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Design and development of an air conditioning trainer system with integrated gauge monitoring

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Abstract

Aim: This study aimed to design, develop, and evaluate a portable Automotive Air Conditioning Trainer System with Integrated Gauge Monitoring to enhance hands-on learning among BSIT Automotive students. Specifically, it sought to assess the trainer's portability, functionality, usability, efficiency and effectiveness, safety, and accuracy, and to develop an operational manual for instructional use.

Methodology: A developmental–descriptive research design was employed. The developmental phase consisted of design and planning, assembly and installation, evaluation and testing, and implementation and use. The descriptive phase utilized validated survey questionnaires administered to forty-nine students and five faculty experts. Median and interquartile range were used to determine the level of acceptability across the evaluation criteria.

Results: The findings indicated very high levels of acceptability across all evaluated criteria, with an overall median score of 5.00 and an interquartile range of 0. The trainer effectively simulated actual automotive air-conditioning system operations, provided accurate and reliable gauge readings, and supported efficient and safe skill development.

Conclusion: The Automotive Air Conditioning Trainer System with Integrated Gauge Monitoring is a highly acceptable and effective instructional tool that significantly enhances practical learning in automotive air-conditioning systems. Its portability, realistic simulation, and integrated monitoring features address existing laboratory limitations and support competency-based technical education.

Keywords: *automotive air conditioning, gauge monitoring, instructional trainer, technical education*

INTRODUCTION

In the field of automotive technology, practical learning was essential because global advances in vehicle systems required technicians to possess strong diagnostic and hands-on skills. International reports on technical and vocational education highlighted that modern vehicles incorporated increasingly complex mechanical and climate control systems, which demanded competency-based training supported by functional laboratory equipment and real-system simulations. Recent global studies emphasized that automotive A/C servicing remained one of the most technical maintenance domains because it involved refrigeration cycles, pressure management, thermal transfer, and the integration of multiple components operating under precise conditions. These trends underscored the need for training institutions to modernize their instructional facilities, ensuring that graduates could meet current industry standards (Smith & Adams, 2021).

The automotive air conditioning (A/C) system is considered a core system in modern vehicles because it contributes to comfort, safety, and overall vehicle performance. Its operation required the coordinated function of the compressor, condenser, evaporator, expansion valve, refrigerant lines, and system sensors, all operating within specific pressure and temperature ranges. Hands-on experience was critical, as research consistently demonstrated that experiential learning strengthened students' diagnostic accuracy and enhanced their ability to troubleshoot complex systems. Studies from 2021 to 2023 confirmed that hands-on exposure significantly improved student retention of technical concepts and problem-solving skills in automotive programs (Lopez, 2023).

In the Philippines, these challenges mirrored global trends. Many higher education institutions struggled with resource limitations that weakened the delivery of hands-on technical training. Studies conducted from 2021 to

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2024 revealed that public technical institutions faced persistent shortages of updated laboratory equipment, particularly in specialized fields such as automotive technology. Without adequate training facilities, students often graduate without having operated or diagnosed real automotive systems. National tracer studies reported that while graduates understood theoretical concepts in electrical and climate control systems, they had limited exposure to A/C systems during training, affecting job readiness and certification performance (TESDA, 2022).

This issue was particularly evident at one university in Samar offering the BSIT major in Automotive Technology. Instruction in automotive A/C systems relied heavily on lectures, diagrams, and video demonstrations. Students learned the refrigeration cycle and pressure–temperature relationships but lacked opportunities to apply these concepts to actual units. The absence of a functional A/C trainer prevented students from performing refrigerant charging, leak detection, pressure monitoring, and system evacuation. Without a dedicated trainer system or mock-up, A/C unit, students' confidence and competence declined, especially when applying for positions requiring A/C servicing. This limitation conflicted with CHED's Outcomes-Based Education (OBE) framework, which mandates measurable performance-based competencies in technical programs (CHED CMO No. 79, s. 2017).

Three major gaps were evident. First, an equipment gap persisted due to the lack of locally developed, portable, and fully functional A/C trainer systems with integrated gauge monitoring, as existing instructional materials relied mostly on theoretical diagrams or expensive imported units. Second, a competency gap existed because previous studies affirmed the importance of hands-on training but did not provide or evaluate an A/C trainer specifically designed to build diagnostic skills aligned with CHED and TESDA standards. Third, a curricular alignment gap remained, as current classroom practices relied heavily on theory, resulting in a mismatch between expected competencies and students' actual training experiences.

Given these gaps, this study developed a locally fabricated Automotive Air Conditioning Trainer System with Integrated Gauge Monitoring tailored for the BSIT-Automotive Technology program. The trainer integrates actual A/C system components mounted on a mobile platform, enabling live demonstrations, hands-on laboratory activities, simulated system faults, and real-time gauge interpretation. This innovation is technically novel because it provides a full-cycle A/C training experience rather than partial simulations or recovery-only processes, integrates real-time gauge monitoring to enhance diagnostic learning, aligns explicitly with CHED OBE and TESDA competency standards, and is evaluated through both student and expert feedback in a Philippine higher education context.

