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Development and Evaluation of Heating Ventilating Airconditioning (HVAC) Trainer With Embedded Internet of Things (IoT) Based Monitoring System

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Abstract: *This study aimed to develop and evaluate a Heating Ventilating Airconditioning (HVAC) trainer with embedded Internet of Things (IOT) based monitoring system to enhance technical skills in installation, troubleshooting capabilities, digital literacy and instruction in the field of HVAC industry. The research employed a combination of design and development, experimental, and descriptive methods to guide the creation and evaluation of the trainer. Conducted at Agusan del Sur State College of Agriculture and Technology, the study involved 7 HVAC system experts, 8 HVAC instructors and 35 Heating Ventilating Airconditioning Refrigeration Technology (HVACRT) students who assessed the device using a validated questionnaire.*

Results from functional analysis revealed that HVAC trainers with embedded IOT significantly outperformed the existing HVAC trainers in functionality, reliability, usability, efficiency, maintainability, and portability. The device was designed with modular components and integrated features conducive to competency-based learning, all while maintaining a lower production cost of ₱ 23,328.00. A detailed Gantt chart outlined the development timeline, while the construction and assembly procedures were carefully documented to ensure replicability. The final product was tested for performance and operational safety, confirming its effectiveness as a practical teaching tool. The study recommends instructor training, device enhancement, regular maintenance, and consideration for intellectual property protection to maximize its educational value and sustainability.

Keywords: HVAC with embedded IOT, Trainer Device, Development, Instructional material, Perceptions

1. INTRODUCTION

The Technology in Heating, Ventilating, and Airconditioning (HVAC) is changing rapidly. It is not just about mechanical parts. Heating Ventilating Airconditioning (HVAC) systems are now connected to the Internet. They use the Internet of Things (IoT) to improve efficiency, make monitoring easier, and allow control through smartphones.

In the Philippines, the demand for homes and energy-efficient buildings is on the rise. Home and business owners want to trace their electricity use in real time. Because of this, industry needs technicians who understand more than just the Heating Ventilating Airconditioning (HVAC) cycle. They should also know basic networking, how to read sensors, and how to understand data from an app. There is a persistent need to update current training methods to fit this new model.

The main reason for developing and evaluating the Heating Ventilating Airconditioning (HVAC) Trainer with Embedded Internet of things (IoT) monitoring based system is to update technical education so it meets the current needs of the Heating Ventilating Airconditioning (HVAC) industry. Heating Ventilating Airconditioning (HVAC) Systems are not just mechanical; they use sensors, automation, and the Internet of Things (IoT). However, many

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schools in the Philippines still use old, analog trainers that do not work like the modern units found in the field. Because of this, graduates are good at mechanical tasks but lack the digital skills needed for the systems.

Solving this problem is a key to helping students get ready for jobs in a high-tech and energy-efficient industry. The Heating Ventilating Airconditioning (HVAC) Trainer uses Internet of Things (IoT) and real-time monitoring to give students a modern learning experience. Furthermore, this study is important because it helps schools modernize their laboratories, teaches students about safety and saving energy, and encourages new research on tools for Industry.

This research focuses on the skills gap among new Heating Ventilating Airconditioning (HVAC) technicians. Many technical schools and training centers still use outdated equipment. Consequently, graduates know old models but are not prepared for modern Heating Ventilating Airconditioning (HVAC) units with Internet of Things (IoT) features. They lack practical experience in setting up, troubleshooting, and maintaining these systems. `

The main aim of this study is to develop and evaluate a working Heating Ventilating Airconditioning (HVAC) Trainer with embedded Internet of Things (IoT) based monitoring system. This equipment will provide trainees with hands-on learning experience in several areas:

Installing Internet of Things (IoT) sensors for temperature and humidity, as well as power meters in Heating Ventilating Airconditioning (HVAC) system Configuring Wi-Fi for remote monitoring, Reading and understanding data displayed on a dashboard or mobile app

This proposed study will create a complete trainer model. The design will include all standard components of Heating Ventilating Airconditioning (HVAC) unit, such as the compressor, condenser, expansion valve, and evaporator. However, it will also feature embedded Internet of Things (IoT) components. We will include a microcontroller like an ESP32 or Raspberry Pi, to connect to the sensors. A web dashboard or app will be designed to enable students to view data and control the unit.

