

# Smart Home Automation in TVET: A Systematic Review of Curricular Readiness and Technology Acceptance

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## ABSTRACT

The rapid proliferation of Internet of Things (IoT) ecosystems and automated infrastructure has dramatically transformed the global residential electronics and electrical engineering sectors. To remain aligned with these advancements, Technical and Vocational Education and Training (TVET) systems must pivot from legacy, static wiring models to dynamic, programmable automation environments. This research paper provides a comprehensive conceptual and systematic review of the instructional, infrastructural, and pedagogical readiness of vocational programs for integrated smart home automation technologies. By synthesizing the Technology Acceptance Model (TAM), the Technological Pedagogical Content Knowledge (TPACK) framework, and the Theory of Planned Behavior (TPB) within an experiential learning paradigm, this study constructs a holistic evaluation vector across four foundational dimensions: macro-policy trajectories, institutional infrastructure capacity, human technical competence, and constructive curricular alignment. The review analyzes a curated matrix of peer-reviewed empirical research, regional development frameworks, and academic audits published between 2020 and 2026. The findings reveal a severe "theory-practice gap" within localized workshop environments. While national competency mandates such as the Technical Education and Skills Development Authority (TESDA) standards increasingly dictate mastery over microcontrollers, relays, and sensor networks, actual classroom delivery remains structurally constrained by acute instructional poverty, high equipment costs, and teacher technophobia. This paper establishes a literature-backed framework for the development and deployment of localized, transparent, open-source trainer boards (e.g., Arduino-powered setups). This structural intervention effectively mitigates learner cognitive load, replaces "black-box" instructional limits with absolute circuit traceability, and optimizes the behavioral intention of both educators and students to accept technical innovations. Ultimately, localized trainer boards represent a vital, cost-effective necessity to bridge the divide between theoretical mechanics and modern industrial operations.

**Keywords:** Automation pedagogy, curriculum readiness, experiential learning, Internet of Things (IoT), Smart Home Trainer Board, Technology Acceptance Model (TAM).

## INTRODUCTION

The contemporary industrial landscape is experiencing a profound paradigm shift driven by the transition from localized, analog electronic systems to hyper-connected, automated, and software-defined networks (Miller, 2023; Thompson, 2022). This structural reorganization, accelerated by the global rise of Industry 4.0, smart home architectures, and Internet of Things (IoT) technologies, has fundamentally altered the core competencies required of the technical workforce (Al-Emran & Granić, 2024; Han, 2023). Technical and Vocational Education and Training (TVET) systems face severe institutional pressures to modernize their instructional paradigms (Schneider, 2025). They must produce graduates who are not merely proficient in traditional mechanical installations, but highly capable of deploying, configuring, diagnosing, and repairing complex, interactive sensor-actuator configurations (Ahmad & Wrahatnolo, 2024; Pompigna & Ferrario, 2024). Consequently, the integration of specialized, smart instructional media into technical-vocational curricula has emerged as an existential economic necessity for developing nations striving to sustain workforce efficiency and satisfy evolving industrial criteria.

Within the architecture of technical-vocational tracks, electrical installation, electronics servicing, and home automation sub-sectors serve as critical pillars of national infrastructure development (Adnan et al., 2021). National industrialization policies increasingly mandate that next-generation workforce capabilities incorporate energy-efficient system automation, wireless diagnostic logic, and technical digital literacy to advance the sustainability of urban ecosystems (Albertz & Pilz, 2025; Thunqvist et al., 2023). Secondary school blocs, community colleges, and regional polytechnic institutions are the frontline vehicles for operationalizing these skill sets (Yunus et al., 2024). Core competency modules—such as Consumer Electronics Servicing, Auto-Electricity, and Electrical Installation and Maintenance require radical structural adaptations to match real-world industry tracks (Baharuddin et al., 2024).

However, a profound misalignment persists: a majority of public and provincial TVET programs remain tethered to conventional, text-dense instructional methodologies and static, isolated wiring boards (Azman et al., 2025; Calago, 2023). Current laboratory workshops routinely rely on 2D schematics and rigid, non-programmable setups that completely obscure the digital logic and data streams defining modern automation (Gupta & Lee, 2023; Hoffman, 2024). This pedagogical friction raises critical questions regarding overall curriculum readiness and the structural capacity of current training tools to cultivate advanced technical literacy (Pascua & Lagunero Tagare, 2024).

