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Smart Home Technology Integration and Technical Skills Readiness in Electrical Installation and Maintenance Instruction

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ABSTRACT

This study investigated the integration of smart home technology and its contribution to technical skills readiness in Electrical Installation and Maintenance instruction at Mahatao National High School, Batanes. A cross-sectional explanatory-predictive design was employed, with participants selected through proportionate stratified random sampling. Data were collected using a validated researcher-developed questionnaire that measured instructional demonstration, hands-on application, device and system configuration, testing and troubleshooting, performance-based assessment, and technical skills readiness. Partial Least Squares Structural Equation Modeling and importance-performance map analysis were used to evaluate the measurement and structural models. Results showed a high overall level of smart home technology integration and technical skills readiness. Learners demonstrated stronger readiness in electrical and system safety, tool utilization, and conventional installation, while fault diagnosis and smart device configuration remained less developed. All dimensions of technology integration significantly predicted technical skills readiness and jointly explained 64.3% of its variance. Testing and troubleshooting produced the strongest predictive effect but received the lowest performance score, identifying it as the primary area for instructional improvement. The findings indicate that technical readiness is strengthened when smart home concepts are translated into practical configuration, testing, diagnosis, and corrective tasks. The study recommends expanding fault-based laboratory activities, teacher training, equipment provision, connectivity support, and performance assessments that integrate wiring, automation, safety, and troubleshooting.

Keywords: *electrical installation and maintenance, internet of things, partial least squares structural equation modeling, smart home technology, technical skills readiness, vocational education*

INTRODUCTION

Electrical work in residential buildings is no longer limited to installing conductors, switches, convenience outlets, lighting fixtures, and protective devices. Many homes now use sensors, automated controls, smart meters, wireless switches, security devices, and appliances that can be monitored or operated through mobile phones and computer networks. These devices form part of a smart home system in which physical equipment exchanges information through the Internet of Things. A smart home combines electrical components, electronic devices, communication technologies, software, and user interfaces to provide automated control, safety monitoring, energy management, and greater convenience for occupants. Alaa et al. (2017) explained that smart home applications rely on connected devices and control systems that allow household equipment to communicate and respond to user commands or programmed conditions.

The structure of a smart home requires knowledge that crosses the boundaries of conventional residential wiring. Its operation may involve sensors that detect motion, light, temperature, smoke, gas, or unauthorized entry; controllers that process information; relays that switch electrical loads; and communication protocols that connect devices to a gateway or central control platform. Mocrii et al. (2018) described IoT-based smart homes as systems built from hardware, software, communication networks, and security mechanisms that must work together reliably. This combination means that the installer must understand not only how electrical power is distributed but also how devices are connected, configured, tested, and maintained as part of an integrated system.

Smart home technology also has an important role in managing household electricity. Automated lighting, programmable controls, occupancy sensors, smart plugs, and energy-monitoring devices can help users identify consumption patterns and manage electrical loads. Home energy management systems may schedule appliance operation, monitor power demand, coordinate renewable energy sources, and provide information that supports more responsible energy use. Raza et al. (2024) found that smart home energy management systems bring together load monitoring, forecasting, scheduling, optimization, demand response, and renewable energy resources. These functions show why electrical workers need stronger preparation in measurement, device configuration, control circuits, system testing, and fault diagnosis.

Changes in electrical technology also affect the type of preparation expected from technical and vocational education. Work processes shaped by automation, digital control, and connected equipment require workers who can combine manual competence with digital understanding and systematic problem solving. Spöttl and Windelband (2021) noted that Industry 4.0 changes work organization, occupational tasks, and the interaction between people and technology, creating a need to update vocational curricula and training practices. For Electrical Installation and Maintenance learners, preparation should still develop accuracy in wiring, measurement, tool use, and compliance with safety standards. At the same time, learners need opportunities to work with sensors, control modules, communication devices, programmable functions, and diagnostic procedures that are now found in modern residential systems.

The need to align technical training with changing occupational requirements is also evident in the Philippine setting. The Asian Development Bank (2021) reported that technical and vocational education and training in the Philippines must respond to Industry 4.0 through stronger links among training standards, instructional programs, technology, and labor market needs. The report recognized that digitalization can change both the content of technical occupations and the skills required of graduates. The Organisation for Economic Co-operation and Development also stated that vocational education systems must remain responsive to changing skill demands and use digital technology to improve training design and delivery (OECD, 2023). These directions support the inclusion of practical learning experiences that prepare students for both established electrical tasks and emerging forms of residential automation.

Electrical Installation and Maintenance instruction in senior high school already provides an essential foundation for residential electrical work. The curriculum covers competencies related to tools and equipment, roughing-in activities, communication and distribution systems, electrical wiring, and other tasks associated with the EIM NC II qualification. The Department of Education (2019) identifies performance-based competencies that require learners to apply technical knowledge through actual work processes. This competency-based structure is suitable for incorporating smart home activities because many automation tasks can be taught through circuit assembly, sensor installation, device connection, testing, and troubleshooting. The presence of a strong conventional foundation, however, does not automatically mean that learners receive sufficient practice in connected home technologies. The depth of integration depends on the equipment available; the teacher's competence, the design of learning activities, and the amount of guided practice provided to students.

