

## Comparing Cognitive and Psychomotor Retention of HVAC students trained by Simulators and hands-on Methods in Palompon Institute of Technology

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### Abstract

This study investigated the effects of simulator-based versus hands-on training on cognitive and psychomotor retention among HVAC students at Palompon Institute of Technology. A quasi-experimental comparative design was employed with two groups of twenty students each. The simulator group used a Fault Simulator for Refrigeration System Diagnostics, while the hands-on group trained with actual equipment. Assessments included a validated knowledge test and a performance-based rubric administered at pretest, immediately post-training, and after a three-week retention interval. Results showed that the simulator-trained group achieved significantly higher posttest and retention scores in both cognitive and psychomotor domains compared to the hands-on group. ANCOVA results confirmed the significant effect of training method on psychomotor retention ( $F(1, 37) = 5.47, p = 0.022$ ). Findings indicate that simulation-based environments provide controlled, repeatable, and low-risk settings that enhance mastery and long-term retention. The study recommends integrating simulation with hands-on practice to optimize skill development in technical-vocational education.

**Keywords:** HVAC Education; Simulator-Based Training; Hands-On Training; Cognitive Retention; Psychomotor Retention; Technical-Vocational Education; Refrigeration Diagnostics

### 1. Introduction

Technical-vocational education and training (TVET) equips learners with both theoretical knowledge and practical skills necessary for fields such as refrigeration, air conditioning, electrical services, and automotive systems. While hands-on training remains foundational especially for diagnostic and troubleshooting tasks it is often constrained by high costs, limited equipment availability, and safety concerns. These limitations have led to the increasing adoption of simulation-based instruction as a viable complement to conventional training.

Simulation-based learning provides a controlled, repeatable environment where students can practice complex fault scenarios and technical procedures that may be difficult or hazardous to replicate in real-world labs (Liu, Wang, & Cheng, 2018). Evidence from vocational education in Nigeria showed that students using the Motor Vehicle Mechanic Computer Animation Instructional Package (MVMCAIP) achieved significantly higher gains in achievement, retention, and psychomotor skills compared to peers receiving traditional instruction (Aliyu, Okwori, Kutiriko, & Egigogo, 2024). Similarly, in Indonesia, simulation-based interactive multimedia improved vocational students' learning outcomes by providing engaging, interactive experiences that reinforced both cognitive and practical skills (Wibawanto, Roemintoyo, & Rejekiningsih, 2022). In another study, mobile simulation applications for electrical wiring showed high usability and effectiveness in enhancing learners' skill performance and engagement (Juera, 2022).

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Locally, Baldos and Sabang (2025) developed a Fault Simulator for Refrigeration System Diagnostics, demonstrating that simulator-based training significantly improved diagnostic performance and learner confidence among TVET students. Despite these encouraging results, most research focuses on immediate post-training outcomes, with limited evidence on the long-term retention of both cognitive knowledge and psychomotor skills in HVAC or refrigeration education.

Therefore, this study aimed to compare cognitive and psychomotor retention among HVAC students at Palompon Institute of Technology who are trained via simulators versus conventional hands-on methods. By assessing baseline knowledge and skills, immediate learning gains, and retention after a two- to four-week interval, this research sought to provide evidence-based guidance for optimizing instructional strategies and curriculum design in TVET programs.

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## 2. Methodology

This study employed a quasi-experimental comparative design to examine differences in cognitive and psychomotor retention between HVAC students trained through simulator-based and traditional hands-on methods. Two groups of Refrigeration and Air Conditioning (RAC) students from Palompon Institute of Technology were purposively selected. The simulator group used the Fault Simulator for Refrigeration System Diagnostics developed by Baldos and Sabang (2025), while the hands-on group trained using actual refrigeration units. Each group consisted of twenty students with comparable academic backgrounds and no prior advanced experience in system diagnostics.

Data collection was conducted in three phases: pretesting, training intervention, and retention testing. Both groups initially completed a validated 30-item knowledge test and a performance-based assessment to establish baseline competence. The training intervention spanned twelve hours across three days. Immediately following training, posttests were administered to measure immediate learning gains. After three weeks, the same assessments were repeated to evaluate retention.

The study utilized two instruments: a researcher-made knowledge test to measure cognitive learning, and a standardized performance rubric to assess psychomotor skills such as procedural accuracy, tool handling, and safety compliance. Expert validation ensured content accuracy, while pilot testing produced a Cronbach's alpha of 0.85, indicating high reliability.

