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A multi-framework case study on advancing outcome-based education in Aircraft Maintenance Technology

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Abstract

Instructional quality in Aircraft Maintenance Technology (AMT) is essential for aviation safety, regulatory compliance, and workforce readiness. In the Philippines, Outcome-Based Education (OBE) implementation remains inconsistent, particularly in technical programs where cognitive objectives, practical training, and assessment strategies are often misaligned. This study developed and validated an integrated instructional framework that combines Bloom's Taxonomy, Competency-Based Training and Assessment (CBTA), and Kolb's Experiential Learning Theory (ELT). A qualitative case study approach was used, drawing data from curriculum documents, instructor interviews, and thematic analysis of instructional practices in a state-run AMT program. The findings revealed heavy reliance on lower-order thinking outcomes, limited experiential learning opportunities, and weak integration of CBTA principles. The proposed framework provides a structured model that connects theoretical knowledge with practical competencies while ensuring alignment with the standards of the Commission on Higher Education (CHED) and the International Civil Aviation Organization (ICAO). Key recommendations include sustained faculty development, redesign of assessment tools to emphasize performance-based outcomes, and institutional adoption of the framework as part of quality assurance mechanisms. Although this study focused on a single institution, the model is adaptable to other regulated technical and engineering programs. It also provides a basis for future multi-institutional validation, longitudinal evaluation of learning outcomes, and benchmarking instructional quality in global aviation education.

Keywords: *outcome-based education (OBE), competency-based training and assessment (CBTA), Bloom's taxonomy, experiential learning, aircraft maintenance technology (AMT)*

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1. Introduction

Aircraft Maintenance Technology (AMT) education is vital to aviation safety, operational efficiency, and regulatory compliance. As aircraft systems grow more complex and international training standards converge, institutions face increasing pressure to adopt performance-based instructional approaches aligned with global requirements. Outcome-Based Education (OBE) has become a preferred model for shifting pedagogy toward measurable, student-focused outcomes (Piyasena et al., 2023). Recent studies highlight its effectiveness in technical education, emphasizing the shift toward competencies rather than traditional knowledge-based instruction (Sunra et al., 2024). This transition is particularly urgent in Southeast Asia, where rapid aviation growth demands a highly skilled and mobile workforce.

The International Civil Aviation Organization (ICAO), through Doc 9868, and the Civil Aviation Authority of the Philippines (CAAP) have mandated Competency-Based Training and Assessment (CBTA) frameworks for AMT programs to ensure international compatibility and regulatory compliance (ICAO, 2020; CAAP, 2023). These reforms are further complemented by the ASEAN Qualifications Reference Framework (AQRF), which supports the standardization of educational outcomes across member states**.** Despite these mandates, OBE implementation in AMT and broader Technical and Vocational Education and Training (TVET) programs remains inconsistent. Persistent gaps remain between intended learning outcomes, instructional practices, and assessment mechanisms, especially in lab-intensive disciplines like AMT (Md Sin & Hussin, 2024). Many curricula continue to emphasize lower-order cognitive skills, with practical competencies often assessed poorly (Akella, 2018). Fragmented application of educational frameworks, such as Bloom's Taxonomy, CBTA, and Kolb's Experiential Learning Theory (ELT), further undermines instructional coherence and outcome-based reforms (Yaacoub et al., 2025). Existing OBE models also fall short in programs that require strong links between cognitive progression and real-world performance**.** Traditional approaches tend to focus on cognitive and assessment alignment but lack mechanisms to integrate experiential learning with stringent aviation competencies**.** Consequently, there is a clear need for an instructional model that unites cognitive, behavioral, and experiential domains in AMT education.

This study addresses the need by developing and validating a unified instructional model that integrates Bloom's Taxonomy, CBTA, and Kolb's ELT. Bloom's framework provides cognitive scaffolding (Kurukwar, 2022), CBTA establishes performance-based training standards (ICAO, 2021), and Kolb's ELT supports reflective, hands-on learning essential to AMT training (Kolb & Kolb, 2018). Although these models have each been validated individually, their integration as a combined framework specific to AMT has not been operationalized. This qualitative case study, conducted in a Philippine AMT program, seeks to fill that gap. Although context-specific, the study offers insights relevant to Southeast Asia and other regions aiming to align aviation maintenance education with international training standards.

The research is guided by three questions: (1) How are current AMT curricula aligned with the three frameworks? (2) What instructional and assessment gaps exist in implementing OBE in AMT programs? (3) How can an integrated multi-framework model support a more coherent and outcome-aligned AMT education system? The study is both theoretically and practically significant. It provides curriculum developers, educators, and policymakers with a replicable instructional model that supports regulatory alignment, institutional quality assurance, and workforce readiness. Theoretically, it contributes to the growing discourse on framework integration in competency-driven education, particularly in safety-critical, technically complex learning environments such as AMT.

