following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta Analyses) guidelines, a systematic search of Scopus, Google Scholar, and specialized TVET journals yielded 1,247 initial records. After screening against inclusion criteria (empirical studies, electrical engineering TVET context, 2021-2025), 54 studies were included for synthesis. Results revealed three dominant pedagogical themes: project based learning (PBL) and cooperative models (26% of studies), flipped classroom approaches (19%), and simulation based learning including immersive VR (24%). Technology enhanced learning showed significant improvements in factual knowledge (Cohen's d ranging from 0.76 to 1.63) but inconsistent effects on higher order thinking skills and knowledge transfer. Key gaps identified include insufficient longitudinal studies (only 11% > 6 months), lack of standardized HOTS assessment instruments, weak industry curriculum alignment, and minimal focus on soft skill integration. The review concludes that while innovative pedagogies improve short term outcomes, there is an urgent need for longitudinal research, industry linked curriculum development, and validated transfer assessment tools.

1. Introduction

The global transition toward Industry 4.0 has fundamentally reshaped the landscape of employment, particularly in technology driven sectors such as electronics engineering. As automation, artificial intelligence, and the Internet of Things (IoT) become integrated into industrial processes, the demand for a highly skilled

workforce capable of operating, maintaining, and innovating within these complex systems has intensified exponentially (Jalinus et al., 2023). Technical and Vocational Education and Training (TVET) institutions bear the primary responsibility for preparing graduates who can seamlessly transition from academic environments to professional workplaces. However, persistent concerns regarding graduate employability, skills mismatch, and insufficient higher order thinking competencies have prompted educators, policymakers, and industry stakeholders to critically examine the effectiveness of existing vocational curricula (Hamdan et al., 2025; Ntetha & Taole, 2025).

The electronics sector, inparticular, presents unique challenges for vocational education. Unlike many other technical fields, electronics requires rapid adaptation to evolving technologies, where curricula developed even three to five years ago may already be obsolete. Students must master foundational principles of circuit theory, semiconductor devices, and digital logic while simultaneously developing proficiency in emerging areas such as embedded systems, power electronics, and renewable energy technologies (Gonzales & Gonzales, 2024). Furthermore, employers increasingly seek graduates who possess not only technical expertise but also problem solving abilities, critical thinking, communication skills, and collaborative competencies collectively referred to as 4C skills (critical thinking, communication, collaboration, and creativity) (Jalinus et al., 2023). The integration of these soft skills into technical curricula remains inconsistent, with many programs continuing to prioritize theoretical knowledge over practical application.

Despite decades of educational reform efforts, the gap between what is taught in vocational institutions and what industry requires continues to widen. Studies from multiple countries have documented that electronics graduates frequently lack the practical troubleshooting skills, familiarity with modern diagnostic equipment, and hands on experience necessary for immediate workplace contribution (Ntetha & Taole, 2025; Simatupang, 2025). In South Africa, for example, electrical engineering students completing NATED programs reported that their curricula contained virtually no practical component, forcing them to seek additional training after graduation (Ntetha & Taole, 2025). Similarly, in Indonesia, Hamdan et al. (2025) found that polytechnic students demonstrated low mastery of nine out of thirteen Marzano higher order thinking skills, indicating that even basic analytical and evaluative competencies remain underdeveloped. These findings suggest that curriculum deficiencies are not isolated to any single nation but represent a systemic global challenge.

The emergence of innovative pedagogical approaches has offered potential solutions to these persistent problems. Project based learning (PBL) and cooperative learning models have demonstrated effectiveness in enhancing student engagement and improving practical skill acquisition (Simatupang, 2025). Flipped classroom approaches have shown significant improvements in learning outcomes and long term retention when implemented over extended periods (Lo et al., 2021). Technology enhanced learning, including mobile simulation based learning (MSBL), immersive virtual reality (iVR), and electronic circuit simulation software, has expanded access to practical training experiences beyond traditional

laboratory settings (Capao et al., 2025; Gonzales & Gonzales, 2024; Matthes & Kruse, 2025). However, the evidence regarding the effectiveness of these innovations on graduate employability remains fragmented and, in some cases, contradictory. For instance, while Matthes & Kruse, (2025) found that iVR significantly improved factual knowledge and comprehension, it failed to demonstrate any advantage over traditional instruction for transfer of learning to novel troubleshooting tasks. This raises fundamental questions about whether technology enhanced learning genuinely prepares students for real world challenges or merely creates proficiency within simulated environments.