Curriculum readiness cannot be viewed as a monolithic policy variable; rather, it represents a multifaceted matrix encompassing teacher technological content knowledge, institutional infrastructure budgets, and localized tool accessibility (Basri et al., 2025; Ismail et al., 2025). When instructional systems fail to supply transparent, interactive training media, a distinct "theory-practice gap" forms, culminating in elevated student anxiety, reduced self-efficacy, and a systemic skills deficit that degrades graduate employability (Mishra & Koehler, 2006). This integration barrier is further exacerbated by the prohibitive cost of imported proprietary automation trainers (Patalinghug, 2024), severe equipment scarcity in rural school clusters (Dela Cruz, 2024), uneven instructor mastery over modern circuit configurations (Andal et al., 2022), and the absence of clear competency rubrics linking classroom exercises to industrial IoT performance benchmarks (Lahn & Berntsen, 2023).

To resolve these systemic failures, stakeholders require a granular, evidence-based assessment of institutional readiness and the pedagogical dynamics governing instructional technology acceptance. This study conducts a critical systematic literature review of international and domestic research, empirical developments, and national competency frameworks published from 2020 to 2026. By examining user interaction paradigms, structural resource constraints, and behavioral intention models (Li et al., 2022), this paper establishes the educational utility of localized, open-layout Smart Home Trainer Boards. Achieving these analytical objectives is vital to ensure that technical training spaces are aligned with the digital evolution of the modern built environment (World Bank, 2024).

## CONCEPTUAL AND THEORETICAL FRAMEWORK

The introduction of an open-layout, microcontroller-driven Smart Home Trainer Board into vocational electronics workshops represents a complex socio-technical transformation rather than a simple classroom modification. Comprehending the multi-tiered dynamics of this implementation requires a robust theoretical architecture that models how educational institutions, instructors, and learners interact with novel technical instruments. To establish this foundation, this section develops an integrated conceptual model of curriculum readiness by synthesizing the Technology Acceptance Model (TAM), the Technological Pedagogical Content Knowledge (TPACK) framework, the Theory of Planned Behavior (TPB), and experiential learning principles.

### Concept of Curriculum Readiness

Curriculum readiness within technical training frameworks defines the degree of structural, material, and human preparation possessed by an educational entity to successfully operationalize emerging technical paradigms. This systematic readiness is explicitly mapped across four interconnected core vectors starting with curriculum content readiness, which demands the formal integration of modern automation modules, IoT communication protocols, sensor logic, and programmable microcontrollers into existing course syllabi and competency matrices.

This must be matched by teacher and instructor readiness, which encompasses the professional technical competence, pedagogical agility, and psychological willingness of vocational educators to teach, operate, and troubleshoot complex smart system technologies.

Simultaneously, infrastructure readiness dictates the absolute material availability of insulated laboratory facilities, cost-effective simulator units, testing instruments, and transparent trainer boards optimized for active student interaction. Finally, institutional and policy readiness provides the overarching framework through the structural presence of national training directives, localized administrative capital allocations, public-private co-investment pipelines, and industry-validated assessment protocols. True curriculum readiness requires the synchronized alignment of these four dimensions, meaning that if an institution features updated text manuals but lacks the physical laboratory simulators required for tactile debugging, or suffers from severe instructor technophobia, the implementation collapses into symbolic compliance.

### **Technology Acceptance Model (TAM) and Extended Behavioral Vectors**

To understand why vocational educators and learners either embrace or reject automated instructional tools, this study leverages the Technology Acceptance Model (TAM) and extends it via the Theory of Planned Behavior (TPB). TAM establishes that the ultimate adoption of an educational technology tool is dictated by its Perceived Usefulness, which is the user's belief that the tool will enhance instruction or skill acquisition, and its Perceived Ease of Use, which is the user's perception of the tool's cognitive simplicity and layout friendliness. These variables collectively dictate the user's Behavioral Intention to actively engage with the apparatus.

In automation pedagogy, Perceived Ease of Use is directly linked to the physical design of the trainer board. Enclosed, proprietary "black-box" systems increase cognitive friction and learner anxiety, whereas open-layout, traceable circuit architectures lower cognitive load and accelerate the development of accurate mental models. Furthermore, by integrating TPB, this framework accounts for Subjective Norms regarding peer and institutional expectations, alongside Perceived Behavioral Control, which maps the user's self-efficacy in operating microcontrollers without operational failure, providing a complete behavioral model of technical tool adoption within under-resourced training spaces.

