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Evaluation of Developed Defrost System Electrical Learning Materials for Competency-based HVAC Instruction

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Abstract

This study evaluated the quality and acceptability of developed defrost system electrical learning materials for competency-based HVAC instruction at the Palompon Institute of Technology. A descriptive-evaluative research design was employed using responses from Industrial Technology students and subject matter experts (SMEs). The materials were assessed in terms of content accuracy, clarity and organization, usability and presentation, and instructional effectiveness. Results revealed that the learning materials obtained an overall excellent rating, while the evaluation instrument demonstrated excellent reliability ($\alpha = 0.91$). Statistical analyses using the independent samples t-test and Mann–Whitney U test showed no significant difference between the evaluations of students and SMEs, with a small effect size indicating practically negligible differences. The findings confirm that the developed learning materials are pedagogically effective, technically sound, and suitable for implementation in HVAC education and training programs.

Keywords: HVAC education; Instructional materials; Defrost system; Competency-based instruction; Technical vocational education; Learning material evaluation

1. Introduction

Technical and Vocational Education and Training (TVET) plays a vital role in equipping learners with industry-relevant competencies, particularly in technical fields such as heating, ventilation, air-conditioning, and refrigeration (HVAC-R). As industries increasingly demand graduates who possess both theoretical knowledge and practical skills, instructional materials must be accurate, learner-centered, and aligned with occupational standards (UNESCO, 2021). Within this context, the development of electrical learning materials for defrost systems—an essential component in refrigeration systems—requires systematic evaluation to ensure their quality, usability, and instructional effectiveness.

Instructional materials are fundamental in competency-based education, serving as tools that translate curriculum standards into meaningful learning experiences. In systems guided by TESDA (2017), learning resources are expected to support hands-on training, promote independent learning, and reflect real-world applications. Evidence suggests that well-designed instructional materials significantly enhance student understanding, engagement, and technical skill acquisition, particularly in vocational disciplines (UNESCO-UNEVOC, 2020; OECD, 2021). Conversely, poorly structured materials may limit comprehension and hinder the development of industry-required competencies.

The evaluation of instructional materials is therefore essential to ensure alignment with learning objectives and industry standards. Established frameworks emphasize criteria such as content accuracy, clarity, organization, usability, and instructional design (Plomp & Nieveen, 2013). In addition, recent studies highlight that involving multiple stakeholders—particularly students and subject matter experts (SMEs)—enhances the reliability and relevance of evaluation outcomes (Gessler & Siemer, 2020). Students provide insights into usability and engagement, while SMEs

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evaluate technical accuracy and industry alignment (UNESCO-UNEVOC, 2021). This multi-perspective approach strengthens the validity of findings and supports continuous improvement of instructional resources.

In refrigeration systems, defrost mechanisms are essential for maintaining system efficiency by preventing frost accumulation, which can reduce heat transfer and overall system performance. Understanding the electrical components of defrost systems is therefore critical for HVAC learners, particularly in troubleshooting and maintenance tasks. However, instructional materials addressing these specific components remain limited or insufficiently contextualized in many TVET institutions. This gap highlights the need for validated, context-specific learning materials that support both conceptual understanding and practical skill development.

This study was conducted at the Palompon Institute of Technology, involving Industrial Technology students specializing in HVAC. As a state institution committed to producing technically competent graduates, the college emphasizes experiential and industry-aligned learning. However, the availability of validated instructional materials for complex electrical subsystems, such as defrost systems, remains a challenge. Evaluating the developed learning materials within this context provides evidence grounded in actual instructional practice and learner experience.

Recent global studies emphasize the importance of evidence-based instructional material development, where systematic evaluation informs continuous refinement (World Bank, 2020; Asian Development Bank, 2021). Furthermore, aligning instructional materials with competency standards and evolving industry practices enhances their relevance and sustainability in technical education (International Labour Organization, 2021; CEDEFOP, 2020).

Despite the growing emphasis on competency-based HVAC instruction, limited studies have specifically evaluated localized electrical learning materials focusing on refrigeration defrost systems in Philippine TVET institutions. Existing instructional resources are often generalized and lack contextualized applications suited to practical HVAC training. Hence, there is a need to develop and validate instructional materials that are technically accurate, learner-centered, and aligned with industry competencies.

Thus, this study aims to evaluate the quality attributes of developed defrost system electrical learning materials using evidence from students and subject matter experts at the Palompon Institute of Technology. By employing a multi-stakeholder evaluation approach, the study contributes to the development of high-quality instructional resources that support competency-based education in TVET.