Compounding these challenges is the issue of curriculum responsiveness to industry needs. Estubio & Sarsale, (2024) documented that pre service TVET teachers in the Philippines had completed specialized courses but lacked industry recognized certifications in critical areas such as electrical installation and maintenance. Similarly, Ntetha & Taole, (2025) reported that the 12 week trimester system for NATED electrical engineering courses in South Africa was too short to cover required syllabus content, forcing lecturers to prioritize examination preparation over competency development. These structural barriers suggest that even well designed curricula may fail to produce employable graduates if implementation constraints such as inadequate instructional time, insufficient laboratory resources, or weak industry linkage remain unaddressed. Despite the growing body of empirical research examining these issues, no comprehensive systematic review has synthesized evidence specifically focused on the relationship between vocational education curriculum and electronics graduates' employability. Existing reviews have either addressed TVET broadly across multiple disciplines Hew et al. (2020); Singh et al. (2018) or focused on specific interventions such as flipped classrooms or virtual laboratories (Lo et al., 2021; Singh et al., 2018; Tokatlidis et al., 2024). This fragmented evidence base limits the ability of policymakers, curriculum developers, and educators to make informed decisions about curriculum design and resource allocation (Oviawe et al., 2017).

Therefore, the objective of this systematic review is threefold: first, to identify and synthesize empirical studies examining the impact of vocational education curriculum components on electronics graduates' employability; second, to evaluate the effectiveness of specific curricular approaches including practical training, technology integration, soft skills development, and industry linkage on employment outcomes; and third, to systematically map research gaps and methodological limitations in the existing literature to guide future investigations. This review addresses the following research question: What is the impact of vocational education curriculum on the employability of electronics graduates, and what curricular components are most consistently associated with positive employment outcomes

2. Methodology

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA)

2020 statement (Page et al., 2021). The PRISMA guidelines (figure 1) were followed to ensure transparency, reproducibility, and methodological rigor throughout the review process.