Smart home technology integration should involve more than showing learners videos, diagrams, or commercial products. Meaningful integration requires students to handle components, read technical specifications, prepare wiring diagrams, connect devices, configure controls, test system responses, identify faults, and explain the operation of the completed installation. Dake et al. (2023) observed that the Internet of Things can support interactive and application-oriented learning, but its educational use may be affected by limited infrastructure, cost, technical support, privacy concerns, and insufficient user competence. Jeon (2025) likewise explained that technology can strengthen vocational training through simulated work environments, improved assessment, and better alignment with labor needs, provided that teachers receive appropriate support and technology is used with sound teaching practices.

Technical skills readiness refers to the learner's preparation to perform required tasks safely, accurately, and with an acceptable degree of independence. In EIM instruction, this readiness may be reflected in the ability to interpret plans, select proper tools and materials, install wiring and protective devices, observe safety procedures, conduct electrical measurements, test circuits, and correct installation faults. Smart home applications add other demands, including the ability to connect sensors and controllers, configure devices, verify communication between components, and diagnose problems involving both electrical and digital elements. Security and privacy must also be considered because connected home devices can expose users and systems to unauthorized access when they are improperly configured. Mocrii et al. (2018) identified communication, privacy, and security as central concerns in IoT-based smart home systems, while Raza et al. (2024) emphasized the technical complexity involved in coordinating devices, loads, and control functions.

The literature has given considerable attention to the design of smart home systems, energy management, IoT applications, and the digital development of vocational education. Less attention has been given to how the actual use of smart home technology in secondary-level EIM instruction is associated with the technical skills readiness of learners. Access to devices alone cannot establish whether students are ready to perform installation and maintenance work. It is necessary to determine whether the technology is used in demonstrations, laboratory activities, performance tasks, assessment, and troubleshooting exercises, and whether such use is accompanied by observable competence. Examining these areas can provide a clearer basis for decisions concerning instructional materials, laboratory equipment, teacher training, competency assessment, and curriculum enrichment.

This study examine the place of smart home technology within the teaching and learning of EIM and its association with learners' readiness to carry out relevant technical tasks. The study recognizes the continuing value of conventional electrical competencies while considering the additional knowledge and skills required by connected residential systems. Its findings may help teachers and school administrators identify areas of strength, address instructional limitations, and design practical learning experiences that prepare students for electrical work shaped by automation, digital control, energy management, and interconnected devices.

Literature Review

Smart Home Technology as Applied Laboratory Content

Smart home technology can be taught effectively when learners are allowed to build, connect, configure, and test functional Internet of Things systems rather than merely study their components through printed materials. Smart home installations depend on the coordinated operation of sensors, controllers, relays, communication modules, electrical loads, and user interfaces. These components provide suitable materials for laboratory tasks involving circuit preparation, device installation, programming, testing, and fault identification. Rao and Elias-Medina (2024) developed an IoT laboratory that exposed students to sensors, embedded systems, databases, and security issues through practical activities tied to actual applications. Their findings showed that laboratory participation increased students' confidence in understanding secure IoT systems, which supports the value of structured and equipment-based instruction. In Electrical Installation and Maintenance classes, a similar approach may involve motion-controlled lighting, automated switching, temperature monitoring, alarm circuits, smart energy meters, and mobile-controlled appliances. Such activities connect traditional electrical competencies with device communication and digital control. Smart home integration should therefore be examined through the extent to which technologies are used in demonstrations, laboratory exercises, project construction, system configuration, troubleshooting, and performance assessment. These instructional applications can reveal whether technology is treated only as additional information or used as a regular part of technical skill development.

Teacher Digital Competence and Instructional Technology Use

The quality of smart home technology integration depends greatly on the teacher's capacity to select suitable devices, explain their operation, design practical activities, and address technical problems during instruction. Electrical knowledge alone may not be sufficient when lessons involve wireless communication, digital interfaces, device applications, data exchange, and system security. Cattaneo et al. (2022) assessed the digital competence of vocational teachers and found that both personal and work-related conditions influenced their competence, with workload and individual factors affecting their ability to develop and apply digital skills. Their findings indicate that teachers differ in their readiness to use technology even when they work within the same vocational education system. Antonietti et al. (2022) also found that vocational teachers' beliefs about their digital competence were positively associated with their perceptions of technology's usefulness and ease of use. Perceived usefulness, in turn, influenced their intention to use digital tools in teaching. These findings suggest that supplying smart devices to an EIM laboratory does not automatically lead to meaningful classroom integration. Teachers must possess the confidence, technical preparation, and instructional judgment needed to convert those devices into relevant learning experiences. Professional training, access to technical assistance, adequate preparation time, and opportunities to practise with smart home equipment are therefore important conditions when examining technology integration in EIM instruction.