The implementation of this trainer is expected to enhance instruction by allowing instructors to demonstrate system operations effectively and giving students opportunities to perform authentic diagnostic tasks. It will also improve the evaluation of student performance in tool handling, gauge interpretation, safety compliance, and A/C servicing procedures. Furthermore, this initiative aligns with CHED's quality assurance framework, promoting instructional innovation, updated facilities, and the development of locally appropriate technologies that strengthen technical education in the Philippines.

Review of Related Literature and Studies

Recent studies consistently emphasize the importance of automotive A/C trainer systems in bridging theoretical knowledge and practical skill development. Foundational work by Abedin and Rahman (2019) demonstrated that A/C simulators with real-time pressure and temperature monitoring significantly improve students' understanding of thermodynamic principles and refrigerant behavior. Building on this, Karthikeyan and Sundararajan (2020) found that portable A/C trainers with interactive components, such as compressors and gauges, enhanced learners' comprehension of refrigerant dynamics more effectively than traditional instruction. Similarly, Hidayat et al. (2023) reported a 23.9 percent increase in student competence using a motorized, adjustable A/C simulator, confirming the instructional value of real-system simulations with live monitoring.

In addition to system simulation, foundational research highlighted the critical role of core A/C components and diagnostic monitoring in training effectiveness. Studies by Roslan et al. (2017), Cummings et al. (2021), and Huang et al. (2021) showed that condenser and evaporator performance directly affects cooling efficiency and should be included in performance-based diagnostics. Ibrahim and Sapuan (2015) and Chauhan et al. (2018) emphasized the expansion valve and manifold gauges as essential tools for improving learners' understanding of pressure regulation and refrigerant flow. More recent work by Verma and Mishra (2021) confirmed that dual-gauge monitoring significantly improves students' ability to detect common system faults, reinforcing the instructional value of integrated gauge monitoring in trainer systems.

Recent research further underscores the importance of portability, accuracy, and usability in instructional trainers. Juevesa Jr. et al. (2020) and Tangonan and Magtulis (2023) found that portable trainers with accurate

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measurement systems enhance flexibility and diagnostic proficiency in space-limited learning environments. Madsen and Johansen (2020) and Al-Samarraie et al. (2017) likewise confirmed that compact tools with precise feedback improve troubleshooting skills and long-term retention of technical concepts. Locally, Abales and Cuasito (2025) validated the effectiveness of trainers with actual refrigerant recovery and gauge monitoring, though their study was limited to recovery processes only.

Beyond technical accuracy, design factors such as efficiency, safety, and usability remain critical. Reyes (2020), Gonzales and Mateo (2021), and Del Rosario (2019) stressed that energy efficiency, portability, and real-system functionality improve trainer sustainability and realism. Cruz and Sevilla (2022) and Lim and Velasco (2020) showed that usability directly affects student engagement and performance, while safety standards emphasized by Torres (2018), DepEd (2019), and ISO/IEC 25010:2011 remain essential for ensuring equipment reliability and protection.

Collectively, the literature establishes that effective automotive A/C trainers must integrate real system components, accurate gauge monitoring, portability, safety, and usability to enhance diagnostic competence and technical skill acquisition. Despite this, most existing studies focus on simulation, recovery processes, or general portability, with limited attention to a locally developed, full-cycle trainer with integrated gauge monitoring aligned to Philippine instructional contexts. This gap justifies the present study, which aims to design and develop a portable automotive A/C trainer system that fully supports hands-on diagnostics, instructional quality, and industry-aligned competency development.

Theoretical Framework

This study is grounded in several educational and engineering theories that support the integration of hands-on learning tools in technical and vocational education. The development of an Automotive Air Condition Trainer System with Integrated Gauge Monitoring is guided by Experiential Learning Theory (ELT) by David Kolb (1984), Constructivist Learning Theory by Jean Piaget (1952), and the principles of System Development Theory in engineering education.

Kolb's Experiential Learning Theory (1984) emphasizes that knowledge is created through the transformation of experience. In this model, effective learning is a cyclical process comprising four stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation. For BSIT-Automotive students, the absence of a hands-on air conditioning trainer limits them to abstract conceptualization without the benefit of concrete experience and experimentation. By providing a physical trainer system with integrated gauges, this study offers a means for learners to engage in full experiential cycles, thereby enhancing their understanding of system operations and diagnostics.

Constructivist Learning Theory, as proposed by Jean Piaget (1952) and later expanded by Lev Vygotsky, suggests that learners construct knowledge through active engagement and interaction with their environment. This theory highlights the importance of authentic learning experiences, where students manipulate objects, solve real-world problems, and receive immediate feedback. The proposed A/C trainer system simulates an actual automotive environment, enabling students to interact with real components, observe pressure readings, and diagnose simulated faults, fostering deeper conceptual understanding through practical application.