During the development phase, we will build the actual prototype based on the design. We will ensure the trainer meets competency standards. This includes not only basic Heating Ventilating Airconditioning (HVAC) standards but also the new skills that the industry requires for Internet of Things (IoT). The focus of this study is to design, develop, and evaluate a Heating Ventilating Airconditioning (HVAC) Trainer with embedded Internet of things (IoT) technology to combine mechanical, electrical, electronics, welding fabrication and IT skills.

Once the prototype is fully functional, it will undergo testing and evaluation. A group of students, trainees, experts, heating Ventilating Airconditioning (HVAC) teachers, and industry technicians will use the trainer. We will deploy survey questionnaires and practical tests to determine if the trainer is effective in teaching skills and if it is user-friendly and relevant to actual jobs.

The results of the evaluation will confirm the trainer's success. The goal is to use it to upgrade the laboratories in technical institutions for the Bachelor of Industrial Technology (BIndTech). Since the design will be documented, the trainer can be adapted and replicated by other schools. This will help more students become ready for the modern Heating Ventilating Airconditioning (HVAC) industry.

II. STATEMENT OF THE PROBLEM

This study attempts to develop and evaluate Heating Ventilating Airconditioning (HVAC) trainers with embedded Internet of Things (IOT) based monitoring system.

Specifically, this study attempted to answer the following problems:

1. What is the functional analysis of existing Heating Ventilating Airconditioning (HVAC) Training equipment compared with the proposed (HVAC) trainer with embedded Internet of Things (IOT) based monitoring system.
2. What design will be developed for the Heating Ventilating Airconditioning (HVAC) trainer based on the findings in the analysis phase in terms of:

1.1 Technical features; and

1.2 Costing?

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3. What technical procedures and timetable will be undertaken in the development of the Heating Ventilating Airconditioning (HVAC) Trainer?

III. RESEARCH DESIGN

The study utilized the combination of design and development, experimental and descriptive methods. Design and development were used since the study dealt with the process of HVAC design and the fabrication of the device. The descriptive method is used because it involves the collection of data concerning the respondents' perception on the design of the device.

Research Environment

The actual fabrication of the device and the conduct of the research was primarily done at the BIndTech laboratory of the Agusan del Sur State college of agriculture and technology, located at BUNAWAN Agusan Sur. The materials used in the study were collected from local market establishments at different places where the materials are available.

Research Respondents

The respondents of the study are 7 HVAC expert 8 HVACRT Instructors and 35 Heating Ventilating Airconditioning and Refrigeration Technology (HVACRT) Students of the said University.

Research Instrument

The questionnaire adopted from previous related studies was used to gather the necessary data and information of the study. The respondents have answered and selected their best choices as to their perception of the proposed device. There are two sets of questionnaires on the third problem for comparison of the two devices used in HVAC installation.

Data Analysis

The data gathered during the study are analyzed and interpreted. In determining the profile of respondents, percentage would be used. Weighted means would be used for the acceptability and effectiveness of the device. T-test would be used for the test of Significance Effect of the students' performance.

IV. RESULTS AND DISCUSSIONS

Functional analysis of the development and evaluation of heating ventilating air-conditioning (HVAC) trainer with embedded internet of things (IOT) based monitoring system over existing HVAC trainer

Table 1. Functional Analysis of the Existing and Developed HVAC

Feature	Equipment	Validator	Mean	SD	QD
Functionality	Existing HVAC	HVAC Expert	1.00	0.00	P
		Instructor	1.00	0.00	P
	Developed HVAC with IoT	HVAC Expert	4.71	0.49	E
		Instructor	4.75	0.46	E
Reliability	Existing HVAC	HVAC Expert	1.00	0.00	P
		Instructor	1.00	0.00	P
	Developed HVAC with IoT	HVAC Expert	4.29	0.76	E
		Instructor	4.50	0.54	E
Usability	Existing HVAC	HVAC Expert	1.00	0.00	P
		Instructor	1.00	0.00	P