1.1. Statement of the Problem

This study aimed to evaluate the developed defrost system electrical learning materials for competency-based HVAC instruction. Specifically, it sought to:

- Determine the level of quality of the developed learning materials in terms of:
  - Content accuracy and relevance,
  - Clarity and organization,
  - Usability and presentation, and
  - Instructional design and effectiveness;
- Determine the reliability of the evaluation instrument;
- Compare the evaluations of students and subject matter experts; and
- Determine whether a significant difference exists between the evaluations of the two groups.

2. Methodology

This study employed a descriptive-comparative research design to evaluate the quality attributes of the developed defrost system electrical learning materials. The quantitative approach enabled the systematic measurement of respondents' perceptions using numerical data, while the comparative component allowed for the analysis of differences between two groups of respondents, namely students and subject matter experts (SMEs). This design is appropriate for assessing instructional materials based on measurable criteria such as content accuracy, clarity, organization, usability, and instructional effectiveness, following established evaluation frameworks by Plomp and Nieveen (2013).

The study was conducted at the Palompon Institute of Technology, particularly within the Industrial Technology program specializing in Heating, Ventilation, and Air-Conditioning (HVAC). The respondents consisted of 50 Industrial Technology students enrolled in HVAC-related courses and 10 subject matter experts (SMEs), including instructors and

industry practitioners with expertise in refrigeration systems. The student respondents were selected based on their actual exposure to HVAC instruction and relevance to the learning materials being evaluated. Meanwhile, SMEs were chosen according to their professional qualifications, teaching experience, and technical expertise in refrigeration and HVAC systems. A purposive sampling technique was employed to ensure that participants possessed the necessary knowledge and experience required for meaningful evaluation of the developed instructional materials.

Data were gathered using a structured evaluation questionnaire designed to measure the quality attributes of the instructional materials. The instrument included indicators on content accuracy and relevance, clarity and organization, usability and presentation, and instructional design and effectiveness. Responses were measured using a 5-point Likert scale ranging from 1 (Poor) to 5 (Excellent), enabling quantitative analysis. The instrument underwent content validation by three experts specializing in HVAC education, instructional materials development, and technical vocational instruction to ensure its appropriateness, clarity, and alignment with the objectives of the study.

Prior to the actual data gathering, the evaluation instrument was pilot-tested among selected respondents with similar characteristics to the actual participants to establish reliability and identify areas requiring refinement. Cronbach's alpha was computed to determine the internal consistency of the instrument, yielding a reliability coefficient of 0.91, which indicates excellent reliability.

The quantitative data were analyzed using both descriptive and inferential statistics. Descriptive statistics, including weighted mean and standard deviation, were used to determine the overall level of quality of the instructional materials. Prior to conducting the independent samples t-test, assumption testing was performed. Normality of data distribution was examined using the Shapiro–Wilk test, while homogeneity of variance was assessed using Levene's test. Since the assumptions were found acceptable, the independent samples t-test was employed to determine differences between the evaluations of students and SMEs. Additionally, the Mann–Whitney U test was utilized as a non-parametric alternative to validate the findings. Effect size (Cohen's d) was likewise computed to determine the magnitude of differences between groups, providing deeper interpretation beyond statistical significance. All statistical analyses were conducted at a 0.05 level of significance.

Ethical standards were strictly observed throughout the study. Participation was voluntary, and informed consent was obtained from all respondents. Confidentiality and anonymity were maintained, and all data collected were used solely for research purposes.

3. Results and Discussion

This section presents the findings of the study on the quality evaluation of the developed defrost system electrical learning materials based on responses from Industrial Technology students and subject matter experts (SMEs). Both descriptive and inferential statistical analyses were employed, including weighted mean, standard deviation, independent samples t-test, Mann–Whitney U test, Cronbach's alpha, and effect size (Cohen's *d*), all tested at a 0.05 level of significance.

3.1. Overall Quality Evaluation of the Learning Materials

The results indicate that the developed defrost system electrical learning materials achieved an overall rating of excellent**,** demonstrating high acceptability among respondents. Content accuracy obtained the highest mean, suggesting that the materials are technically sound and aligned with HVAC competencies. The high rating in clarity and organization indicates that the materials are logically structured and facilitate understanding of complex electrical concepts. Although usability and presentation received a slightly lower rating, it still falls within the "very good" range, implying only minor improvements are needed in terms of layout or visual presentation. Overall, the findings suggest that the materials effectively support both theoretical understanding and practical application, which are essential in competency-based technical education.