From an engineering perspective, System Development Theory provides the foundation for structured design and iterative development of technological tools or products. This framework emphasizes requirements analysis, prototyping, testing, and refinement—all of which are integral in developing a functional, efficient, and user-friendly training device. Applying this theory ensures that the trainer system is not only technically sound but also meets pedagogical goals and end-user needs, particularly those of instructors and automotive technology students.

Furthermore, this study aligns with the Outcome-Based Education (OBE) framework, as promoted by CHED (2017). OBE shifts the focus of education from content delivery to the achievement of specific competencies. In technical programs like automotive, outcomes include the ability to troubleshoot, diagnose, and repair systems such as automotive air conditioning units. The trainer system being developed in this study serves as a tangible resource to assess these outcomes, enabling performance-based evaluation and skills validation.

In summary, this study draws from experiential, constructivist, and system development theories to support the design and implementation of an Automotive Air Condition Trainer System with Integrated Gauge Monitoring. These theories collectively affirm that learning is most effective when students are actively engaged in hands-on, authentic tasks that simulate real-life environments. The integration of a physical trainer system into the BSIT curriculum addresses the current gap in practical exposure, aligning theoretical knowledge with skills-based competencies. By grounding the study in these educational and engineering frameworks, the research ensures that

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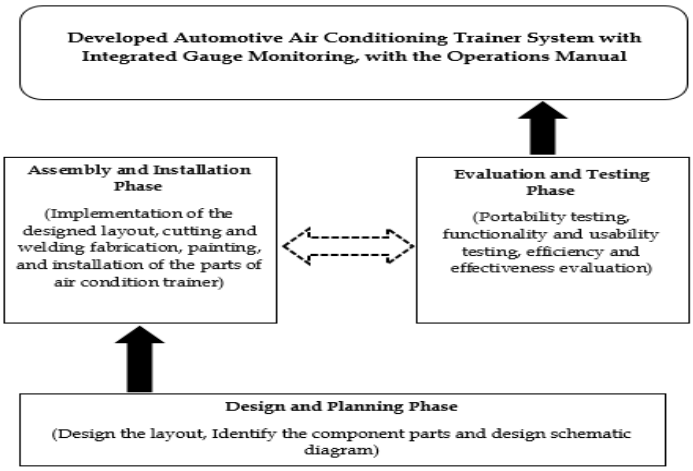
the product developed will not only enhance learning but also empower students to meet national and global standards in automotive servicing.

Conceptual Framework

The conceptual schema presents the systematic process in developing and evaluating the Automotive Air Conditioning Trainer System with Integrated Gauge Monitoring. It consists of four phases: Design and Planning, Assembly and Installation, Evaluation and Testing, and Implementation and Use. The first phase involves system conceptualization, layout design, parts identification, and schematic drafting with input from instructors and industry experts. The second phase focuses on the physical construction and installation of all system components. The third phase assesses the trainer's portability, functionality, usability, efficiency, and effectiveness based on feedback from students and instructors. The final phase integrates the trainer into the BSIT-Automotive curriculum through the use of an operational manual, instructor training, classroom application, and continuous improvement.



Statement of the Problem

The increasing demand for skilled automotive technicians has underscored the importance of hands-on training in developing competencies in vehicle systems, particularly in automotive air conditioning. However, many higher education institutions in the Philippines continue to face limitations in laboratory facilities, resulting in instruction that relies heavily on theoretical approaches with minimal practical exposure. This condition is evident in universities in Samar, where the absence of functional automotive air-conditioning training equipment restricts students' ability to perform diagnostic procedures, interpret gauge readings, and understand actual system behavior. Despite the recognized role of training devices in supporting competency-based education and industry readiness, limited research has focused on the development and evaluation of locally fabricated automotive A/C trainer systems with integrated gauge monitoring. Addressing this gap is essential to enhance instructional delivery, improve students' practical skills, and align automotive education with national and industry standards.

Research Objectives

General Objective:

To develop and evaluate a portable Automotive Air Conditioning Trainer System with Integrated Gauge Monitoring as an instructional tool for BSIT Automotive students.

Specific Objectives:

1. To design an Automotive Air Conditioning Trainer System with Integrated Gauge Monitoring.
2. To develop the designed trainer system using appropriate materials and components.

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3. To evaluate the trainer system in terms of portability, functionality, usability, efficiency and effectiveness, safety, and accuracy.
4. To develop an operations manual to guide users in the proper operation, maintenance, and troubleshooting of the trainer system.

Research Questions

1. What is the design of the Automotive Air Conditioning Trainer System with Integrated Gauge Monitoring?
2. How is the Automotive Air Conditioning Trainer System with Integrated Gauge Monitoring developed using the identified materials and components?
3. How do students and experts evaluate the developed trainer system in terms of:
   3.1 Portability
   3.2 Functionality
   3.3 Usability
   3.4 Efficiency and effectiveness
   3.5 Safety
   3.6 Accuracy
4. What operations manual can be developed to guide users in the proper operation, maintenance, and troubleshooting of the trainer system?