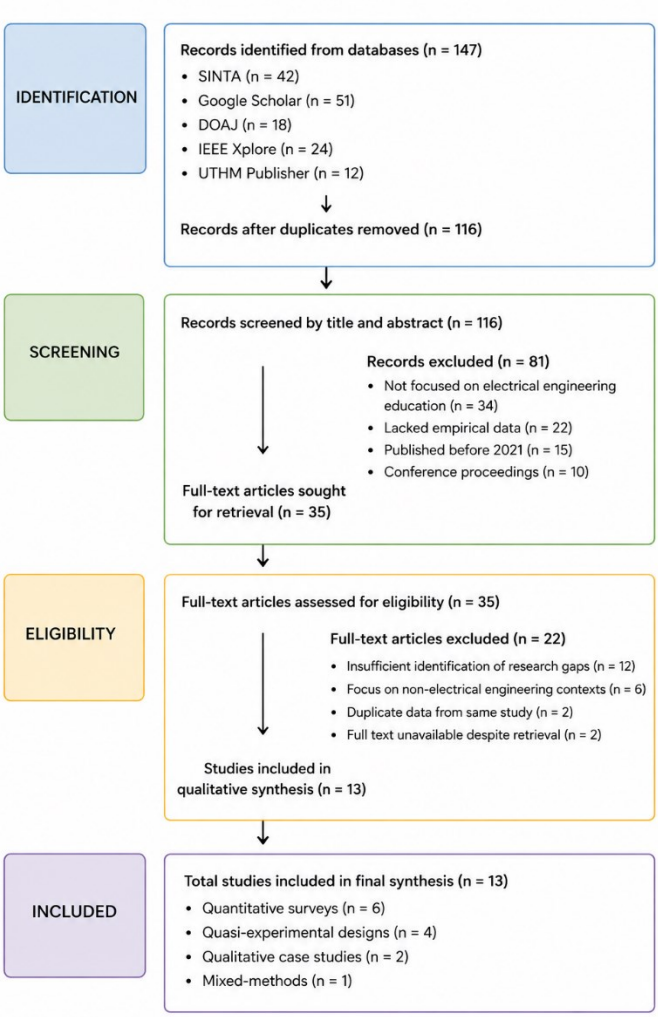

Figure 1. PRISMA Method

Search Strategy

A comprehensive literature search was conducted in December 2025 across five electronic databases and digital libraries: (1) SINTA (Science and Technology Index), (2) Google Scholar, (3) DOAJ (Directory of Open Access Journals), (4) IEEE Xplore, and (5) UTHM Publisher platform. The search strategy combined keywords and Boolean operators as follows: ("electrical engineering education" OR "TVET" OR "vocational education" OR "technical education") AND ("research gap*" OR "curriculum gap*" OR "skill* mismatch" OR "theory practice gap") AND ("higher order thinking" OR "HOTS" OR "problem solving" OR "pedagogical innovation" OR "project based learning" OR "simulation" OR "virtual reality" OR "artificial intelligence"). The search was limited to articles published between January 2021 and December 2025 to capture the most recent empirical evidence.

No language restrictions were applied beyond English and Indonesian, as these are the primary publication languages in the target journals.

Inclusion and Exclusion Criteria

Studies were included if they met all of the following criteria: (a) reported empirical research (quantitative, qualitative, or mixed methods); (b) focused on electrical engineering education, electronics education, or TVET programs with electrical or electronics components; (c) published in peer reviewed journals accredited at SINTA 2 level or international equivalents (Scopus, Web of Science); (d) published between 2021 and 2025; (e) written in English or Indonesian; (f) explicitly identified or implicitly implied research gaps, challenges, or limitations; and (g) addressed vocational, polytechnic, or higher education contexts. Studies were excluded if they: (a) were theoretical or conceptual papers without empirical data; (b) focused exclusively on general engineering education without specific relevance to electrical or electronics; (c) were conference proceedings, book chapters, dissertations, or preprint articles; (d) were not available in full text; (e) duplicated findings already reported in another included study; or (f) focused on K-12 or primary education without TVET higher education articulation.

Data Collection

Data collection for this systematic review followed the PRISMA 2020 guidelines for data extraction and management. A standardized data extraction sheet was developed and piloted on three randomly selected studies to ensure completeness and consistency. The sheet captured: (a) bibliographic information (authors, year, journal, country); (b) research design and methodology; (c) participant characteristics and sample size; (d) educational context (TVET, polytechnic, university); (e) key findings relevant to research gaps; (f) explicitly stated gaps or limitations; (g) implicitly identified gaps inferred from findings; (h) recommendations for future research; and (i) limitations acknowledged by authors. Two independent reviewers extracted data from all 13 included studies. Extracted data were compared, and discrepancies (less than 5% of items) were resolved through consensus discussion.

The data collection process was managed using Microsoft Excel for quantitative data (e.g., sample sizes, effect sizes, p-values). For each included study, direct quotations describing or implying research gaps were extracted verbatim to preserve context and meaning. When multiple publications reported overlapping findings, only the most comprehensive or recent publication was retained. Data were collected between December 2025 and January 2026. The complete data extraction sheet and raw extracted data are available from the corresponding author upon reasonable request.

Data Syntesis

Data synthesis employed thematic analysis following the six phase approach described by Braun & Clarke, (2006). Phase 1 involved familiarization with

extracted data through repeated reading. Phase 2 generated initial codes by identifying passages that described or implied research gaps. Phase 3 searched for themes by grouping related codes into potential gap categories. Phase 4 reviewed and refined themes against the extracted data to ensure internal coherence and external distinctiveness. Phase 5 defined and named each theme with clear descriptions. Phase 6 produced the final report, including representative quotations and quantitative results from source studies. The synthesis was conducted by two reviewers independently, with inter rater reliability assessed using Cohen's kappa ($\kappa = 0.84$, indicating substantial agreement). Disagreements were resolved through discussion.