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Efficiency	Developed HVAC with IoT	HVAC Expert	5.00	0.00	E
		Instructor	4.75	0.46	E
	Existing HVAC	HVAC Expert	1.00	0.00	P
		Instructor	1.00	0.00	P
	Developed HVAC with IoT	HVAC Expert	4.43	0.54	E
		Instructor	4.63	0.52	E
Maintainability	Existing HVAC	HVAC Expert	1.00	0.00	P
		Instructor	1.00	0.00	P
	Developed HVAC with IoT	HVAC Expert	5.00	0.00	E
		Instructor	4.63	0.52	E
Portability	Existing HVAC	HVAC Expert	1.00	0.00	P
		Instructor	1.00	0.00	P
	Developed HVAC with IoT	HVAC Expert	4.43	0.54	E
		Instructor	4.75	0.46	E

The data presented in Table 1 reveals a comparative evaluation of the existing (HVAC) trainer and development and evaluation of (HVAC) trainer with embedded Internet of thing (IOT) based monitoring system, based on expert assessments across six key parameters: functionality, reliability, usability, maintainability, and portability. The HVAC trainer with embedded IOT consistently scored higher across all these parameters, indicating significant enhancements in its overall design and performance. These improvements reflect current pedagogical trends in Bachelor of Industrial Technology (BIndTech), which advocate for hands-on, modular, and competency-based approaches to ensure industry-relevant skills development. The HVAC trainers with embedded IOT improved functionality and usability suggest a more interactive and learner-centered interface, likely integrating real-time simulations and component modularity.

Furthermore, higher scores in efficiency, maintainability, and portability highlight the HVAC trainers with embedded IOT adaptability to various learning environments and its ease of use over time—critical attributes in addressing the logistical and technical demands of education. Its superior reliability indicates stable performance under extended and diverse operational conditions, which supports the continuity of practical learning without technical disruptions. The results of this functional analysis validate the HVAC trainer with embedded IOT trainer as a more effective educational tool, aligned with global calls for advanced and responsive learning technologies in the field of HVAC industry.

Development and Evaluation of Heating Ventilating Airconditioning (HVAC) Trainer with Embedded Internet of Things (IOT) Based Monitoring System

The following figures shown below is the two-dimensional and three-dimensional design of the developed and evaluation of HVAC trainer with embedded IOT based monitoring system drawn using CAD system.

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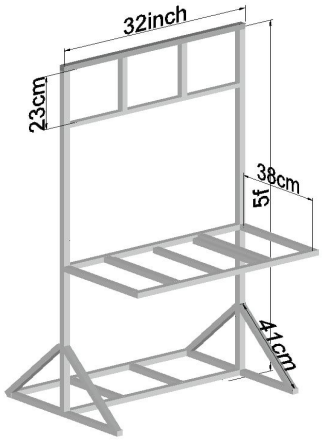
Figure 1. 2-Dimensional design of the device



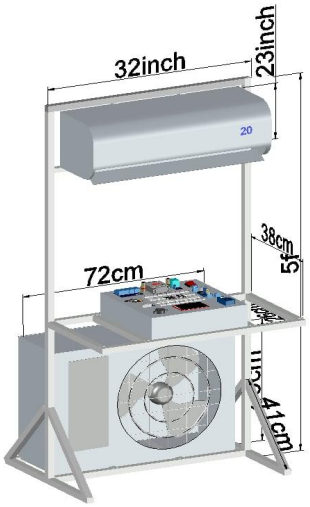


Figure 2. 3-Dimensional design of the device

Table 2. Total costing of the material for (HVAC) Trainer

Qty	Unit	Description of materials	Unit cost	Total cost
1	PC	5V Relax 4 Channel	₱99.00	₱99.00
1	PC	5SR 60A	₱159.00	₱159.00
1	PC	12V Power Supply	₱185.00	₱185.00
2	PCS	Buck Converter	₱65.00	₱130.00
1	PC	TFT LCD 4”	₱889.00	₱399.00
1	PC	12V RGB LED	₱92.00	₱368.00
3	PCS	10 CM Female-Female	₱55.00	₱165.00
3	PCS	30 cm male-male	₱99.00	₱297.00
1	PC	3-24v Buzzer	₱50.00	₱50.00
1	PC	AC Voltage Sensor	₱1,375.00	₱1,375.00
2	PCS	Acrylic Sheet	₱430.00	₱860.00