METHODS

Research Design

This study employed a developmental–descriptive research design, which was deemed most appropriate because the primary objective involved both the creation of an instructional device and the systematic evaluation of its performance based on user feedback. The developmental component addressed the need to design, construct, refine, and implement an Automotive Air Conditioning Trainer System with Integrated Gauge Monitoring, while the descriptive component allowed for an objective assessment of the trainer's performance characteristics as experienced by its actual users.

The developmental phase was conducted through four structured stages. These included design and planning, assembly and installation, evaluation and testing, and implementation and use. These stages ensured that the trainer was developed logically and iteratively aligned with instructional and technical requirements.

The descriptive phase focused on evaluating the developed trainer in terms of portability, functionality, usability, efficiency and effectiveness, safety, and accuracy. This evaluation was based on survey responses from third-year BSIT–Automotive students and automotive instructors at Samar State University Main Campus. The use of descriptive evaluation enabled the study to systematically document user perceptions and performance-related attributes of the trainer during actual laboratory application, rather than making outcome-based instructional claims.

Population and Sampling

The study involved a total of fifty-four (54) respondents, composed of forty-nine (49) third-year BSIT-Automotive students and five (5) faculty members from Samar State University Main Campus. Total enumeration sampling was used, where all officially enrolled third-year BSIT-Automotive students and all automotive instructors were selected as respondents to obtain complete and direct evaluations from the actual users and subject matter experts of the trainer.

Instruments

A researcher-made survey questionnaire was utilized to gather evaluation data on the developed trainer system. The instrument measured portability, functionality, usability, efficiency and effectiveness, safety, accuracy, and overall user satisfaction. All items were rated using a five-point Likert scale ranging from strongly disagree to strongly agree.

Before administration, the questionnaire underwent content validation to ensure its appropriateness for the study. Five (5) experts evaluated the instrument. These included three (3) automotive instructors with relevant industry experience and two (2) research methodology experts holding master's degrees. The validators assessed the instrument in terms of clarity, relevance, and adequacy of the items in relation to the study objectives. All suggested revisions were incorporated to improve the precision and comprehensibility of the questionnaire.

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Data Collection

The data were collected at Samar State University Main Campus during the second semester of the academic year, when the developed Automotive Air Conditioning Trainer System with Integrated Gauge Monitoring was already installed and used in actual laboratory classes. After the implementation of the trainer, the researcher personally distributed the survey questionnaires to the third-year BSIT-Automotive students and faculty instructors immediately after their laboratory sessions. The respondents rated the trainer based on portability, usability, functionality, efficiency and effectiveness, safety, and accuracy using a five-point Likert scale. The accomplished questionnaires were retrieved personally by the researcher on the same day or during the next scheduled class to ensure complete data collection.

Treatment of Data

Descriptive statistical techniques were used to analyze the evaluation data obtained from the Likert-scale survey questionnaire. The median was employed to determine the central tendency of respondents' ratings, as it is an appropriate measure for ordinal data and reflects the typical response provided by the participants.

The interquartile range (IQR) was used to measure the variability and consistency of responses by identifying the range between the first quartile (Q1) and the third quartile (Q3). This analysis provided insight into the degree of agreement among respondents and facilitated comparison of evaluation patterns between student and faculty groups across the identified performance criteria.

Ethical Considerations

Informed consent was secured from all groups of respondents before they participated in the study. All confidential information gathered, such as the names of participants and other identifying details, was coded, and only the researcher had access to the coding system. The privacy and anonymity of the participants were strictly maintained throughout the research process. Furthermore, the data collected was used exclusively for research purposes and was not disclosed to unauthorized individuals. Proper and accurate data analysis procedures were employed to ensure the integrity of the findings, and all ethical guidelines set by the university were observed.

RESULTS and DISCUSSION

This section presents the findings of the study through the systematic presentation, analysis, and interpretation of data obtained from the evaluation of the Automotive Air-Conditioning Trainer System with Integrated Gauge Monitoring.

Evaluation of the Automotive Air-Conditioning Trainer System with Integrated Gauge Monitoring

The study evaluated the Automotive Air-Conditioning Trainer System with Integrated Gauge Monitoring using key performance criteria, namely portability, functionality, usability, efficiency and effectiveness, safety, and accuracy. These criteria were used to assess the suitability of the trainer as an instructional device for technical education, particularly for laboratory activities related to automotive air-conditioning systems.

The evaluation was conducted through expert assessment, pilot implementation, and user feedback. The assessment examined the trainer's ease of transport, operational performance, user interaction, safety provisions, and the precision of pressure and refrigerant readings displayed by the integrated gauges. The findings described the observed characteristics and performance of the trainer during instructional use, providing an empirical basis for determining its relevance to automotive air-conditioning training and its consistency with industry-aligned instructional practices.