2. Literature Review

2.1 CBTA and Bloom's Taxonomy Alignment

Integrating Bloom's Taxonomy with CBTA frameworks has proven effective in aligning educational practices with cognitive development and performance-based objectives. Research indicates that Bloom's structure facilitates the clear articulation of learning outcomes, instructional design, and formative and summative assessment planning across various disciplines (Tshering et al., 2025; Lau et al., 2018). It also facilitates the construction of AI-generated assessments and critical thinking activities that align with CBTA requirements, particularly in technical education and digital training environments (Yaacoub et al., 2025; Ramsoonder et al., 2020). Furthermore, Bloom's findings support constructive alignment between teaching methods and assessment criteria, which enhances learning effectiveness and promotes higher-order thinking (Jaiswal, 2019). The synergy between Bloom's method and CBTA ensures a more holistic and cognitively progressive instructional experience.

2.2 Experiential Learning Models in Aircraft Maintenance Training

Experiential learning models, particularly Kolb's Experiential Learning Cycle, are increasingly employed in aircraft maintenance training to improve skill acquisition and performance. The model's emphasis on concrete experience, reflective observation, abstract conceptualization, and active experimentation aligns well with the hands-on nature of maintenance education (Kolb & Kolb, 2018). Studies highlight its successful application in domains like radio navigation aid training and aeronautical lab activities (Rubio et al., 2023; Lehane, 2020). The use of mixed reality and augmented reality technologies has further enhanced engagement and learning retention in technical training contexts (Mustapha et al., 2021; Pai, 2020). Additionally, emerging tools such as machine learning for predictive maintenance are being explored to extend experiential models into data-driven learning environments (Al Hasib et al., 2023). However, challenges remain in terms of cost, instructor readiness, and curriculum integration, necessitating continued research to optimize implementation strategies (Morris, 2019; Tyagi et al., 2023).

2.3 Outcome-Based Education, Cognitive Skills, CBTA, and Experiential Learning in AMT: Synthesis and Critical Gaps

Despite clear mandates from CHED and ICAO, the practical implementation of OBE in AMT remains uneven, especially in the context of TVET. While regulatory documents such as ICAO Doc 9868 and CHED's standards articulate strong frameworks for competency development, significant barriers persist. Many AMT institutions struggle to align the intensive hands-on nature of lab-based training with the formal, outcome-driven demands of OBE (Ramsoonder et al., 2024). Challenges include not only inadequate institutional resources and limited faculty training in assessment design, but also the continued reliance on traditional, knowledge-based evaluation methods that fail to measure higher-order cognitive and technical growth.

Cognitive skill development is a recognized research priority, with Bloom's Taxonomy commonly used to scaffold learning objectives in aviation education. Yet, studies consistently show that most AMT curricula overemphasize lower-order skills, such as recall and comprehension, at the expense of analysis, evaluation, and creation (Akella, 2018; Swart & Daneti, 2019). Even recent innovations, including alternate taxonomies and cognitive audit tools, have yet to significantly shift the assessment culture towards fostering deeper, more transferable cognitive abilities (Ligale, 2025; Lourdusamy et al., 2022). The consequence is a persistent gap between intended learning outcomes and the real-world skills needed for safe and effective maintenance practice.

CBTA frameworks, introduced by ICAO and enforced by CAAP, are designed to bridge this divide by embedding performance-driven, criterion-referenced assessments in AMT programs (ICAO, 2020). However, their practical adoption faces resistance rooted in organizational culture, regulatory ambiguity, and faculty preparedness (Ziakkas et al., 2022; Vaskova Kjulavkovska et al., 2021). While some institutions are experimenting with integrations, such as Lean Six Sigma and AI to enhance assessment agility, systematic evidence of success is still limited. Furthermore, CBTA alone may neglect the cognitive and reflective dimensions essential for true professional competence.

Kolb's Experiential Learning Theory (ELT) offers a compelling foundation for integrating hands-on learning and reflection into AMT curricula. Its staged approach is particularly well-suited for lab-based and real-time troubleshooting tasks, supporting engagement and knowledge retention (Kolb & Kolb, 2018; Rubio et al., 2023). However, ELT's strengths are rarely leveraged holistically alongside cognitive and competency-based models; its application tends to remain isolated in experiential activities rather than systematically embedded across curricula and assessments.