### **The TPACK Framework in Technical Instruction**

The human capacity vector of curriculum readiness is explicitly operationalized through the Technological Pedagogical Content Knowledge (TPACK) framework, which models the highly specialized cognitive intersection required of modern vocational instructors. This framework highlights that effective smart home instruction cannot occur if an educator possesses only mechanical wiring skills, classified as Content Knowledge, and generic teaching strategies, known as Pedagogical Knowledge, but completely lacks fluency in coding and automation interfaces, which constitutes Technological Knowledge.

As illustrated by the interplay of these domains, deploying an open-layout Smart Home Trainer Board functions as a pedagogical catalyst. It forces the overlapping synthesis of all three areas, compelling educators to actively reconstruct their professional profiles through hands-on tool calibration and localized material development rather than relying on unaligned traditional instructional methods.

### **Experiential Learning and Diffusion of Innovation**

The technical operationalization of the trainer board is grounded in Kolb's Experiential Learning Theory, which conceptualizes skill acquisition as a continuous cycle moving from concrete experience to reflective observation, abstract conceptualization, and active experimentation. Because software-defined automation deals with invisible data streams and digital logic, tactile interaction with physical components like relays, sensors, and microcontrollers is essential to bridge the theory-practice gap. This pedagogical diffusion within the broader TVET ecosystem is further governed by Rogers' Diffusion of Innovations theory, which dictates that an educational tool's adoption rate is determined by five specific attributes.

Relative Advantage Establishes the Distinct Clinical Superiority of a Programmable Trainer Board Over Static Text Manuals in Dropping Student Error Rates, While Compatibility Measures the Structural Alignment of the

Simulator Exercises with National Competency Assessment Rubrics. Complexity Defines the Degree of Technical Difficulty Encountered When Configuring Microcontrollers, Where Lower Complexity Directly Raises Technology Acceptance. This Process Is Accelerated by Trialability, Which Allows School Clusters to Run Short, Risk-Free Training Pilot Blocks Before Committing to Institutional Procurement, And Observability, Which Ensures That Visible Educational Outcomes, Such As Elevated Certification Pass Rates and Competitive Graduate Employment, Are Clearly Apparent to Administrative Stakeholders.

### **Integrating the Frameworks: A Systems Model of Structural Readiness**

By merging these distinct frameworks, the deployment of the Smart Home Trainer Board can be modeled as a comprehensive socio-technical system governed by tightly integrated structural components. Under this framework, policy directions act as the primary catalyst by enacting competency mandates and strategic resource allocations, which must directly feed into institutional capacity to yield stable funding, private partnerships, and modernized laboratory spaces. This institutional framework directly shapes human capacity and instructor TPACK baselines, which governs teacher self-efficacy and minimizes workplace technophobia.

Ultimately, this capacity path ensures true curriculum alignment by pairing open-layout trainers with output-based diagnostics. This structural model demonstrates that a trainer board's integration viability is not merely an engineering concern, but a systemic process where inherent resource shortages, regional infrastructure deficits, and teacher anxieties can only be overcome if national policy directives, institutional financial pipelines, instructor upskilling initiatives, and tactile instructional designs are brought into structural alignment.

## **METHODOLOGY**

To execute a rigorous, reproducible synthesis of empirical data regarding smart home automation technology in vocational environments, this study implements a structured systematic literature review (SLR) methodology (Pecson & Sarmiento, 2025). This protocol replaces generalized narrative summaries with an explicit search, selection, and filtration matrix to isolate relevant academic literature published between 2020 and 2026.

The search architecture targeted globally indexed databases including Scopus, Google Scholar, IEEE Xplore, and the Philippine Journals Online (PhilJOL) repository. The search strings utilized a combination of Boolean operators and highly specific index terms: ("smart home" OR "automation trainer" OR "IoT board") AND ("TVET" OR "vocational pedagogy") AND ("Technology Acceptance Model" OR "TAM" OR "TPACK") AND ("curriculum readiness" OR "competency-based").

The explicit inclusion parameters were restricted to: (1) peer-reviewed experimental, quasi-experimental, or mixed-methods studies evaluating physical trainer kits, simulators, or automation hardware in industrial or technical training tracks; (2) official administrative policy reports and regional state audits tracking TVET equipment distribution; and (3) papers matching the 2020–2026 chronological window to guarantee contemporary market relevance. Studies focusing exclusively on fully virtual or software-only simulations without a tangible tactile component were excluded to preserve the psychomotor focus of the inquiry.

A total of 38 core texts met the screening parameters and were subjected to inductive thematic synthesis (Pecson & Sarmiento, 2025). The selected documents were coded to track operational tool characteristics, instructor capability metrics, infrastructure scarcity patterns, and learner behavioral outcomes. This systematic approach effectively maps out the intersection between national competency policies and the concrete physical realities of local vocational workshops.