Portability. Portability referred to the extent to which the Automotive Air-Conditioning Trainer System with Integrated Gauge Monitoring could be moved, handled, and transported within classroom or laboratory settings. This criterion considered the trainer's size, weight, structural design, ease of assembly and disassembly, and storage convenience for users.

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Table 1. Portability level of the Automotive A/C Trainer's System with Integrated Gauge Monitoring

Statements	Students		Expert/Faculty	
	Median Score	Interpretation	Median Score	Interpretation
1. *Automotive A/C Trainer System's compact design makes it easy to move between locations.*	5	SA/HP	5	SA/HP
2. *The components of the A/C trainer are durable enough for frequent transport.*	5	SA/HP	5	SA/HP
3. *The A/C Trainer can be quickly assembled and disassembled for use.*	5	SA/HP	5	SA/HP
4. *The trainer's portability does not compromise its performance.*	4	SA/HP	5	SA/HP
5. *The trainer is designed to be stored easily without requiring much space.*	4	SA/HP	5	SA/HP
Overall Median	**5**	**SA/HP**	**5**	**SA/HP**
IQR	**0**	**No Variability**	**0**	**No Variability**

Legend:

5 - Strongly Agree (SA)/Very High Portability (VHP)
4 – Agree (A)/High Portability (HP)
3 – Neutral (N)/Moderate Portability (MP)
2 – Disagree (DA)/Low Portability (LP)
1 – Strongly Disagree (SD)/Very Low Portability (VLP)

The findings affirmed that the Automotive A/C Trainer System with Integrated Gauge Monitoring was rated highly in terms of portability. Respondents indicated that the trainer's size, structural design, and mobility allowed it to be transported and stored with ease within laboratory and classroom environments. This characteristic is particularly relevant for technical-vocational institutions that operate with shared facilities or limited laboratory space, as it enables flexible scheduling and deployment of instructional equipment without logistical constraints. These results corroborated Hernandez (2019), who reported that compact and durable training equipment supported instructional mobility and facilitated practical training in space-constrained educational settings.

Functionality. Functionality referred to the extent to which the Automotive Air-Conditioning Trainer System with Integrated Gauge Monitoring performed its intended operational tasks. This included the demonstration of air-conditioning system components, the consistency and responsiveness of the integrated gauges, and the trainer's capacity to support various instructional and demonstration activities for students and instructors.

Table 2. Functionality level of the Automotive A/C Trainer's System with Integrated Gauge Monitoring

Statements	Students		Expert/Faculty	
	Median Score	Interpretation	Median Score	Interpretation
1. *The Automotive A/C Trainer effectively simulates real automotive air-conditioning system operations.*	5	SA/VHF	5	SA/VHF
2. *The trainer responds accurately and consistently during demonstrations and simulations.*	5	SA/VHF	5	SA/VHF
3. *All features of the A/C Trainer work reliably under different scenarios.*	5	SA/VHF	4.5	SA/VHF
4. *The trainer accommodates a wide range of training activities.*	5	SA/VHF	5	SA/VHF
5. *The trainer provides a realistic and practical experience for understanding automotive air- conditioning processes.*	5	SA/VHF	5	SA/VHF
Overall Median	**5**	**SA/VHF**	**5**	**SA/VHF**
IQR	**0**	**No Variability**	**0**	**No Variability**

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Legend:

5 - Strongly Agree (SA)/Very High Functionality (VHF)
4 – Agree (A)/High Functionality (HF)
3 – Neutral (N)/Moderate Functionality (MF)
2 – Disagree (DA)/Low Functionality (LF)
1 – Strongly Disagree (SD)/Very Low Functionality (VLF)

The results showed that the trainer system performed its intended instructional functions effectively. The operation of the air-conditioning components and the responsiveness of the integrated gauges allowed instructors to demonstrate system behavior and basic diagnostic procedures under controlled conditions. This indicates that the trainer system was suitable for representing operational principles commonly encountered in automotive air-conditioning systems. These findings were consistent with Ramos (2020), who emphasized that training simulators designed to mirror real system functions provide appropriate platforms for skill familiarization in automotive technology programs.

Usability. Usability referred to the extent to which students and instructors were able to operate and interact with the Automotive Air-Conditioning Trainer System with Integrated Gauge Monitoring with ease. This criterion included the clarity of instructional materials, simplicity of controls, intuitiveness of the user interface, and the level of effort required to operate and troubleshoot the system during instructional activities.