Learner Digital Competence and Technical Skills Readiness

Technical skills readiness for smart home installation requires more than familiarity with mobile phones, computers, or internet applications. Learners must apply digital knowledge to specific occupational tasks, including interpreting device specifications, connecting sensors and control modules, configuring operating parameters, testing system responses, protecting user information, and diagnosing faults. Findeisen and Wild (2022) identified low, medium, and high digital competence profiles among beginning vocational trainees, showing that learners enter training programs with different levels of preparation. Their study also found that previous learning opportunities and the regular use of certain digital tools were associated with competence levels. Wild and Schulze Heuling (2020) similarly reported that vocational students demonstrated lower digital competence than students enrolled in cooperative higher education programs. These findings challenge the assumption that regular exposure to digital devices guarantees the ability to use technology for technical work. For EIM learners, readiness must be judged through observable performance rather than general confidence or frequency of device use. A student may be comfortable using applications but still experience difficulty reading wiring diagrams, selecting correct terminals, establishing device communication, following safety procedures, or identifying the source of a system malfunction. The assessment of technical skills readiness should therefore cover knowledge, procedural accuracy, tool handling, electrical safety, device configuration, testing, and troubleshooting within actual or simulated smart home installations.

Assessment and School Conditions Supporting Skills Development

A sound examination of technical skills readiness should consider the different abilities required for learning and performing technology-based tasks, together with the conditions provided by the school. Tan et al. (2024) developed a digital learning competence scale for secondary vocational students and identified five related dimensions: cognitive processing and reading, technology use, thinking skills, activity management, and will management. These dimensions show that competence involves technical ability as well as the capacity to understand information, manage tasks, solve problems, and sustain effort during learning. In smart home activities, learners must interpret technical instructions, plan installation procedures, make decisions when devices fail to communicate, and complete tasks despite repeated testing or correction. Zubizarreta Pagaldai et al. (2025) found that school-level factors were the strongest predictors of digital competence among basic vocational education students, followed by attitudes toward technology and the frequency of technology use. These finding places attention on laboratory availability, device access, internet connectivity, instructional support, opportunities for guided practice, and the school's capacity to maintain digital equipment. Technical readiness cannot be attributed solely to learner ability when students have limited access to functional tools and smart home components.

Examining both competence and learning conditions can provide a more accurate account of how smart home technology integration supports the preparation of EIM learners for installation, testing, maintenance, and troubleshooting tasks.

METHODS

Research Design

The study employed a cross-sectional explanatory-predictive research design. This design was selected because the investigation measured smart home technology integration and technical skills readiness at a single period and examined whether the first construct significantly predicted the second. It went beyond a conventional descriptive-correlational approach by evaluating the contribution of each dimension of smart home technology integration to the readiness of learners to perform installation, configuration, testing, safety, and troubleshooting tasks. No instructional treatment or manipulation was introduced. Instead, the study gathered evidence from the participants' actual experiences in Electrical Installation and Maintenance instruction. The predictive component also allowed the analysis to identify which areas of technology integration carried the greatest practical importance for the development of technical competence.

Research Locale

The study was conducted at Mahatao National High School, located in Panatayan, Mahatao, Batanes. The school served as the setting where Electrical Installation and Maintenance instruction and the use of smart home technologies were examined. It provided an appropriate locale because the investigation focused on how learners encountered technology-supported electrical activities within their regular instructional environment. Data collection took place in designated classrooms and learning areas without interrupting scheduled lessons, practical exercises, assessments, or other school activities. Permission to undertake the study was secured from the appropriate school authorities before any participant was approached.

Participants and Sampling Technique

The participants were senior high school learners who were officially enrolled in Electrical Installation and Maintenance subjects and had already participated in classroom or laboratory activities involving electrical wiring, installation procedures, testing instruments, control devices, or related technical tasks. Learners who had not yet received relevant EIM instruction during the data collection period were excluded because they could not provide an informed assessment of the variables. Proportionate stratified random sampling was applied to preserve the representation of eligible learners from the existing grade-level and class groupings. Each stratum contributed participants according to its proportion in the eligible population. The names of qualified learners were assigned identification codes, after which a computer-generated randomization procedure was used to select participants. This method reduced selection bias while ensuring that no eligible instructional group was disproportionately represented.

Research Instrument

Data were gathered through the researcher-developed Smart Home Technology Integration and Technical Skills Readiness Questionnaire. The first scale measured the integration of smart home technology through instructional demonstration, hands-on application, device and system configuration, testing and troubleshooting activities, and performance-based assessment. The second scale measured technical skills readiness in terms of electrical installation, sensor and controller connection, device configuration, circuit testing, fault diagnosis, tool utilization, and observance of safety procedures. The statements were rated using a five-point response scale. Higher scores represented stronger technology integration and greater technical skills readiness.

The initial instrument underwent content validation by specialists in Electrical Installation and Maintenance, technical-vocational education, educational technology, and research measurement. The validators examined each item for relevance, clarity, technical correctness, alignment with the study variables, and suitability for senior high school learners. The item-level content validity indices ranged from .83 to 1.00, while the scale-level content validity index based on the average method was .95. These values indicated excellent content validity. Statements that received lower ratings were revised to improve technical precision, eliminate overlapping ideas, simplify unfamiliar terminology, and clarify the specific task or behavior being measured. Two items were combined because they assessed similar instructional practices, while one item was removed because it did not directly represent either of the principal constructs.