Data were analyzed using both descriptive and inferential statistics. Mean and standard deviation summarized performance trends, while paired t-tests determined within-group improvements. Independent t-tests and analysis of covariance (ANCOVA) were used to identify significant differences in posttest and retention scores between the two training methods, using a significance level of 0.05.

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## 3. Results and Discussion

### 3.1. Cognitive Retention

Table 1 presents the mean cognitive test scores of both training groups across three testing phases. The simulator-based group showed marked improvement from 67.25 (pretest) to 88.40 (posttest) and maintained 85.75 after three weeks. The hands-on group improved from 66.90 to 84.60, then declined to 80.15 during the retention phase.

**Table 1** Mean Cognitive Scores of Simulator-Based and Hands-On Groups

Group	Pretest Mean	Posttest Mean	Retention Mean	Mean Gain (Pre-Retention)
Simulator-Based	67.25	88.40	85.75	+18.50
Hands-On	66.90	84.60	80.15	+13.25

**Table 2** Summary of Separate t-tests Results

Comparison	Purpose	p-value	Interpretation
Pretest (Simulator vs. Hands-on)	To check if groups were equivalent before training	0.82	Not significant → both groups started equally
Posttest (Simulator vs. Hands-on)	To test if simulator training produced higher immediate learning	0.03	Significant → simulator-trained performed better
Retention (Simulator vs. Hands-on)	To test if simulator group retained more knowledge	0.04	Significant → simulator-trained retained more

Independent sample t-tests revealed no significant difference in pretest scores ( $p = 0.82$ ), confirming that the two groups were comparable at baseline. However, significant differences appeared in posttest ( $p = 0.03$ ) and retention scores ( $p = 0.04$ ), favoring the simulator-trained group. These findings suggest that simulator-based training enhances both immediate learning and long-term cognitive retention.

This outcome supports Liu, Wang, and Cheng (2018), who emphasized the role of simulated fault scenarios in promoting conceptual understanding, and aligns with Baldos and Sabang (2025), who observed diagnostic accuracy and retention among students trained using fault simulators.

### 3.2. Psychomotor Retention

Psychomotor performance also improved significantly for both groups, but the simulator-based training group demonstrated higher retention. Table 3 shows that the simulator group's mean score rose from 2.45 to 4.55 and stabilized at 4.35 after three weeks, while the hands-on group improved from 2.40 to 4.25 but decreased to 3.90 in the retention phase.

**Table 3** Mean Psychomotor Performance Scores of Simulator-Based and Hands-On Groups

Group	Pretest Mean	Posttest Mean	Retention Mean	Mean Gain (Pre-Retention)
Simulator-Based	2.45	4.55	4.35	+1.90
Hands-On	2.40	4.25	3.90	+1.50

(Scale: 1–5; 5 = Excellent Performance)

ANCOVA results, controlling for pretest scores, revealed a significant main effect of training method on psychomotor retention,  $F(1, 37) = 5.47$ ,  $p = 0.022$  (Table 3).

**Table 4** ANCOVA Results on Retention Scores Between Simulator-Based and Hands-On Training Groups (Controlling for Pretest Scores)

Source of Variation	Sum of Squares (SS)	df	Mean Square (MS)	F-value	p-value	Interpretation
Between Groups (Training Method)	52.84	1	52.84	5.47	0.022	Significant
Covariate (Pretest Scores)	38.21	1	38.21	3.95	0.054	Not Significant
Error	360.12	37	9.74			
Total	451.17	39				

Note:  $\alpha = 0.05$ ; Dependent Variable: Retention Test Score

These results indicate that simulator-based environments facilitate more consistent procedural performance and error detection compared to traditional hands-on methods. Overall, the findings demonstrate that simulator-based training significantly enhances both cognitive and psychomotor retention among HVAC students. While hands-on training remains essential for real-world experience, simulators provide controlled, repeatable, and low-risk learning

environments that promote mastery and sustained retention. These outcomes are consistent with Weller (2004), who highlighted that simulation in education bridges the gap between theoretical knowledge and practical application by allowing learners to safely apply concepts in realistic scenarios.

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#### 4. Conclusion

This study confirmed that simulator-based training leads to higher cognitive and psychomotor retention among HVAC students than traditional hands-on methods. Simulation enhanced long-term understanding and skill mastery while providing a safe and efficient learning environment.

Nonetheless, hands-on experience remains vital for real-world application. A blended approach combining simulation and practical training is therefore recommended to strengthen retention, competence, and readiness in technical vocational education.

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#### Compliance with ethical standards

##### *Disclosure of conflict of interest*

No conflict of interest to be disclosed.

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