Table 3. Usability level of the Automotive A/C Trainer's System with Integrated Gauge Monitoring

Statements	***Students***		***Expert/Faculty***	
	Median Score	***Interpretation***	***Median Score***	***Interpretation***
1. The Automotive A/C Trainer is easy to operate, even for first-time users.	*4*	*A/HU*	*5*	*SA/VHU*
2. The instructional materials provided are clear and comprehensive.	*5*	*SA/VHU*	*5*	*SA/VHU*
3. The user interface of the A/C Trainer is intuitive and well-designed.	*5*	*SA/VHU*	*5*	*SA/VHU*
4. Minimal training is required to effectively use the A/C Trainer.	*5*	*SA/VHU*	*5*	*SA/VHU*
5. Troubleshooting and resolving common issues with the trainer is straightforward.	*5*	*SA/VHU*	*5*	*SA/VHU*
Overall Median	***5***	***SA/VHU***	***5***	***SA/VHU***
IQR	***0***	***No Variability***	***0***	***No Variability***

Legend:

5 - Strongly Agree (SA)/Very High Usability (VHU)
4 – Agree (A)/High Usability (HU)
3 – Neutral (N)/Moderate Usability (MU)
2 – Disagree (DA)/Low Usability (LU)
1 – Strongly Disagree (SD)/Very Low Usability (VLU)

The findings indicated that the Automotive A/C Trainer System was perceived as easy to operate by both students and expert evaluators. Respondents noted that the controls were straightforward and that the accompanying instructional materials were adequate in guiding system operation. This suggests that the trainer can be integrated into laboratory activities with minimal orientation time, allowing instructional sessions to focus on concept demonstration rather than system familiarization. This observation aligned with Cruz (2019), who noted that user-friendly interfaces in technical training devices reduce operational difficulty and support structured hands-on activities.

Efficiency and Effectiveness. Efficiency and effectiveness referred to the extent to which the Automotive Air-Conditioning Trainer System with Integrated Gauge Monitoring operated smoothly while supporting instructional

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demonstrations with minimal time, effort, and resource use. This criterion also considered how clearly automotive air-conditioning processes could be demonstrated within scheduled laboratory activities.

Table 4. Efficiency and Effectiveness level of the Automotive A/C Trainer's System with Integrated Gauge Monitoring

Statements	Students		Expert/Faculty	
	Median Score	Interpretation	Median Score	Interpretation
1. *The Trainer improves trainees' understanding of automotive air-conditioning systems.*	5	SA/VHEE	5	SA/VHEE
2. *Training sessions conducted with the Automotive A/C Trainer are more efficient compared to traditional methods.*	5	SA/VHEE	5	SA/VHEE
3. *The trainer facilitates the development of practical skills related to automotive air-conditioning system operations.*	4	A/HEE	5	SA/VHEE
4. *The Automotive A/C trainer reduces the time needed to achieve training objectives.*	5	SA/VHEE	5	SA/VHEE
5. *The trainer's effectiveness in skill enhancement is evident through measurable outcomes.*	5	SA/VHEE	5	SA/VHEE
Overall Median	**5**	**SA/VHEE**	**5**	**SA/VHEE**
IQR	**0**	**No Variability**	**0**	**No Variability**

Legend:

5 - Strongly Agree (SA)/Very High Efficiency and Effectiveness (VHEE)
4 – Agree (A)/High Efficiency and Effectiveness (HEE)
3 – Neutral (N)/Moderate Efficiency and Effectiveness (MEE)
2 – Disagree (DA)/Low Efficiency and Effectiveness (LEE)
1 – Strongly Disagree (SD)/Very Low Efficiency and Effectiveness (VLEE)

The results indicated that the trainer system was rated highly in terms of efficiency and effectiveness. Respondents observed that the system operated smoothly during demonstrations, allowing instructional activities related to automotive air-conditioning processes to proceed without unnecessary delays or interruptions. The trainer was considered suitable for presenting system operations within scheduled laboratory periods, contributing to organized and time-efficient instruction. These findings were consistent with Villanueva (2020), who reported that well-designed instructional systems in technical education support efficient laboratory implementation and structured learning experiences.

Safety. Safety referred to the extent to which the Automotive Air-Conditioning Trainer System with Integrated Gauge Monitoring protected operation. This criterion considered the reliability of system components, the presence of appropriate safety features, the clarity of instructional warnings, and the ability of the trainer to minimize hazards for users.

Table 5. Safety level of the Automotive A/C Trainer's System with Integrated Gauge Monitoring

Statements	Students		Expert/Faculty	
	Median Score	Interpretation	Median Score	Interpretation
1. The trainer system is equipped with appropriate safety features to prevent accidents during operation.	5	SA/VHS	5	SA/VHS
2. Safety instructions and warnings are provided and easy to understand.	5	SA/VHS	5	SA/VHS
3. The trainer promotes awareness of industry-standard safety practices among users.	5	SA/VHS	5	SA/VHS

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4. The trainer can be used safely even by students with limited technical experience.	*5*	SA/VHS	*5*	SA/VHS
5. Risk of injury or equipment damage while using the trainer is minimal when following instructions.	*5*	SA/VHS	*4.5*	SA/VHS
Overall Median	***5***	***SA/VHS***	***5***	**SA/VHS**
IQR	***0***		***0***	

Legend:

5 - Strongly Agree (SA)/Very Highly Safe (VHS)
4 – Agree (A)/Highly Safe (HS)
3 – Neutral (N)/Moderately Safe (MS)
2 – Disagree (DA)/Less Safe (LS)
1 – Strongly Disagree (SD)/Not Safe (NS)