Critically, the literature reveals that these foundational frameworks, Bloom's, CBTA, and Kolb's ELT, are rarely operationalized in concert within AMT education. Instead, their fragmented implementation leads to significant misalignments: lab activities may encourage active experimentation, but assessments often default to rote recall; CBTA may mandate observable skills, but overlook higher-order thinking and reflective practice. These silos limit the effectiveness of OBE and fail to deliver on the regulatory promise of truly industry-ready graduates. To address these intersecting gaps, this study argues for a unified, empirically validated instructional model that systematically integrates cognitive scaffolding, performance-based assessment, and experiential learning. By critically evaluating the shortcomings of current practice and the limitations of past research, the need for such an integrated framework becomes evident, not only for advancing educational theory, but for ensuring the regulatory and industry relevance of AMT training in safety-critical environments.

2.4 Theoretical Framework

This study is grounded in a multi-framework theoretical foundation that integrates the three frameworks. These were selected to address the fragmented instructional approaches commonly observed in AMT education and to develop a cohesive OBE model tailored to the cognitive, technical, and experiential demands of the aviation maintenance field. Bloom's Taxonomy serves as the cognitive backbone of the model, providing a hierarchical structure for articulating learning outcomes from basic recall to higher-order synthesis and evaluation (Jaiswal, 2019; Kurukwar, 2022). This taxonomy supports the alignment of instructional goals with assessment tools in AMT curricula.

CBTA, as defined by ICAO Doc 9868 and CAAP advisories, introduces performance-based criteria, behavioral indicators, and proficiency benchmarks essential to regulatory compliance and industry readiness (ICAO, 2021; Ziakkas et al., 2023). Its inclusion ensures that the instructional model emphasizes measurable competencies and standards-aligned evaluations. Kolb's ELT complements the cognitive and performance frameworks by emphasizing hands-on application, reflection, and iterative learning, critical components in lab-based and real-world maintenance tasks (Kolb & Kolb, 2018; Rubio et al., 2023). ELT reinforces the reflective and adaptive aspects of technical education, ensuring that learners engage meaningfully with the learning process. Together, these three frameworks form the basis for a unified instructional model that addresses cognitive progression, practical competency, and experiential integration, key dimensions for advancing Outcomes-Based Education (OBE) in Aircraft Maintenance Technology (AMT) programs.

Although Bloom's Taxonomy supports cognitive scaffolding (Kurukwar, 2022), CBTA ensures performance alignment (ICAO, 2021), and Kolb's ELT fosters experiential learning (Kolb & Kolb, 2018), these frameworks are frequently applied in isolation. The literature rarely explores an integrated instructional approach that operationalizes all three dimensions within AMT curricula. The fragmented application of these models has resulted in partial reforms that overlook holistic learning experiences, which are critical for technician training. This study addresses that gap by offering a unified instructional framework that aligns cognition, competency, and experience for OBE in AMT (see Table 1 for comparison of existing models and the proposed framework).

Table 1

Comparison of existing instructional models and the proposed integrated framework

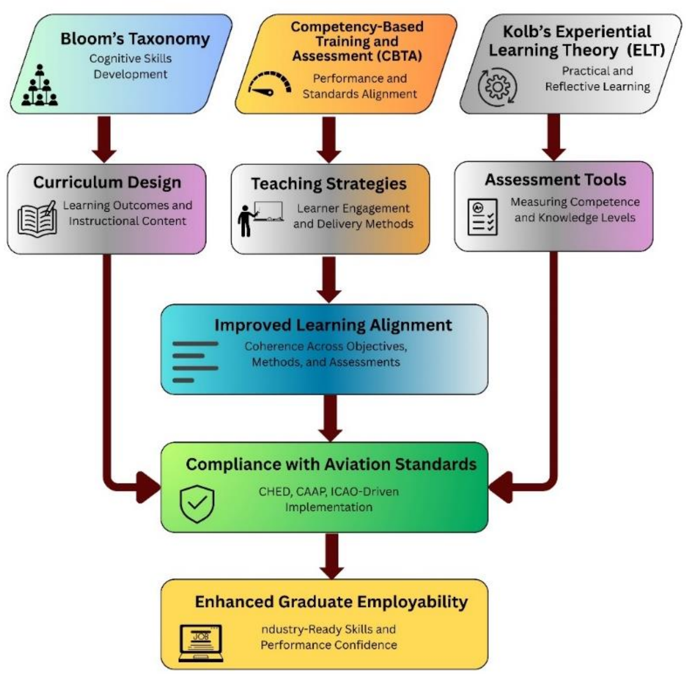
Instructional Model	Focus Area	Strengths	Limitations in AMT Context	Integration in Proposed Framework
Bloom's Taxonomy	Cognitive development	Explicit scaffolding of thinking levels	Lacks behavioral and hands-on dimensions	Used for defining learning outcomes and assessments
CBTA (Competency-Based)	Performance standards	Aligned to industry competencies	Often lacks a cognitive and reflective learning base	Aligns outcomes with observable performance
Kolb's Experiential Learning	Reflective practical learning	Supports hands-on lab work	Lacks formal cognitive hierarchy	Enables real-world learning flow
Proposed Integrated Model	Cognitive, Behavioral, Experiential	Unified instructional alignment	Yet to be empirically implemented	Combines all strengths for OBE in AMT

Table 1 shows that Bloom's Taxonomy, CBTA, and Kolb's model each address different aspects of learning but have gaps when used alone. The proposed integrated model combines their strengths, cognitive scaffolding, performance-based outcomes, and experiential learning, offering a unified approach better suited for OBE in AMT.