The revised questionnaire was pilot-tested among Electrical Installation and Maintenance learners from a comparable public secondary school that was not included in the main investigation. The pilot participants had completed similar classroom and laboratory activities, which allowed the researcher to determine whether the instructions, technical terms, and response choices were understandable. Their responses were excluded from the final analysis. Cronbach's alpha was used to evaluate internal consistency. The Smart Home Technology Integration Scale obtained an alpha coefficient of .91, while the Technical Skills Readiness Scale registered an alpha coefficient of .93. The complete questionnaire produced an overall Cronbach's alpha of .95, indicating excellent internal consistency. Corrected item-total correlations ranged from .46 to .78 for the technology integration items and from .49 to .81 for the technical skills readiness items. No retained statement fell below the minimum acceptable item-total correlation of .30. Minor wording revisions were made after the pilot test, particularly in items concerning device pairing, controller configuration, circuit diagnosis, and system communication, to ensure that the final questionnaire measured the intended competencies clearly and consistently.

Data Gathering

The researcher first submitted a formal request to the school administration that explained the purpose, participants, procedures, proposed schedule, and safeguards of the study. After permission had been granted, the list of eligible learners was obtained through the authorized school personnel and was used solely for sampling. The selected participants and their parents or guardians received information sheets explaining the nature of participation, confidentiality measures, possible inconvenience, and the right to decline or withdraw.

The questionnaires were administered during an agreed period that did not interfere with examinations, laboratory exercises, or other required activities. Before distribution, the researcher explained the directions without suggesting desirable responses. Participants completed the instrument individually and were given sufficient time to review every statement. Accomplished questionnaires were checked only for completeness and were placed in a sealed envelope or secured digital folder. No participant was required to supply a name on the questionnaire. The collected responses were encoded using identification numbers, checked against the original forms, and screened for missing entries, duplicate records, and invalid response patterns before statistical analysis.

Data Analysis

Descriptive measures were first used to summarize the two principal constructs and their dimensions. Means and standard deviations described the general level and dispersion of responses, while medians and interquartile ranges were also examined to determine whether the distributions were affected by extreme values or response concentration. Item distributions, missing data, skewness, and kurtosis were inspected before the predictive model was evaluated.

Partial Least Squares Structural Equation Modeling was used as the principal statistical treatment. PLS-SEM was chosen because smart home technology integration and technical skills readiness were latent constructs represented by several observable indicators, and the study sought to explain and predict readiness rather than merely establish whether two total scores were correlated. The measurement model was evaluated through indicator loadings, Cronbach's alpha, composite reliability, average variance extracted, and the heterotrait-monotrait ratio. Indicator loadings of at least .70, reliability coefficients of at least .70, an average variance extracted of at least .50, and acceptable discriminant validity were used as evaluation criteria.

The structural model was assessed through collinearity statistics, standardized path coefficients, coefficient of determination, effect size, and predictive relevance. Statistical significance was tested through bootstrapping with 5,000 resamples. The path coefficient showed the direction and strength of the predictive relationship, while the coefficient of determination indicated the proportion of variance in technical skills readiness explained by smart home technology integration. Effect size estimates identified whether each integration dimension produced a small, moderate, or substantial contribution. Predictive relevance was examined through a blindfolding procedure.

An importance-performance map analysis was also conducted after the structural model had been evaluated. This procedure compared the predictive importance of each smart home technology integration dimension with its observed level of performance. Dimensions with high importance but comparatively low performance were treated as priority areas for instructional improvement, laboratory enhancement, teacher development, or resource allocation. A significance level of .05 was applied to the inferential decisions.

Ethical Consideration

The study observed the principles of voluntary participation, informed consent, learner assent, privacy, confidentiality, and protection from harm. Approval was obtained from the appropriate school authorities before recruitment and data collection. Because some senior high school learners could have been below the legal age of consent, written permission was secured from their parents or guardians, together with the learners' written assent. Participation did not affect grades, attendance, access to equipment, assessment results, or relationships with teachers and school personnel.

The participants were informed that they could refuse to answer any statement or withdraw from the study without penalty. The questionnaire did not request names, student numbers, contact details, or other unnecessary identifiers. Codes were used during data encoding and analysis, and results were reported only in aggregate form. Electronic files were stored in a password-protected device, while printed materials were placed in a secured location accessible only to the researcher. The information was used exclusively for the stated academic purpose and was handled in accordance with applicable data privacy requirements. The research records were scheduled for secure deletion or disposal after the required retention period. Any possible conflict of interest arising from the researcher's professional role was managed by emphasizing that participation was voluntary and by preventing teachers directly responsible for grading from influencing the learners' decision to participate.

RESULTS AND DISCUSSION

Table 1. *Descriptive Results for Smart Home Technology Integration and Technical Skills Readiness*

Construct and dimension	Mean	SD	Median	IQR	Interpretation
Smart Home Technology Integration					
Instructional demonstration	4.16	0.55	4.20	0.70	High
Hands-on application	3.88	0.63	4.00	0.80	High
Device and system configuration	3.54	0.70	3.60	1.00	High
Testing and troubleshooting activities	3.36	0.72	3.40	1.00	Moderate
Performance-based assessment	3.80	0.62	3.80	0.80	High
Overall Smart Home Technology Integration	3.75	0.52	3.80	0.70	High
Technical Skills Readiness					
Electrical installation	4.08	0.58	4.20	0.80	High
Sensor and controller connection	3.73	0.65	3.80	0.80	High
Smart device configuration	3.42	0.72	3.40	1.00	High
Circuit testing	3.84	0.61	4.00	0.80	High
Fault diagnosis	3.31	0.74	3.40	1.00	Moderate

Tool and instrument utilization	4.14	0.53	4.20	0.60	High
Electrical and system safety	4.29	0.49	4.40	0.60	Very high
Overall Technical Skills Readiness	3.83	0.49	3.86	0.64	High

Note. Interpretation was based on the following ranges: 4.21 to 5.00, very high; 3.41 to 4.20, high; 2.61 to 3.40, moderate; 1.81 to 2.60, low; and 1.00 to 1.80, very low. IQR refers to interquartile range.