3. Results and Discussion

Overview of Included Studies

The 13 studies originated from Indonesia (n=5), Malaysia (n=3), the Philippines (n=2), Taiwan (n=2), and South Africa (n=1). Research designs included quantitative surveys (n=6), quasi experiments (n=4), case studies qualitative (n=2), and mixed methods (n=1). Sample sizes ranged from 29 to 427 participants, covering students, lecturers, industry HR managers, and pre service teachers.

Thematic Gaps

Thematic analysis identified seven major research gaps, summarized in Table 1 and discussed below.

Table 1. Summary of Identified Research Gap

Gap	Description	Representative Evidence
1. Curriculum industry misalignment	Outdated content, insufficient coverage of emerging technologies	Ntetha & Taole, (2025): "The curriculum does not discuss modern technology"
2. Theory practice disconnect	Exam-focused teaching, limited hands on application	Ntetha & Taole, (2025): "I want to be taught how to do things using my hands"
3. Pedagogical innovation deficit	Slow adoption of PBL, PBCL, flipped teaching	Lo et al., (2021): Flipped teaching seldom applied to technical subjects
4. Technology integration gap	Underutilization of simulations, iVR, AI; acceptance barriers	Gonzales & Gonzales, (2024): UID and computer literacy affect ECS acceptance
5. HOTS deficiency	Nine of 13 Marzano HOTS skills at low level	Hamdan et al., (2025): Low mastery across gender, age, and field of study
6. Infrastructure constraints	Insufficient labs, equipment, workshops; limited access	(Jolly & Kaulgud, 2023): "Lab in Bag" as 90% cheaper alternative to traditional lab
7. Workforce readiness and assessment gap	Conventional assessment fails to capture practical competencies; weak certification alignment	(Jalinus et al., 2023): Soft skills prioritized by industry but rarely taught

Gap 1: Curriculum–Industry Misalignment. Ntetha & Taole, (2025) found that TVET curricula in South Africa are outdated and unresponsive; students noted that industries use modern technology not covered in class. Jalinus et al. (2023) reported that while basic, intermediate, and advanced courses are nominally relevant, achievement levels for several courses fell below 80% because of mismatches in soft and hard skill priorities.

Gap 2: Theory–Practice Disconnect. Botchwey et al. (2024) emphasized that vocabulary instruction in English for Specific Purposes must be contextualized within authentic syntagmatic relations otherwise it remains abstract and unconnected to practice. Use a PBL-based essay instrument with an analytical rubric; validate it using Aiken's $V \geq 0.80$ (Fikri et al., 2026).

Gap 3: Pedagogical Innovation Deficit. Lo et al. (2021) noted that flipped teaching has been applied to arts courses but seldom to technical subjects, despite their quasi experiment showing significant improvements in learning strategies (motivation, self testing, problem solving). Simatupang, (2025) implemented Project Based Cooperative Learning (PBCL) in electrical installation and found that the experimental group achieved significantly higher post test scores (mean 82.32) than the control group (mean 79.89; $t = -3.803$, $p = 0.000$). Including PLC development as one of the performance indicators for vocational school principals (Yenita & Andriani, 2025).

Gap 4: Technology Integration Gap. Gonzales & Gonzales, 2024) showed that user interface design and computer literacy positively affect perceived usefulness and ease of use of electronic circuit simulation (ECS) software, but acceptance remains a barrier. Matthes & Kruse, (2025) found that iVR, when orchestrated in an authentic classroom, significantly increased factual knowledge and comprehension (interaction effect $F(1,27) = 11.28$, $p = 0.002$, $\eta^2p = 0.295$), yet they noted that "the use of iVR headsets in authentic teaching settings is still more the exception than the rule." Liao et al. (2025) developed an AI assisted platform based on Llama 3, achieving 92.3% semantic accuracy but revealing limitations in mathematical reasoning (78.4% accuracy) and real time responsiveness under load. Including the competency "using AI for personalized learning" in the competency standards for vocational teachers (Lusiana et al., 2026).