2.5 Conceptual Framework

Figure 1

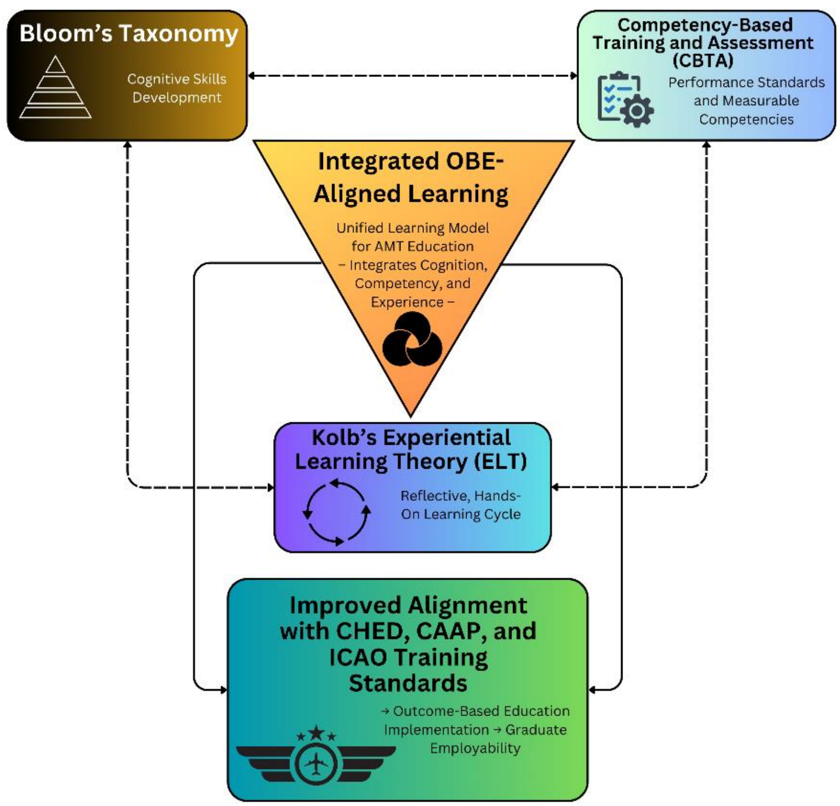
Conceptual framework for advancing outcome-based education in aircraft maintenance technology through multi-theoretical integration



The conceptual framework of this study is rooted in the integration of the three foundational models. These frameworks inform the analysis of curriculum documents, assessment tools, and pedagogical practices in AMT programs. As illustrated in Figure 1, the research investigates how each framework contributes to distinct but complementary domains of cognitive development, competency performance, and experiential engagement. Through triangulated data collection (document analysis, interviews, Delphi), the study aims to develop a validated instructional model that enhances OBE implementation in AMT education by aligning learning outcomes, instructional strategies, and assessment tools. This framework guides the methodological structure and anchors the interpretation of findings within both regulatory and pedagogical contexts.

Figure 2

Triadic conceptual model for AMT instructional alignment



To complement the structural framework in Figure 1, the triadic conceptual model in Figure 2 illustrates the integrated interplay between the three frameworks as guiding frameworks for instructional alignment in AMT OBE implementation.

3. Methodology

3.1. Research Design

This study adopts a qualitative case study design to explore and validate a multi-framework instructional model for advancing OBE in AMT. The case study approach is particularly suitable for examining complex educational practices in real-world settings, allowing for the contextual interpretation of pedagogical strategies, institutional mandates, and regulatory alignment (Yin, 2018). Given the need to synthesize multiple educational frameworks, this research employs a theory-driven, exploratory design that permits deep curriculum analysis, stakeholder input, and model validation.

To anchor the analysis, ten AMT courses were purposely selected based on two criteria: (1) compliance with CAAP licensure requirements under Philippine Civil Aviation Regulations (PCAR Part 3 and Part 6), and (2) institutional mandates essential to the technical and cognitive formation of aircraft maintenance graduates. These include foundational and system-based subjects such as reciprocating engines, turbine engines, hydraulic systems, aircraft structures and landing gears, sheet metal, propellers, fuels and lubricants, composites, and others specified in the list. The selected courses collectively represent the cognitive and psychomotor demands placed on AMT graduates and form the basis for assessing the alignment and gaps in current instructional practices.