Table 1 shows that smart home technology integration obtained an overall mean of 3.75, indicating that it was highly integrated into Electrical Installation and Maintenance instruction. Among its dimensions, instructional demonstration received the highest mean of 4.16. This result suggests that teachers frequently introduced smart home concepts through explanations, equipment demonstrations, circuit illustrations, and guided presentations. Smart home devices appeared to be visible in instruction, and learners were generally exposed to their operating principles and possible applications.

Hands-on application and performance-based assessment also received high evaluations, with means of 3.88 and 3.80, respectively. These findings indicate that learners were given opportunities to assemble circuits, handle devices, complete practical activities, and demonstrate their skills through performance tasks. Practical laboratory exposure is important because connected devices cannot be understood fully through lectures alone. Rao and Elias-Medina (2024) found that structured IoT laboratory activities substantially improved learners' confidence and understanding of connected systems and their security concerns. This supports the finding that practical exposure contributed to the generally favorable condition of smart home technology integration.

The lowest mean was recorded for testing and troubleshooting activities at 3.36, interpreted as moderate. Device and system configuration also received a lower mean of 3.54 compared with instructional demonstration and hands-on application. These results reveal that learners encountered smart home devices but were not consistently required to diagnose communication failures, correct faulty connections, reconfigure control parameters, or trace problems involving several interconnected components. The difference between demonstration and troubleshooting suggests that technology was more frequently shown and assembled than examined under fault conditions.

The overall technical skills readiness mean of 3.83 indicates that learners were generally prepared to perform EIM tasks involving conventional electrical work and selected smart home applications. Electrical and system safety obtained the highest mean of 4.29, followed by tool and instrument utilization at 4.14 and electrical installation at 4.08. These results suggest that the strongest learner competencies were associated with safe work habits, proper use of tools, circuit preparation, and established installation procedures.

Fault diagnosis obtained the lowest readiness mean of 3.31, while smart device configuration obtained 3.42. Learners were therefore less prepared to identify complex faults and adjust digital or communication settings than to carry out physical installation tasks. This pattern reflects an uneven readiness profile in which basic electrical competencies were stronger than advanced digital and diagnostic competencies. Findeisen and Wild (2022) found that vocational trainees did not possess uniform digital competence and that differences were associated with prior learning opportunities and the types of digital activities they had performed. Their findings support the need to provide repeated, occupation-specific practice rather than assume that general familiarity with digital devices leads to technical readiness.

Table 2. *Reliability and Convergent Validity of the Measurement Model*

Construct	Retained Indicators	Loading Range	Cronbach's Alpha	rho_A	Composite Reliability	AVE
Instructional demonstration	4	0.756 to 0.866	0.844	0.849	0.895	0.681
Hands-on application	5	0.728 to 0.853	0.826	0.832	0.879	0.621
Device and system configuration	5	0.709 to 0.842	0.810	0.817	0.868	0.568
Testing and troubleshooting activities	5	0.721 to 0.861	0.838	0.845	0.884	0.605

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Construct	Retained Indicators	Loading Range	Cronbach's Alpha	rho_A	Composite Reliability	AVE
Performance-based assessment	4	0.748 to 0.874	0.856	0.862	0.898	0.688
Technical skills readiness	7	0.701 to 0.879	0.924	0.929	0.938	0.685

Note. rho_A refers to Dijkstra-Henseler's reliability coefficient. AVE refers to average variance extracted.

Table 2 presents the assessment of indicator reliability, internal consistency, and convergent validity. The outer loadings ranged from 0.701 to 0.879. These values indicate that the retained indicators made acceptable contributions to their respective constructs. No indicator was removed from the final model because all loadings reached the acceptable level and were theoretically consistent with the construct being measured.

Cronbach's alpha coefficients ranged from 0.810 to 0.924, while composite reliability values ranged from 0.868 to 0.938. These results demonstrate that the indicators within each scale consistently measured the same underlying construct. The reliability coefficients were not excessively high, except for the broad technical skills readiness construct, which contained several related skill dimensions. The results therefore indicated dependable measurement without serious evidence that most items were unnecessary repetitions.

The AVE values ranged from 0.568 to 0.688, exceeding the required level of 0.50. Each construct therefore explained more than half of the variance in its indicators. The lowest AVE was recorded for device and system configuration, although its value of 0.568 remained acceptable. The lower result may be attributed to the range of activities covered by configuration, including pairing devices, selecting operating parameters, establishing communication, and confirming system responses. Hair et al. (2022) explained that indicator loadings, internal consistency coefficients, and AVE should be examined together when assessing reflective measurement models. Based on these criteria, the measurement model demonstrated adequate reliability and convergent validity.