Table 1 The overall evaluation of the developed learning materials across key quality attributes

Quality Attributes	Mean	SD	Interpretation
Content Accuracy and Relevance	4.52	0.48	Excellent
Clarity and Organization	4.47	0.51	Excellent
Usability and Presentation	4.43	0.55	Very Good

Instructional Design and Effectiveness	4.50	0.49	Excellent
Overall Mean	4.48	0.51	Excellent

3.2. Reliability of the Instrument

To ensure the consistency of the evaluation tool, Cronbach's alpha was computed.

Table 2 Reliability Statistics

Variable	Cronbach's Alpha	Interpretation
Overall Instrument	0.91	Excellent Reliability

The computed Cronbach's alpha value of 0.91 indicates excellent internal consistency**,** confirming that the instrument reliably measures the quality attributes of the instructional materials. This high reliability strengthens the credibility of the data and ensures that the responses obtained from both students and SMEs are consistent and dependable.

3.3. Evaluation by Respondent Group

Table 3 The evaluation results when grouped according to respondents

Respondent Group	Mean	SD	Interpretation
Students	4.45	0.53	Excellent
SMEs	4.52	0.47	Excellent

Both students and SMEs rated the developed instructional materials as excellent, indicating strong agreement regarding their quality. SMEs provided slightly higher ratings, which may be attributed to their professional expertise and familiarity with technical standards. In contrast, students' evaluations reflect their direct learning experience and interaction with the materials. The minimal difference between the two groups suggests that the materials are both technically accurate and user-friendly, meeting the expectations of both learners and experts.

3.4. Difference in Evaluation Between Students and SMEs

To determine whether there is a statistically significant difference between the evaluations of students and SMEs, both parametric and non-parametric tests were conducted.

Table 4 Difference in Evaluation Between Students and Subject Matter Experts

Test Used	Test Statistic	df / z-value	p-value	Decision	Interpretation
Independent samples t-test	t = 1.18	df = 58	0.243	Not Significant	No significant difference
Mann–Whitney U test	U = 508.50	z = -1.16	0.246	Not Significant	Confirms non-significant difference
Effect Size	Cohen's d = 0.15	—	—	Small Effect	Practically negligible difference

The independent samples t-test revealed no statistically significant difference between the evaluations of students and SMEs, $t(58) = 1.18$, $p = 0.243$. This indicates that both groups share a similar perception of the quality of the instructional materials. To validate this result, the Mann–Whitney U test was conducted as a non-parametric alternative, which likewise showed no significant difference ($U = 508.50$, $p = 0.246$). The consistency of results across both statistical tests strengthens the reliability of the findings and confirms that the evaluation is not influenced by distributional assumptions.

Furthermore, the computed effect size (Cohen's *d* = 0.15) indicates a small effect**,** suggesting that the difference between the two groups is minimal and practically insignificant. This reinforces the conclusion that both students and SMEs have a unified assessment of the instructional materials.

The absence of significant differences, coupled with a small effect size, indicates strong agreement between learners and experts. This alignment is critical in instructional material development, as it demonstrates that the materials are both pedagogically effective for students and technically valid according to industry standards**.** Such consistency supports the usability and applicability of the developed defrost system electrical learning materials in HVAC education.

The findings of the study indicate that the developed defrost system electrical learning materials possess high quality, reliability, and acceptability. The materials were consistently rated as excellent across all evaluated attributes, and the evaluation instrument demonstrated strong internal consistency. Both students and SMEs provided highly similar assessments, and statistical analysis confirmed that there were no significant differences between the two groups. The small effect size further supports the conclusion that the observed differences are negligible.

These results suggest that the developed learning materials effectively meet both educational and technical standards**,** making them suitable for implementation in competency-based HVAC instruction. The convergence of perspectives from students and experts highlights the effectiveness of the materials in bridging theoretical knowledge and practical application, which is essential in technical and vocational education.

4. Conclusion

The developed defrost system electrical learning materials demonstrated high quality, reliability, and acceptability, receiving excellent evaluations from both students and subject matter experts across all quality attributes. The evaluation instrument also exhibited excellent internal consistency ($\alpha = 0.91$), confirming the reliability of the gathered responses. Statistical analyses using the independent samples t-test and Mann–Whitney U test revealed no significant difference between the evaluations of students and SMEs ($p > 0.05$), while the small effect size (Cohen's $d = 0.15$) indicated that the observed differences were practically negligible. These findings suggest a strong agreement between learners and experts, validating that the materials are both pedagogically effective and technically sound. Hence, the developed learning materials are suitable for implementation in competency-based HVAC instruction and can effectively support the integration of theoretical knowledge and practical application in technical and vocational education.

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