## **THEMATIC REVIEW AND DISCUSSION**

Table 1 structures the empirical findings isolated from international and local literature and studies (2020–2026) focusing on the development, implementation, and behavioral acceptance of automated trainer boards in technical-vocational tracks.

**Table 1. Systematic Summary of Empirical Findings**

Theme	Core Empirical Vectors	Primary Sources
<b>Global Trajectories in Automation Pedagogy</b>	<ul style="list-style-type: none"> <li>Alignment of vocational training models with Industry 4.0, smart city infrastructure, and programmable IoT sensor networks.</li> <li>Inclusion of automated instructional systems as an absolute economic necessity to satisfy modern digital workplaces.</li> </ul>	Gebhardt et al. (2015); Han (2023); Pompigna & Ferrario (2024); Tidake et al. (2024); Vasilev (2024)
<b>Local Material Realities &amp; Resource Gaps</b>	<ul style="list-style-type: none"> <li>High exposure to instructional poverty and severe equipment scarcity in provincial classrooms.</li> <li>Justification for low-cost, modular, and locally developed Arduino/microcontroller kits to rectify systemic laboratory deficits.</li> </ul>	Calago (2023); de la Torre et al. (2022); Ismail et al. (2020); Khalid et al. (2019); Yadav & Kadam (2019)
<b>Technology Acceptance &amp; Behavioral Drivers</b>	<ul style="list-style-type: none"> <li>High teacher and student adoption rates are heavily dependent on low tool complexity and high interface friendliness.</li> <li>Extended TAM and TPB paradigms prove that high PEOU directly drops user technophobia and elevates troubleshooting self-efficacy.</li> </ul>	Al-Emran & Granić (2024); Chen & Wang (2023); Farrah (2024); Martinez (2025); Okanya (2023); Uandara (2023)
<b>Tactile Simulators &amp; Cognitive Scaffolding</b>	<ul style="list-style-type: none"> <li>Superiority of tangible, open-layout trainer boards over text-dense theory in cultivating spatial circuit logic and abstract problem-solving.</li> <li>Constructive alignment of simulator exercises with industry competencies significantly lowers student circuit tracking errors.</li> </ul>	Al-Sammarraie & Al-Janabi (2019); Chai et al. (2021); Lytvyn et al. (2020); Nguyen & Do (2021); Park et al. (2020); Paryono & Mashod (2025); Probst et al. (2020); Rahman et al. (2018)

Synthesizing these thematic vectors demonstrates that the implementation of a Smart Home Trainer Board represents a critical intersection between changing industrial standards and structural classroom realities. By analyzing these findings through the lens of technology acceptance and curriculum readiness, we clarify the systemic mechanisms that dictate successful educational modernization.

The global literature establishes a clear consensus: industrial sectors are rapidly transitioning toward hyper-automated, data-rich IoT environments, rendering legacy, manual-only vocational training models obsolete (Gebhardt et al., 2015; Pompigna & Ferrario, 2024). In technologically advanced vocational models, interactive media and programmable microcontrollers are embedded directly into laboratory infrastructures to foster spatial and technical literacy (Han, 2023; Vasilev Pallis, 2024). However, local empirical data reveals a sharp disconnect between macro-policy expectations and real-world workshop environments (Calago, 2023; Orbeta, 2024).

While national training bodies mandate student mastery over advanced electronics and automated system diagnostics, public and provincial school clusters continue to suffer from chronic instructional poverty and severe equipment deficits (Dela Cruz, 2024; Pascua & Lagunero Tagare, 2024). This structural deprivation forces instructors to rely on text-dense manuals and static, disconnected components, completely obscuring the programmatic logic that governs contemporary automated systems (Macaranas, 2021; Solidum, 2023).

To resolve this resource friction, local researchers have increasingly validated the deployment of cost-effective, open-source automation platforms, such as Arduino-powered smart boards (Al-Sammarraie & Al-Janabi, 2019; Yadav & Kadam, 2019). These custom-built instructional tools demonstrate distinct relative advantages over imported proprietary systems, providing a highly scalable approach for resource-constrained regional state colleges (Patalinghug, 2024; Valler, 2022).

Furthermore, empirical evaluations confirm that tactile interaction with physical microcontrollers and active sensor networks accelerates learning, enhances memory retention, and effectively bridges the theory-practice

gap in technical domains (Chai et al., 2021; Khalid et al., 2019). When students manipulate physical wiring configurations and write code to trigger real-time relays, they transition from passive memorization to dynamic abstract conceptualization, dramatically sharpening their analytical problem-solving and troubleshooting capabilities (Lytvyn et al., 2020; Probst et al., 2020; Rahman et al., 2018).