Table 3. *Heterotrait-Monotrait Ratios among the Study Constructs*

Construct	ID	HA	DSC	TT	PA	TSR
Instructional demonstration (ID)	1.000					
Hands-on application (HA)	0.681	1.000				
Device and system configuration (DSC)	0.604	0.738	1.000			
Testing and troubleshooting activities (TT)	0.637	0.756	0.802	1.000		
Performance-based assessment (PA)	0.712	0.701	0.664	0.723	1.000	
Technical skills readiness (TSR)	0.694	0.781	0.746	0.815	0.768	1.000

Table 3 shows that the HTMT values ranged from 0.604 to 0.815. None of the ratios exceeded the conservative threshold of 0.85. The constructs were therefore sufficiently distinct from one another, even though they formed related parts of smart home technology instruction.

The highest HTMT value was observed between testing and troubleshooting activities and technical skills readiness at 0.815. This relatively strong association was expected because diagnostic tasks required learners to apply electrical knowledge, measurement skills, system interpretation, and corrective action. The value remained below the required limit, indicating that testing and troubleshooting was related to readiness but did not measure exactly the same construct.

Device and system configuration also had a comparatively strong association with testing and troubleshooting, with an HTMT value of 0.802. This result reflects the practical connection between configuring a system and identifying why it does not operate as intended. A learner who changes control settings, pairs devices, or establishes communication must also verify whether those settings function correctly. Despite this practical overlap, the discriminant validity results confirmed that configuration and troubleshooting represented

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distinguishable instructional activities. Based on the measurement model results, the structural relationships could be examined without serious concern that the constructs were statistically indistinguishable.

Table 4. PLS-SEM Structural Model Predicting Technical Skills Readiness

Predictive Path	β	Bootstrapped SE	t-value	p-value	95% Confidence Interval	VIF	f²	Decision
Instructional demonstration → Technical skills readiness	0.112	0.055	2.05	.041	0.018 to 0.205	1.82	0.024	Significant
Hands-on application → Technical skills readiness	0.247	0.059	4.18	<.001	0.134 to 0.361	2.11	0.087	Significant
Device and system configuration → Technical skills readiness	0.221	0.063	3.52	.001	0.099 to 0.339	2.26	0.069	Significant
Testing and troubleshooting activities → Technical skills readiness	0.298	0.059	5.06	<.001	0.181 to 0.414	2.35	0.126	Significant
Performance-based assessment → Technical skills readiness	0.176	0.060	2.91	.004	0.059 to 0.291	1.94	0.050	Significant

Model Criterion	Result
R^2 for technical skills readiness	0.643
Adjusted R^2	0.634
Q^2 predictive relevance	0.417

Note. Significance was assessed through bootstrapping with 5,000 resamples. β refers to the standardized path coefficient. VIF refers to variance inflation factor. f^2 refers to effect size.

Table 4 shows that all five dimensions of smart home technology integration significantly predicted technical skills readiness. The variance inflation factors ranged from 1.82 to 2.35, indicating that the predictor constructs did not exhibit problematic collinearity. Each predictor therefore contributed distinct information to the explanation of learner readiness.

Testing and troubleshooting activities emerged as the strongest predictor of technical skills readiness, with a standardized path coefficient of 0.298, a t-value of 5.06, and a probability value below .001. Its effect size of 0.126 was the largest among the five predictors. The result means that learners who experienced more frequent fault simulation, circuit testing, error identification, and corrective procedures tended to report higher readiness to carry out technical tasks. Troubleshooting required learners to move beyond following fixed procedures because they had to interpret symptoms, isolate possible causes, test alternatives, and confirm whether a correction restored system operation.

This result is particularly important because testing and troubleshooting obtained only a moderate descriptive rating. The dimension was not the most frequently implemented area, yet it produced the strongest contribution to technical readiness. This pattern indicates that increasing the frequency and quality of troubleshooting exercises may produce greater improvement than adding more demonstrations alone. Rao and Elias-Medina (2024) reported that carefully designed IoT laboratory activities connected to practical problems increased student understanding of embedded and connected systems. The present result extends that instructional principle to EIM by showing that active diagnosis and testing may be more influential than passive exposure.

Hands-on application was the second strongest predictor, with a coefficient of 0.247 and a probability value below .001. This result confirms that actual manipulation of tools, wiring components, sensors, control devices, and electrical loads contributed substantially to readiness. Learners developed confidence and procedural control when they repeatedly performed tasks instead of merely observing completed installations. Hands-on application also produced an effect size of 0.087, showing that its contribution remained meaningful after the other dimensions were considered.

Device and system configuration significantly predicted technical skills readiness, with a coefficient of 0.221 and a probability value of .001. This finding shows that readiness increased when learners had opportunities to pair smart devices, adjust settings, establish communication, program control responses, and verify device operation. The result also confirms that digital configuration was not separate from electrical competence. It became part of the technical work required to install and maintain connected residential systems.

Performance-based assessment produced a significant coefficient of 0.176. This result suggests that learners became more technically prepared when assessment required actual task completion, correct tool use, compliance with safety standards, and observable system performance. Performance assessment likely encouraged learners to organize their knowledge into complete procedures because they were required to demonstrate competence rather than simply recall definitions.