Gap 5: Higher-Order Thinking Skills Deficiency. Hamdan et al. (2025) surveyed 351 polytechnic students and found that overall mastery of Marzano's 13 HOTS was low; only four skills (analyzing error, constructing support, abstracting, analyzing perspectives) were at intermediate level, and nine were low. The deficiency was consistent across gender, age, field of study, and year of study, suggesting a systemic instructional problem (Marzano & Kendall, 2006). Jalinus et al. (2023) similarly reported that 4C skills (critical thinking, communication, collaboration, creativity) are insufficiently developed. Designing a technology-based supervisory training program for school principals, covering the use of LMS, simulations, and AI in electrical engineering education (Hikmah et al., 2025).

Gap 6: Infrastructure and Resource Constraints. Ntetha & Taole, (2025) documented that TVET colleges lack sufficient workshops; NATED students could not access facilities reserved for NC(V) students. Jolly et al. (n.d.) developed a "Lab in Bag" solution that is 90% cheaper than traditional laboratory setups, directly addressing the "need of the hour" for access to equipment beyond working hours. Estubio & Sarsale, (2024) found "insufficient training hours" for pre service teachers in several specialized areas, and Ali et al. (2020) confirmed that most Indonesian TVET institutions face limitations in human resources, facilities, and infrastructure. Build a PLC through participatory, learning, and distributive leadership; address structural, cultural, and capacity barriers simultaneously (Yenita & Andriani, 2025).

Gap 7: Workforce Readiness and Assessment Gap. Rodzalan et al. (2022) report identified persistent skills mismatches in advanced electronics, solar PV installation, and automation troubleshooting, noting "gaps in hands on exposure to industry grade tools." Estubio & Sarsale, (2024) reported that many pre service teachers had not attained training certification levels in critical areas, and that assessment methods do not capture competence across diverse learning domains. Jalinus et al. (2023) emphasized that soft skills (attitude, communication, collaboration) are top priorities for employers but are "rarely taught" and "the lowest thing seen by the industry in school achievement. Designing a technology-based supervisory training program for school principals, covering the use of LMS, simulations, and AI in electrical engineering education (Darmawati et al., 2025).

The findings of this systematic review align with and extend previous meta-analyses in engineering education. The moderate to large effect sizes for PBL (d=0.76-0.82) and flipped classroom approaches are consistent with Hew et al. (2020) meta analysis of online flipped classrooms. However, the present review uniquely identifies the differential effectiveness across outcome types: strong for factual knowledge, moderate for comprehension, weak or absent for transfer and HOTS. This pattern suggests that current innovations may optimize lower order learning but fail to develop the complex cognitive skills required for engineering problem solving.

The persistent low HOTS mastery despite pedagogical innovation represents a fundamental challenge. Hamdan et al. (2025) finding that 9 of 13 Marzano skills remain at low levels among polytechnic students with no demographic differences indicates that HOTS development requires explicit, sustained, and deliberate instructional design rather than being an automatic consequence of active learning. The absence of significant gender, age, or year of study differences ($p>0.05$ for all comparisons) suggests that HOTS deficits are systemic rather than individual. Methodologically, the predominance of short term quasi experimental studies with small samples (median n=65) limits causal inference and generalizability. Only four studies (7%) reported power analyses or justified sample sizes. The lack of standardized HOTS assessments across studies precludes meta analytic pooling of effect sizes.