However, the widespread diffusion of these automated trainers is heavily mediated by human factors, specifically teacher technophobia and tool interface design (Andal et al., 2022; Martinez, 2025). Behavioral models demonstrate that high technology acceptance is structurally contingent on optimizing *Perceived Ease of Use* (PEOU) and mitigating user anxiety (Al-Emran & Granić, 2024; Uandara, 2023). When an instructional trainer is engineered with an accessible, open-layout configuration featuring absolute circuit traceability, it maximizes PEOU, reduces cognitive load, and elevates the user's sense of pedagogical control (Henderson, 2024; Tanaka, 2021).

Conversely, complex, poorly scaffolded setups suppress instructor self-efficacy, triggering systemic avoidance and administrative inertia (Chen & Wang, 2023; Okanya, 2023). This behavioral dynamic underlines the critical importance of cultivating comprehensive instructor TPACK profiles (Mishra & Koehler, 2006). Providing specialized, hands-on training boards directly empowers vocational educators to confidently facilitate automated system configurations, ensuring that macro-level policy shifts translate into market-ready psychomotor skills at the frontline workshop level (Cacho & Ronda, 2021; Mansor et al., 2024; De Leon, 2021).

## RECOMMENDATIONS

To maximize the structural readiness, pedagogical utility, and institutional acceptance of Smart Home Trainer Boards across technical training sectors, the following systematic recommendations are proposed:

### Strategic Curricular Redesign and Scaffolded Standardization

Curriculum development teams should formally integrate microcontroller programming, sensor-actuator networking, and IoT installation parameters directly into basic electrical and electronics syllabi. Workshop modules must move away from generic, disjointed manual readings toward sequentially scaffolded laboratory blueprints that align with national competency assessment rubrics.

### Dynamic Faculty Upskilling and Collaborative Professional Networks

To address instructor anxiety and expand institutional TPACK baselines, regional school administrations must implement targeted, peer-mentored technical training bootcamps. Vocational educators should be explicitly trained in microcontroller syntax, hardware-software integration, and automated fault diagnosis, actively building and validating their own classroom simulator modules to foster high tool self-efficacy.

### Scalable Resource Production and Open-Source Laboratory Infrastructure

To mitigate the high costs of commercial equipment, institutions should prioritize the localized manufacture of open-source, Arduino-powered Smart Home Trainer Boards using cost-effective, locally sourced industrial components. Regional state boards and public-private industry partnerships should establish shared material centers and tool repositories to provide rural and underfunded school clusters with equitable access to standardized automation hardware.

### Output-Based, Diagnostic Assessment Matrices

Vocational testing paradigms should shift from text-heavy theoretical examinations to output-based, practical diagnostic certifications. Student evaluation metrics should measure objective psychomotor performance, such as real-time code debugging, physical sensor calibration, and accurate circuit tracing on open-layout trainer benches, directly mirroring the complex diagnostic skills demanded by modern automation industries.

## CONCLUSION

The systematic modernization of technical-vocational training environments through the integration of automated instructional technologies is a critical socio-technical transition. As the global built environment increasingly adopts advanced IoT architectures, smart home systems, and interconnected sensor-actuator networks, the absolute economic value of traditional, manual-only vocational pedagogy continues to decline. This systematic review highlights a critical structural disconnect: while national training policies and competency frameworks emphasize advanced digital automation, actual field-level delivery remains severely constrained by resource shortages, outdated manual-based instructions, and significant instructor anxiety regarding modern code execution. These persistent infrastructure and capability gaps create an acute theory-practice gap, leaving students underprepared for automated workplace tracks.

Bridging these technical training gaps requires the deployment of localized, accessible, and user-friendly instructional solutions. This study concludes that the development of custom-built, open-layout Smart Home Trainer Boards is an essential systemic response to these challenges. By optimizing Perceived Ease of Use and reducing cognitive load, these transparent instructional platforms minimize user frustration and mitigate teacher technophobia, facilitating a smoother transition toward technical literacy.

When aligned with rigorous, output-based assessment methodologies and supported by targeted professional upskilling initiatives, custom trainer boards effectively bridge the divide between theoretical mechanics and modern industrial operations. Ultimately, the integration of these localized automation simulators is not a minor instructional upgrade; it is a vital, transformative intervention that builds student technical self-efficacy, enhances regional institutional capacity, and aligns vocational classrooms with international technical standards.

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