The research site is a Philippine AMT institution offering CHED-compliant and CAAP-recognized programs. The case is instrumental in exploring how fragmented instructional approaches can be realigned through a unified, validated framework grounded in regulatory requirements and contemporary educational theory.

The integrated research design, drawing from Bloom's cognitive taxonomy, CBTA's outcome mapping, and Kolb's learning cycle, was operationalized through a case study framework. Figure 2 presents the research design flowchart, illustrating the methodological progression from framework integration to data collection, curriculum mapping, and synthesis of instructional implications.

3.2 Research Site

The study was conducted at two aviation training institutions in Pampanga, Philippines both offering AMT programs. These sites were chosen for their location within or near the Clark Freeport Zone, a major aviation and logistics hub with active Maintenance, Repair, and

Overhaul (MRO) facilities and training centers, providing authentic contexts for examining curriculum implementation and assessment practices under OBE and CBTA frameworks.

The use of two distinct institutional profiles, a private academic college and an industry-aligned aviation training organization, enables the study to explore variability in OBE implementation, particularly in terms of integrating cognitive, competency-based, and experiential learning frameworks. Both institutions represent real-world environments where AMT students are trained under regulatory pressures, practical constraints, and evolving educational reforms. Their contrasting approaches to instructional design provide an opportunity to test the adaptability and coherence of a proposed multi-framework instructional model rooted in the three frameworks.

3.3 Data Collection Methods

The study used three qualitative data collection methods—document analysis, semi-structured interviews, and the Delphi technique—to develop and validate a multi-framework instructional model for OBE in AMT. These methods enabled data triangulation across institutional records, stakeholder perspectives, and expert input, enhancing the credibility and applicability of findings.

Document analysis examined curricula, syllabi, assessment rubrics, and learning outcomes. Using deductive coding, the review assessed alignment with Bloom's cognitive levels, CBTA performance criteria (ICAO Doc 9868), and Kolb's experiential learning stages, identifying instructional inconsistencies and misaligned assessments.

Semi-structured interviews with AMT instructors and curriculum developers explored their understanding and application of OBE, integration of CBTA, and use of experiential learning in classroom, laboratory, and OJT settings. Thematic analysis of transcripts provided insights into current practices, alignment challenges, and barriers to framework integration.

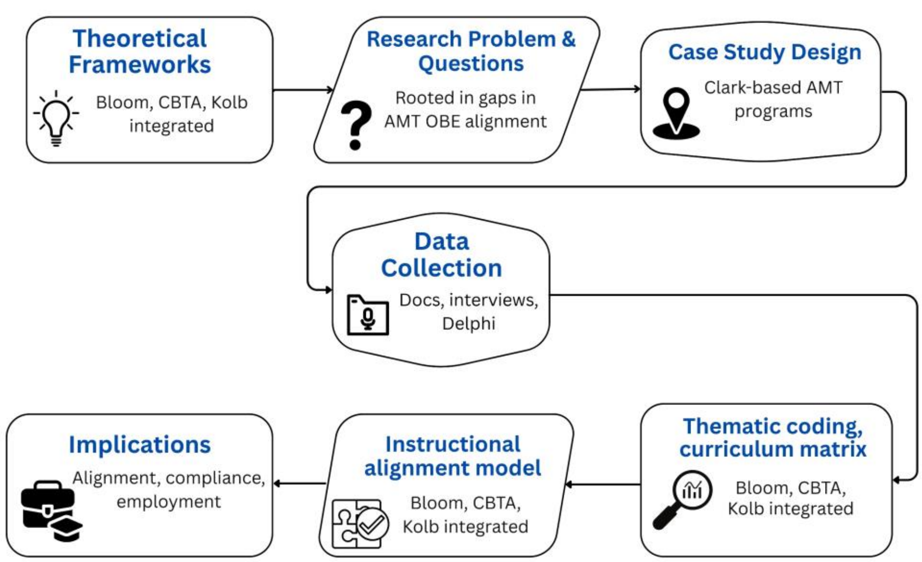
The Delphi technique validated the proposed instructional model through a two-round process with aviation education, regulatory, and instructional design experts. Round 1 involved evaluation of the model's coherence and regulatory alignment using a Likert scale and open-ended feedback. After revisions, Round 2 achieved consensus, defined as an interquartile range (IQR) ≤ 1. The results confirmed the model's theoretical robustness and practical feasibility for AMT curriculum reform.