Instructional demonstration recorded the smallest coefficient at 0.112, although its influence remained statistically significant at $p = .041$. Demonstrations helped learners recognize equipment, understand sequences, and observe correct practices, but their predictive contribution was weaker than active application, configuration, and troubleshooting. This finding does not diminish the value of demonstration. It indicates that demonstrations were most useful when they served as preparation for learner performance rather than as the final instructional activity.

The model explained 64.3 percent of the variance in technical skills readiness. This result indicates that the five integration dimensions collectively provided substantial explanatory power. The adjusted coefficient of determination was 0.634, showing that the model retained nearly the same predictive capacity after accounting for the number of predictors. The Q^2 value of 0.417 was above zero and indicated strong predictive relevance for technical skills readiness. The model therefore did more than describe associations among the constructs. It demonstrated that the instructional use of smart home technologies offered meaningful information for predicting learners' readiness to perform relevant technical work.

The results are consistent with the broader view that vocational competence develops through purposeful learning opportunities rather than ordinary exposure to digital devices. Findeisen and Wild (2022) found that differences in trainees' competence were partly connected to the digital activities and learning opportunities they had experienced. Cattaneo et al. (2022) likewise reported that technology use frequency, attitudes toward technology, and curricular support contributed to digital competence in vocational education. Taken together, these studies support the present finding that the form and quality of instructional integration mattered for technical readiness.

Table 5. *Importance and Performance of Smart Home Technology Integration Dimensions*

Dimension	Importance for Technical Skills Readiness	Performance Score	Priority Rank	Instructional Implication
Testing and troubleshooting activities	0.298	59.00	1	Immediate improvement priority
Device and system configuration	0.221	63.50	2	Major improvement priority
Hands-on application	0.247	72.00	3	Strengthen frequency and task complexity
Performance-based assessment	0.176	70.00	4	Expand authentic and integrated assessment
Instructional demonstration	0.112	79.00	5	Maintain current level and connect to practice

Note. Performance scores were converted to a scale from 0 to 100. Higher importance values indicate a stronger contribution to technical skills readiness.

Table 5 presents the importance-performance map analysis using technical skills readiness as the target construct. Testing and troubleshooting activities obtained the highest importance value of 0.298 but the lowest performance score of 59.00. This combination placed it at the first priority for instructional improvement. The result means that testing and troubleshooting had the strongest capacity to improve readiness, yet its implementation was less developed than the other dimensions.

This finding identifies the main instructional problem revealed by the study. Learners appeared to receive adequate explanations and demonstrations, but they had fewer opportunities to examine defective circuits, communication errors, incorrect settings, intermittent connections, sensor failures, and unresponsive control devices. A learner who can assemble a working circuit may still lack readiness when the same system develops a fault. Training should therefore include deliberate fault insertion, diagnostic worksheets, guided testing sequences, measurement-based decision making, and repeated verification of corrective actions.

Device and system configuration was ranked second because it combined a relatively high importance value of 0.221 with a performance score of 63.50. The dimension required improvement because smart home systems could not operate correctly through wiring alone. Learners needed to understand device pairing, controller parameters, communication settings, addressing, timing functions, and user interface controls. Limited equipment, inconsistent connectivity, restricted laboratory time, and insufficient exposure to different brands or device types may have constrained this area.

Hands-on application obtained the second-highest importance value but a stronger performance score of 72.00. It was therefore placed third in the priority ranking. The finding indicates that hands-on activities were already present but could be improved by increasing their complexity. Instead of repeating isolated switching circuits, learners could be asked to complete integrated projects involving lighting, sensors, alarms, energy monitoring, and mobile control.

Performance-based assessment recorded an importance value of 0.176 and a performance score of 70.00. The dimension was not as influential as troubleshooting or hands-on application, but it still contributed significantly to readiness. Assessment should therefore measure complete work processes, including preparation, wiring accuracy, configuration, testing, safety, system response, fault correction, and documentation. Rubrics should distinguish between a circuit that merely operates and a system that is installed safely, configured properly, and tested systematically.

Instructional demonstration received the highest performance score of 79.00 but the lowest importance value of 0.112. The existing level of demonstration should be maintained, but additional instructional resources should not be concentrated solely in this area. Further gains are more likely to come from redirecting time and equipment toward configuration, testing, and troubleshooting.

Importance-performance mapping is useful because it identifies constructs that combine strong predictive importance with weak observed performance rather than relying only on mean scores or path coefficients. In the present analysis, the method showed clearly that testing and troubleshooting should receive first attention. Ringle and Sarstedt (2016) explained that IPMA extends PLS-SEM findings by identifying areas where improvements are likely to produce the greatest increase in a target outcome.

The priority pattern is also supported by evidence that school-related conditions influence vocational learners' digital competence. Zubizarreta Pagaldai et al. (2025) found that school-level predictors had the strongest influence on students' digital competence, followed by attitudes toward technology and frequency of use. This means that weaknesses in configuration and troubleshooting should not be attributed only to learners. Equipment availability, curriculum planning, laboratory access, teacher preparation, technical support, and the quality of practice opportunities must also be addressed.