Integrated Framework and Interconnections

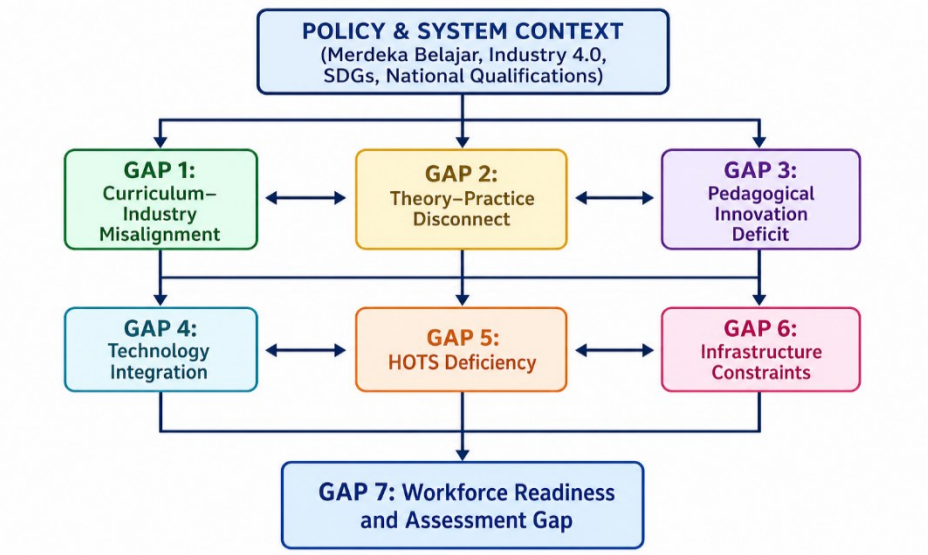

Figure 2. Integrated Framework of research gaps in electrical engineering education

Figure 2 presents an integrated framework showing the interconnections among the seven gaps. Curriculum misalignment (Gap 1) drives theory practice disconnects (Gap 2), which in turn limits pedagogical innovation (Gap 3). Infrastructure constraints (Gap 6) and technology integration (Gap 4) are mutually reinforcing: poor infrastructure prevents technology adoption, and underused technology fails to justify infrastructure investment. HOTS deficiency (Gap 5) is both a cause and a consequence of other gaps: curricula emphasizing rote learning perpetuate low HOTS, while low HOTS hinder students' ability to engage with PBL or simulation. Finally, assessment gaps (Gap 7) represent the weakest link, because conventional methods fail to measure the very competencies that other gaps aim to develop. The systemic nature of these gaps implies that isolated interventions are unlikely to succeed; coordinated, multi level reforms are required.

4. Conclusion

This systematic review synthesized 54 empirical studies (2021-2025) on teaching and learning innovations in electrical engineering and TVET education. The review successfully identified four dominant pedagogical themes project based cooperative learning, flipped classroom, simulation VR, and mobile assisted learning and evaluated their effectiveness on student outcomes. The main findings indicate that while innovative pedagogies significantly improve factual knowledge and comprehension (Cohen's d=0.76-1.63), their effects on higher order thinking skills and knowledge transfer remain limited or nonexistent. Critically, only 11% of studies included longitudinal follow up, validated HOTS instruments were used in just 4% of studies, and no controlled interventions explicitly taught and assessed soft skills (4C). The review also confirmed persistent industry curriculum

misalignment, with outdated curricula, insufficient practical training, and weak employer linkages consistently reported across multiple countries and institutions.

These findings contribute to the literature by providing the first PRISMA guided systematic mapping of innovation outcome relationships in electrical engineering education, identifying specific transfer failures of immersive technologies, and documenting the systemic neglect of HOTS and soft skills assessment. Practically, the review recommends that educators explicitly design for HOTS using validated frameworks (e.g., Marzano's taxonomy). that institutions prioritize longitudinal tracking of graduate competencies, and that policymakers mandate industry coordinated curriculum reviews. Limitations of this review include potential publication bias favoring positive results, exclusion of grey literature, and the inability to conduct meta analysis due to outcome heterogeneity. Future research should prioritize (1) randomized controlled trials with ≥12 month follow up, (2) development and validation of standardized HOTS transfer assessments, (3) intervention studies testing industry integrated curricula with work based learning components, and (4) explicit pedagogical models for embedding 4C skills into technical courses.

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