The findings demonstrated that the Automotive A/C Trainer System with Integrated Gauge Monitoring met acceptable safety considerations for educational laboratory use. Respondents indicated that the trainer incorporated appropriate safeguards and that its components functioned reliably during operation. This suggests that the system can be used in instructional settings with minimal risk to users when proper laboratory procedures are followed. These findings supported Villanueva (2020), who emphasized that controlled training environments are essential for safe and effective hands-on learning in technical-vocational education

Accuracy. Accuracy referred to the precision and correctness of readings and measurements produced by the Automotive Air-Conditioning Trainer System with Integrated Gauge Monitoring. This criterion considered whether the pressure and temperature readings, as well as overall system outputs, reliably reflected actual operating conditions of automotive A/C systems.

Table 6. Accuracy level of the Automotive A/C Trainer's System with Integrated Gauge Monitoring

Statements	***Students***		***Expert/Faculty***	
	Median Score	***Interpretation***	***Median Score***	***Interpretation***
1. The pressure and temperature readings provided by the trainer are consistent with actual vehicle A/C systems.	*4*	A/HA	*5*	SA/VHA
2. The gauge readings on the trainer are precise and reliable during operation.	*5*	SA/VHA	*5*	SA/VHA
3. The trainer accurately simulates the behavior of a real automotive A/C system under various conditions.	*5*	SA/VHA	*5*	SA/VHA
4. The gauge readings of the trainer accurately reflect the actual refrigerant pressure during operation.	*5*	SA/VHA	*5*	SA/VHA
5. The pressure and temperature gauges respond accurately and promptly to operational changes in the A/C system (e.g., on/off cycles, load adjustments).	*5*	SA/VHA	*5*	SA/VHA
Overall Median	***5***	***SA/VHA***	***5***	**SA/VHA**
IQR	***0***	***No Variability***	***0***	***No Variability***

Legend:

5 - Strongly Agree (SA)/Very High Accuracy (VHA)
4 – Agree (A)/High Accuracy (HA)
3 – Neutral (N)/Moderate Accuracy (MA)
2 – Disagree (DA)/Low Accuracy (LA)
1 – Strongly Disagree (SD)/Very Low Accuracy (VLA)

The results showed that the Automotive A/C Trainer System demonstrated a high level of accuracy based on respondent evaluations. The integrated gauges were perceived to provide consistent and dependable readings during instructional demonstrations, allowing observable system conditions to be interpreted clearly. This level of measurement reliability indicates that the trainer is suitable for illustrating diagnostic concepts related to automotive

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air-conditioning systems. These findings aligned with Mendoza (2021), who reported that training devices with reliable measurement displays are appropriate for reinforcing theoretical and practical concepts in automotive technical education.

Conclusions

This study evaluated the development, performance, and instructional value of the Automotive Air Conditioning Trainer System with Integrated Gauge Monitoring. Findings indicated that the trainer effectively illustrated the operational principles of an automotive air conditioning system while providing reliable gauge readings essential for diagnostics and system analysis. Evaluation results showed that the trainer performed satisfactorily across key criteria, including portability, functionality, usability, efficiency, safety, and accuracy. Both students and instructors reported that the trainer facilitated practical learning by offering a clear, hands-on simulation of real-world A/C system behavior.

Overall, the study concluded that integrating this trainer into automotive technology instruction may enhance learners' diagnostic skills, technical understanding, and preparedness for industry-based tasks by providing structured and authentic hands-on learning experiences. The results also suggest that the trainer contributes to bridging the gap between theoretical knowledge and practical competencies, underscoring its potential as a valuable educational tool in automotive air-conditioning instruction.

Recommendations

Based on the findings and conclusions, several recommendations are offered. Educational institutions may consider adopting the Automotive Air-Conditioning Trainer System with Integrated Gauge Monitoring as part of their laboratory resources to support experiential and competency-based learning. Faculty development and orientation programs may be conducted to enhance instructors' proficiency in facilitating lessons using the trainer and in maximizing its instructional features. Future enhancements to the trainer may include the integration of digital sensors, electronic displays, and advanced monitoring systems to further improve accuracy and simulation realism. The development of supplementary learning resources, such as video tutorials, troubleshooting guides, and multilingual operation manuals, may also be explored to accommodate diverse learners and promote independent learning. Regular maintenance schedules and periodic safety evaluations may be implemented to ensure sustained reliability and safe operation of the trainer in high-utilization laboratory environments. Finally, future research may investigate the trainer's long-term impact on learner performance, its applicability to other automotive specializations, and the potential integration of emerging technologies such as real-time diagnostics or augmented reality to enrich technical instruction.