3.4 Data Analysis

Data from institutional documents and interviews were analyzed using thematic coding and curriculum mapping to inform the development of the multi-framework instructional model. Thematic analysis followed Braun and Clarke's (2006) six-phase approach, involving familiarization with the data, coding, pattern identification, and theme definition. Coding was guided by elements of Bloom's cognitive progression, CBTA performance criteria, and Kolb's experiential learning cycle, enabling the identification of recurring instructional issues such as misaligned assessments, limited reflective practice, and insufficient higher-order cognitive outcomes. In parallel, a curriculum mapping matrix was applied to syllabi, learning outcomes, and assessment tasks. Each element was coded against Bloom's cognitive levels, CBTA performance domains (knowledge, skills, attitudes), and Kolb's learning stages (concrete experience, reflection, conceptualization, experimentation). This process highlighted gaps, including outcomes without matching assessments and practical activities lacking reflective components.

The integration of thematic coding and curriculum mapping provided a comprehensive view of alignment issues in AMT instruction. These analyses directly informed the refinement of the proposed instructional model. The study maintained theoretical and regulatory coherence by situating the case within Clark-based AMT programs operating under CHED and CAAP mandates. Figure 3 presents the research flow, illustrating the linkage between theoretical foundations, data collection, analysis, and model development.

Figure 3
Research design flowchart for a multi-framework case study on advancing OBE in AMT



3.5 Ethical Considerations

This study adhered to established ethical standards for educational research involving human participants and institutional data. As the home institution does not maintain a formal Institutional Review Board, the research was conducted in alignment with internationally recognized ethical principles and national data privacy regulations. Informed consent was obtained from all participants, including AMT instructors, curriculum developers, and expert panelists, after providing clear explanations of the study's objectives, data usage, voluntary participation, and the right to withdraw at any time without consequence.

To protect confidentiality, participant identities and institutional affiliations were anonymized in all outputs. Data collected through interviews and Delphi responses were coded and stored securely in password-protected digital files accessible only to the principal researcher. When curriculum documents and internal assessment tools were used, sensitive institutional information was carefully managed to avoid disclosure that could compromise academic or regulatory confidentiality.

Given the study's focus on technical-vocational education and civil aviation training, formal permissions were secured from relevant authorities, including the Commission on Higher Education (CHED) for curriculum access and the Civil Aviation Authority of the Philippines (CAAP) to ensure alignment with CBTA guidelines. All research activities complied with ethical research practices for educational settings and with national data privacy laws.

4. Results

4.1 Curriculum Mapping

The curriculum mapping analysis of CAAP PCAR Part 3-mandated AMT courses revealed a disproportionate emphasis on lower-order cognitive skills as defined by Bloom's Taxonomy**.** Table 2 displays both the absolute and percentage distribution of learning outcomes across Bloom's Taxonomy for each AMT course, enabling immediate comparison of cognitive emphasis. The final column highlights the proportion of outcomes addressing higher-order skills (analyze, evaluate, create), making visible the curriculum's strong bias toward lower-order domains and signaling priority areas for instructional reform. These findings suggest that while the foundational knowledge base is well-represented, the curriculum often falls short of promoting deep cognitive engagement.

Higher-order cognitive domains (analyze, evaluate, and create) are significantly underrepresented across several core subjects. For example, technical-intensive courses such as Hydraulic Systems, Sheet Metal, and Turbine Engines tend to reach the *Apply* level but rarely progress into tasks requiring evaluation or creative problem-solving. This limited scaffolding constrains students' opportunities to develop the critical thinking, diagnostic reasoning, and decision-making capabilities needed for safety-critical, real-world maintenance scenarios.

These findings are further illustrated in Figure 4, the curriculum mapping matrix. The matrix visually reinforces the cognitive imbalance through a gradient-coded heatmap, with darker clusters occupying the lower tiers of Bloom's hierarchy and visibly sparse shading in the higher-order cells. The absence of substantial alignment with the *Evaluate* and *Create* domains across most courses underscores the need for strategic curricular revisions. Integrating experiential learning models and competency-based strategies could close this gap by embedding more performance-driven, reflective, and creative tasks within core AMT instruction.