CONCLUSION

The smart home technology integration contributed significantly to the technical skills readiness of learners in Electrical Installation and Maintenance instruction, particularly when learning activities required hands-on application, device configuration, system testing, and troubleshooting. Although the overall level of integration and readiness was high, weaknesses remained in fault diagnosis, smart device configuration, and troubleshooting activities, indicating that learners were more confident in conventional installation, tool use, and safety procedures than in advanced diagnostic and digital control tasks. Testing and troubleshooting emerged as the strongest predictor of readiness despite receiving the lowest performance rating, which showed that this area required the most immediate attention. Based on these findings, the school should strengthen laboratory activities that involve deliberate fault insertion, sensor and controller configuration, communication testing, error detection, and corrective procedures. Teachers should receive continuing technical training in smart home systems, Internet of Things applications, and performance-based assessment, while the school administration should provide adequate devices, testing instruments, connectivity, and maintenance support. Instructional plans should also give greater emphasis to integrated projects that combine wiring, automation, safety, configuration, and troubleshooting. Future studies may examine the effectiveness of specific smart home training modules through experimental or longitudinal designs and include direct performance assessments to provide stronger evidence of learners' actual technical competence.

References

Alaa, M., Zaidan, A. A., Zaidan, B. B., Talal, M., & Kiah, M. L. M. (2017). A review of smart home applications based on Internet of Things. *Journal of Network and Computer Applications, 97*, 48–65. doi:10.1016/j.jnca.2017.08.017

Antonietti, C., Cattaneo, A., & Amenduni, F. (2022). Can teachers' digital competence influence technology acceptance in vocational education? *Computers in Human Behavior, 132*, Article 107266. doi:10.1016/j.chb.2022.107266

Asian Development Bank. (2021). *Technical and vocational education and training in the Philippines in the age of Industry 4.0*. doi:10.22617/TCS210084

Cattaneo, A. A. P., Antonietti, C., & Rauseo, M. (2022). How digitalised are vocational teachers? Assessing digital competence in vocational education and looking at its underlying factors. *Computers & Education, 176*, Article 104358. doi:10.1016/j.compedu.2021.104358

Dake, D. K., Bada, G. K., & Dadzie, A. E. (2023). Internet of Things (IoT) applications in education: Benefits and implementation challenges in Ghanaian tertiary institutions. *Journal of Information Technology Education: Research, 22*, 311–338. doi:10.28945/5183

Department of Education. (2019, April 12). *K to 12 senior high school TVL industrial arts specialized subject curriculum guide: Electrical Installation and Maintenance NC II for Grade 12* [Curriculum guide]. DepEd Learning Portal.

Findeisen, S., & Wild, S. (2022). General digital competences of beginning trainees in commercial vocational education and training. *Empirical Research in Vocational Education and Training, 14*, Article 2. doi:10.1186/s40461-022-00130-w

Hair, J. F., Jr., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2022). *A primer on partial least squares structural equation modeling (PLS-SEM)* (3rd ed.). SAGE Publications.

Jeon, S. (2025). *How can innovative technologies transform vocational education and training: Insights for Ukraine*. OECD Publishing. doi:10.1787/fb40f416-en

Mocrii, D., Chen, Y., & Musilek, P. (2018). IoT-based smart homes: A review of system architecture, software, communications, privacy and security. *Internet of Things, 1–2*, 81–98. doi:10.1016/j.iot.2018.08.009

Organisation for Economic Co-operation and Development. (2023). *Building future-ready vocational education and training systems*. OECD Publishing. doi:10.1787/28551a79-en

Rao, A. R., & Elias-Medina, A. (2024). Designing an internet of things laboratory to improve student understanding of secure IoT systems. *Internet of Things and Cyber-Physical Systems, 4*, 154–166. doi:10.1016/j.iotcps.2023.10.002

Raza, A., Jingzhao, L., Ghadi, Y., Adnan, M., & Ali, M. (2024). Smart home energy management systems: Research challenges and survey. *Alexandria Engineering Journal, 92*, 117–170. doi:10.1016/j.aej.2024.02.033

Ringle, C. M., & Sarstedt, M. (2016). Gain more insight from your PLS-SEM results: The importance-performance map analysis. *Industrial Management & Data Systems, 116*(9), 1865–1886. doi:10.1108/IMDS-10-2015-0449

Spöttl, G., & Windelband, L. (2021). The 4th industrial revolution: Its impact on vocational skills. *Journal of Education and Work, 34*(1), 29–52. doi:10.1080/13639080.2020.1858230

Tan, X., Lin, X., & Zhuang, R. (2024). Development and validation of a secondary vocational school students' digital learning competence scale. *Smart Learning Environments, 11*, Article 37. doi:10.1186/s40561-024-00325-6

Wild, S., & Schulze Heuling, L. (2020). How do the digital competences of students in vocational schools differ from those of students in cooperative higher education institutions in Germany? *Empirical Research in Vocational Education and Training, 12*, Article 5. doi:10.1186/s40461-020-00091-y

Zubizarreta Pagaldai, A., Cattaneo, A., Imaz Agirre, A., & Marín, V. I. (2025). Factors influencing the digital competence of students in basic vocational education training. *Empirical Research in Vocational Education and Training, 17*, Article 19. doi:10.1186/s40461-025-00198-0