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1	PC	ESP 32 With Jumper Wires/Bread Board	₱643.00	₱643.00
1	PC	DS18B20	₱264.00	₱238.00
1	PC	DHT22	₱360.00	
1	PC	AC Split Type	₱18.000.00	₱18.000.00
TOTAL COST OF MATERIALS:			₱23,328.00	

Table 2 shows the total costing of the developed device is ₱ 23,328.00. Other material used is tubular. It was not included in the costing because this is a recycled material used by the researchers.

Procedures and Timetable in the Development and Evaluation of Heating Ventilating Airconditioning (HVAC) Trainer with Embedded Internet of Things (IOT) Based Monitoring System

Table 3. Gantt chart in the development of the trainer.

Activities	February 02-06,2026	February 09-17, 2026	February 18-26, 2026	February 26-March 05, 2026
1. Define Objectives & Competencies				
2. Research & Curriculum Development				
3. Design System Layout				
4. Procure Components				
5. Assemble Trainer Setup				
6. Testing & Validation				
7.Trainer Orientation/Documentation				

As shown in the table 3, activity of development is finished within thirty fifteen days. Usually, the researchers developed the product during their spare time, so that they can perform their specific task assigned to them.

The development process of the developed device started when the researchers bought the necessary materials needed during its creation. The preparation of the tools and equipment is also part of it. Other processes are measuring, cutting, drilling, polishing, grinding, attaching, assembling, mounting, wiring and commissioning the device.

Technical procedures undertaken in the development and evaluation of HVAC Trainer with Embedded IOT based monitoring system

Construction Procedure

1. Creating the design layout and technical plan of the trainer
2. A durable metal frame was fabricated to support all components securely
3. The compressor, condenser, evaporator, and expansion device were mounted according to the system design.
4. Copper tubing connections were assembled and brazed to interconnect the main components
5. Electrical wiring was installed to connect the compressor, fan motors, switches, and protective devices.
6. Sensors such as temperature and environmental sensors were installed at strategic points in the system.
7. The IoT system was configured to display real-time readings through a digital monitoring interface.
8. A final inspection was conducted to ensure that all components were properly mounted, aligned, and connected in accordance with technical specifications.

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. . Figure 3. Construction Procedure for the trainer

IoT System

1. Sensors installed in the HVAC system detect operational parameters such as temperature and environmental conditions.
2. The collected data from the sensing unit are sent to the microcontroller, which serves as the central processing unit.
3. The microcontroller processes the incoming data, organizes it, and prepares it for transmission.
4. The processed data are transmitted through the communication module to the monitoring interface, which may be a display screen or a digital platform connected through IoT
5. The monitoring interface presents real-time system information, enabling users to observe operating conditions and system behavior accurately.
6. The real-time data allow students and instructors to analyze the performance of the HVAC system.

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Figure 4. IoT System

Trainer Assembly Procedure

1. The main HVAC components were positioned and secured onto the trainer frame.
2. Copper tubing was installed to connect the compressor, condenser, expansion device, and evaporator.
3. After piping assembly, the refrigeration system was evacuated using a vacuum pump
4. Control switches, circuit protection devices, relays, and necessary electrical wiring were installed.
5. Sensors were connected to the microcontroller board, which was programmed to collect, process, and transmit real-time system data
6. Following complete assembly, the trainer was inspected to confirm that all mechanical, electrical, and IoT components