Table 2

Cognitive domain distribution of learning outcomes across AMT courses

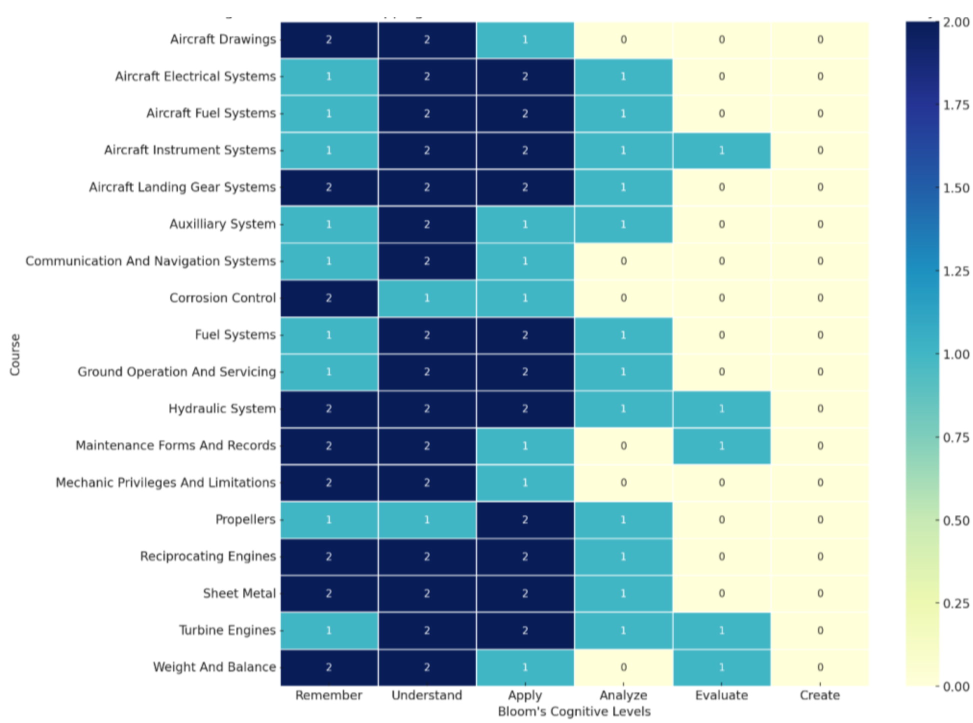
Course	Remember	Understand	Apply	Analyze	Evaluate	Create	Total Out-comes	Higher-Order % (Analyze+)
Aircraft Drawings	2 (40%)	2 (40%)	1 (20%)	0 (0%)	0 (0%)	0 (0%)	5	0%
Aircraft Electrical Systems	1 (16.7%)	2 (33.3%)	2 (33.3%)	1 (16.7%)	0 (0%)	0 (0%)	6	16.70%
Aircraft Fuel Systems	1 (16.7%)	2 (33.3%)	2 (33.3%)	1 (16.7%)	0 (0%)	0 (0%)	6	16.70%
Aircraft Instrument Systems	1 (14.3%)	2 (28.6%)	2 (28.6%)	1 (14.3%)	1 (14.3%)	0 (0%)	7	28.60%
Aircraft Landing Gear Systems	2 (22.2%)	2 (22.2%)	2 (22.2%)	1 (11.1%)	0 (0%)	0 (0%)	9	11.10%
Auxiliary System	1 (25%)	2 (50%)	1 (25%)	1 (25%)	0 (0%)	0 (0%)	5	25%
Communication & Navigation Systems	1 (33.3%)	2 (66.7%)	1 (33.3%)	0 (0%)	0 (0%)	0 (0%)	3	0%
Corrosion Control	2 (50%)	1 (25%)	1 (25%)	0 (0%)	0 (0%)	0 (0%)	4	0%
Fuel Systems	1 (16.7%)	2 (33.3%)	2 (33.3%)	1 (16.7%)	0 (0%)	0 (0%)	6	16.70%

Course	Remember	Understand	Apply	Analyze	Evaluate	Create	Total Out-comes	Higher-Order % (Analyze+)
Ground Operation and Servicing	1 (16.7%)	2 (33.3%)	2 (33.3%)	1 (16.7%)	0 (0%)	0 (0%)	6	16.70%
Hydraulic System	2 (22.2%)	2 (22.2%)	2 (22.2%)	1 (11.1%)	1 (11.1%)	0 (0%)	9	22.20%
Maintenance Forms and Records	2 (33.3%)	2 (33.3%)	1 (16.7%)	0 (0%)	1 (16.7%)	0 (0%)	6	16.70%
Mechanic Privileges and Limitations	2 (40%)	2 (40%)	1 (20%)	0 (0%)	0 (0%)	0 (0%)	5	0%
Propellers	1 (20%)	1 (20%)	2 (40%)	1 (20%)	0 (0%)	0 (0%)	5	20%
Reciprocating Engines	2 (22.2%)	2 (22.2%)	2 (22.2%)	1 (11.1%)	0 (0%)	0 (0%)	9	11.10%
Sheet Metal	2 (22.2%)	2 (22.2%)	2 (22.2%)	1 (11.1%)	0 (0%)	0 (0%)	9	11.10%
Turbine Engines	1 (14.3%)	2 (28.6%)	2 (28.6%)	1 (14.3%)	1 (14.3%)	0 (0%)	7	28.60%
Weight and Balance	2 (33.3%)	2 (33.3%)	1 (16.7%)	0 (0%)	1 (16.7%)	0 (0%)	6	16.70%

Table 2 shows that most AMT course outcomes focus on lower-order cognitive levels, particularly remember, understand, and apply. Higher-order skills such as analyze, evaluate, and especially create are rarely addressed. This indicates a need to redesign learning outcomes and assessments to promote advanced cognitive skills essential for complex maintenance tasks.