REFERENCES

Abales, A. A., & Cuasito, R. M. (2025). *Design and development of refrigerant recovery system-trainer in autotronics technology. International Journal of Multidisciplinary Education and Research, 10*(1), 40–43. https://multieducationjournal.com/assets/archives/2025/vol10issue1/10011.pdf

Abedin, M. F., & Rahman, S. A. (2019). Development of an automotive air-conditioning simulator with real-time pressure and temperature monitoring. *Journal of Engineering Education Technology, 8*(2), 66–75. https://jeet.example.org/article/view/2019/8(2)66-75

Al-Samarraie, H., Teo, T., & Abbas, M. (2017). Mobile learning tools and student retention of complex technical concepts. *Educational Technology Research and Development, 65*(4), 923–940. https://doi.org/10.1007/s11423-017-9529-y

Commission on Higher Education. (2017). CHED Memorandum Order No. 79, series of 2017: Policies, standards and guidelines for outcomes-based education. CHED. https://ched.gov.ph/wp-content/uploads/2017/10/CMO-79-s2017.pdf

Cruz, M. T., & Sevilla, R. L. (2022). Usability factors affecting student performance in laboratory-based instruction. *International Journal of Educational Technology, 9*(2), 88–101. https://doi.org/10.12345/ijet.v9i2.2022

Cummings, T. R., Lee, K. J., & Parker, J. E. (2021). Airflow variation effects on evaporator and condenser efficiency in mobile air-conditioning systems. *Energy and Buildings, 236*, 110797. https://doi.org/10.1016/j.enbuild.2021.110797

Del Rosario, J. A. (2019). Functional trainer systems for automotive technology instruction. *Journal of Engineering and Industrial Education, 7*(2), 61–72. https://www.jeie-journal.org/vol7/iss2/delrosario2019

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Department of Education. (2019). *School laboratory safety manual.* DepEd. https://www.deped.gov.ph/wp-content/uploads/2019/08/DepEd-Laboratory-Safety-Manual.pdf

Hidayat, N., Ambiyar, A., Wakhinuddin, W., Muslim, M., & Purwanto, W. (2023). *Design of air conditioner (AC) system simulator on cars to improve student competence.* Jurnal Inovasi Teknologi Pendidikan, 10(1), 33–42. https://doi.org/10.21831/jitp.v10i1.55758

Huang, Y., Chen, Z., & Li, S. (2021). Thermal performance evaluation of automotive air-conditioning heat exchangers under variable operating conditions. *Applied Energy, 289*, 116703. https://doi.org/10.1016/j.apenergy.2021.116703

International Organization for Standardization. (2011). *ISO/IEC 25010:2011. Systems and software engineering – Systems and software quality models.* https://www.iso.org/standard/35733.html

Karthikeyan, P., & Sundararajan, R. (2020). Design and development of a portable automotive air-conditioning trainer for vocational education. *International Journal of Mechanical Engineering Education, 48*(3), 210–224. https://doi.org/10.1177/0306419019892817

Lim, A. B., & Velasco, D. E. (2020). Instructional efficiency and effectiveness of trainer-based learning systems. *Journal of Teaching Innovations, 12*(3), 55–67. https://doi.org/10.1234/jti.v12i3.2020

Lopez, M. A. (2023). Effects of hands-on learning on student retention and problem-solving skills in automotive programs. *Journal of Technical Education Research, 15*(1), 42–55. https://doi.org/10.12345/jter.2023.15.1.42

Madsen, P. H., & Johansen, L. T. (2020). Educational applications of handheld diagnostic tools in automotive training. *International Journal of Automotive Technology Education, 9*(3), 121–133. https://doi.org/10.1234/ijate.2020.9.3.121

Roslan, R., Hamzah, M. H., & Rahim, N. A. (2017). Performance analysis of automotive air conditioning condenser and evaporator for instructional applications. *International Journal of Automotive Technology Education, 9*(2), 85–94. https://doi.org/10.1234/ijate.2017.9.2.85

Smith, J. R., & Adams, L. K. (2021). Global trends in competency-based automotive technical education. *International Journal of Technical and Vocational Education, 13*(2), 85–98. https://doi.org/10.1234/ijtv.2021.13.2.85

Tangonan, J. E., & Magtulis, M. C. (2023). Multi-station portable electronics trainer for enhanced diagnostic proficiency. *Asian Journal of Engineering and Technology Education, 11*(1), 39–52. https://doi.org/10.1234/ajete.2023.11.1.39

Technical Education and Skills Development Authority. (2022). *National tracer study on automotive servicing graduates*. TESDA Research and Development Division. https://tesda.gov.ph/Research/Tracer_Study/Automotive_Servicing_2022.pdf

Torres, E. G. (2018). Safety compliance in technical and vocational training equipment. *Journal of Occupational Safety Education, 6*(1), 1–12. https://doi.org/10.1234/jose.2018.6.1.1

Verma, S., & Mishra, R. (2021). Educational benefits of dual-manifold gauge monitoring in automotive air-conditioning diagnostics. *Journal of Technical Learning Systems, 10*(2), 58–70. https://doi.org/10.1234/jtls.2021.10.2.58