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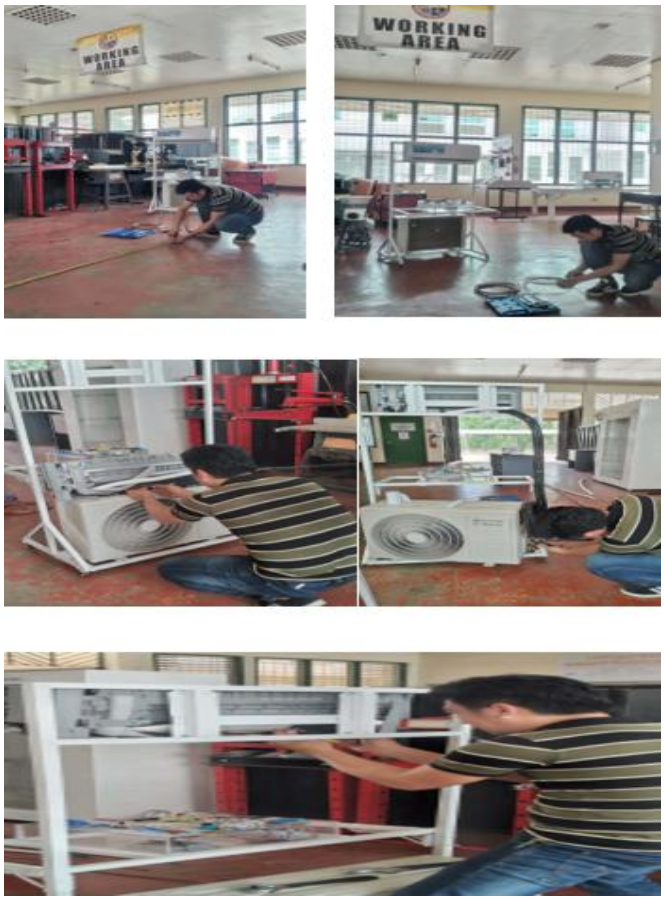

Figure 5. Trainer Assembly Procedure

Final product/trainer testing and implementation in an actual training setup

1. The trainer was powered on, and the operation of the compressor, condenser fan, and other electrical components was observed to ensure that all parts activated properly.
2. Operational parameters such as system pressures and temperature readings were monitored to verify that the refrigeration cycle was functioning within standard operating conditions.
3. The IoT monitoring system was tested by confirming that all installed sensors accurately measured parameters such as temperature and environmental data.
4. The transmission of real-time data from the sensors to the monitoring interface was evaluated.
5. After technical testing, the trainer was introduced into a controlled laboratory setting where instructors and evaluators used it under normal learning conditions
6. Evaluation instruments were used to gather feedback on usability, instructional value, operational efficiency, and overall performance of the trainer.
7. The collected feedback was analyzed to assess the effectiveness of the HVAC trainer as a teaching and learning tool.

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Figure 6. Final Product Testing and implementation procedures.

Operating Procedures

1. The user must inspect the trainer to ensure that all components are properly installed, securely mounted,
2. The trainer should be connected to a stable and appropriate power supply before operation to avoid electrical issues or system malfunction.
3. The main power switch is turned on to energize the trainer. Once activated, the compressor and fan motors begin operating, initiating the refrigeration cycle.
4. During operation, the user may observe the functioning of the condenser, evaporator, expansion device, and other HVAC components to understand system behavior and performance.
5. The IoT monitoring module collects data from installed sensors and displays real-time information on the monitoring interface.
6. After the laboratory activity, the main power supply must be turned off to shut down the system safely.
7. The trainer should be inspected for any irregularities and cleaned to maintain its operational condition and readiness for future laboratory sessions.

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Figure. Operating Procedures

V. RECOMMENDATIONS

1. Electrical instructors and professors should receive training and familiarization with the HVAC trainer with embedded IOT device to effectively use it as an instructional tool. Workshops, seminars, and tutorials should be organized to ensure that instructors are proficient in utilizing the device.
2. Continuously develop and expand the device's capabilities to cover a wider range of HVAC with embedded IOT concepts. This will make it a versatile tool for instructors, catering to a variety of instructional needs.
3. Establish a regular maintenance schedule to keep the device in optimal working condition. This will ensure its longevity and reliability in educational settings.
4. The administration may provide assistance for patenting of this developed device for IP protection and also to augment the scarcity of electrical technology instructional materials for effective instruction.

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