Figure 4

Curriculum mapping matrix for AMT courses based on Bloom's taxonomy



4.2 Interview Themes

Thematic analysis of semi-structured interviews with AMT instructors and curriculum developers revealed three prominent themes concerning the implementation of OBE in AMT programs: (1) instructor awareness and training gaps, (2) systemic barriers to OBE implementation, and (3) assessment misalignment.

Theme 1: Instructor Awareness and Training Gaps

Most participants demonstrated partial familiarity with the principles and practical application of OBE. While some could articulate the language of learning outcomes and competencies, they admitted uncertainty in aligning them with instructional strategies or assessment design. As one instructor noted, *"We know what outcomes are, but we are not always sure how to design activities or assessments that reflect them."* This indicates a disconnect between policy-level OBE mandates and actual instructional capabilities, suggesting the need for targeted faculty development programs that integrate OBE with frameworks such as Bloom's Taxonomy and CBTA.

Theme 2: Systemic Barriers to OBE Implementation

The participants identified several institutional and operational barriers that hinder the effective implementation of OBE. These included rigid syllabi formats, limited autonomy in instructional design, and inadequate access to instructional resources. Instructors also cited time constraints, large class sizes, and outdated training equipment as persistent challenges. A curriculum coordinator expressed concern: *"We try to revise outcomes to fit CAAP and OBE, but there is no support for updating lab activities or tools—it stays theoretical."* These systemic issues prevent instructors from fully operationalizing outcome-based pedagogy in practice.

Theme 3: Assessment Misalignment

There was broad agreement that current assessment practices remain predominantly written and knowledge-based, with minimal linkage to course outcomes or actual competencies required in the field. Several instructors acknowledged that performance-based tasks are informal or inconsistently evaluated. One respondent stated, *"Sometimes we ask students to do practical work, but we do not have a rubric tied to learning outcomes—it is* *more on the spot."* This highlights a significant gap in aligning assessment methods with both Bloom's higher-order domains and CBTA's task-based performance benchmarks.

As shown in Table 3, three major themes emerged from the interviews with AMT instructors and curriculum developers: instructor awareness and preparedness, implementation barriers, and assessment misalignment. These themes were consistently observed across participants and highlight both institutional and instructional challenges in adopting a fully integrated OBE framework.

Table 3

Thematic coding matrix of interview responses on OBE implementation in AMT education

Theme	Description	Sample Quote
Instructor Awareness	Limited understanding of OBE mechanics and assessment strategies	*"We follow outcomes, but are not always sure how to link them to teaching."*
Systemic Barriers	Institutional constraints and a lack of training tools hinder practical application.	*"Outcomes are written well, but we lack the tools to support them."*
Assessment Misalignment	Disconnection between course outcomes and assessment practices	*"We rarely use rubrics for hands-on activities."*

Table 3 shows three key themes from interviews: limited instructor understanding of OBE, institutional barriers such as inadequate training tools, and misalignment between course outcomes and assessments. These issues highlight the need for faculty training, better resources, and improved assessment practices to effectively implement OBE in AMT education.

4.3 Delphi Validation

The proposed multi-framework instructional model underwent a Delphi validation process involving a panel of seven aviation education experts. The panel reviewed the core components of the model and evaluated their relevance, clarity, and applicability in AMT training.

As illustrated in Figure 5, the components "Clear Learning Outcomes," "Bloom-CBTA Alignment," and "Regulatory Alignment (CAAP/ICAO)" received the highest median rating of 5, with low interquartile ranges (IQR = 0–1), indicating strong consensus among the experts. This reflects shared agreement on the foundational importance of regulatory compliance and outcome-based structuring in AMT instruction. Other components, such as "Experiential Integration (Kolb)," "Assessment Strategies," and "Scalability across Institutions," received slightly lower median ratings of 4, with interquartile range (IQR) values of 1. These scores indicate moderate consensus and suggest areas where further clarification, contextual adaptation, or implementation strategies may be necessary.

Table 4 summarizes the expert feedback using median scores and interquartile ranges (IQRs), reinforcing the overall validation of the model while highlighting key areas for refinement. The consistency of the responses across the two Delphi rounds suggests that the model is not only theoretically sound but also practically acceptable for diverse aviation training contexts.

Table 4

Summary of Delphi panel ratings and interquartile ranges

Instructional Component	Median Rating	IQR
Clear Learning Outcomes	5	0
Bloom-CBTA Alignment	5	1
Experiential Integration (Kolb)	4	1
Assessment Strategies	4	1
Regulatory Alignment (CAAP/ICAO)	5	0
Practical Applicability	4	1
Scalability across Institutions	4	1

Figure 5

Delphi panel ratings of instructional model components based on median scores and Interquartile Ranges (IQR)

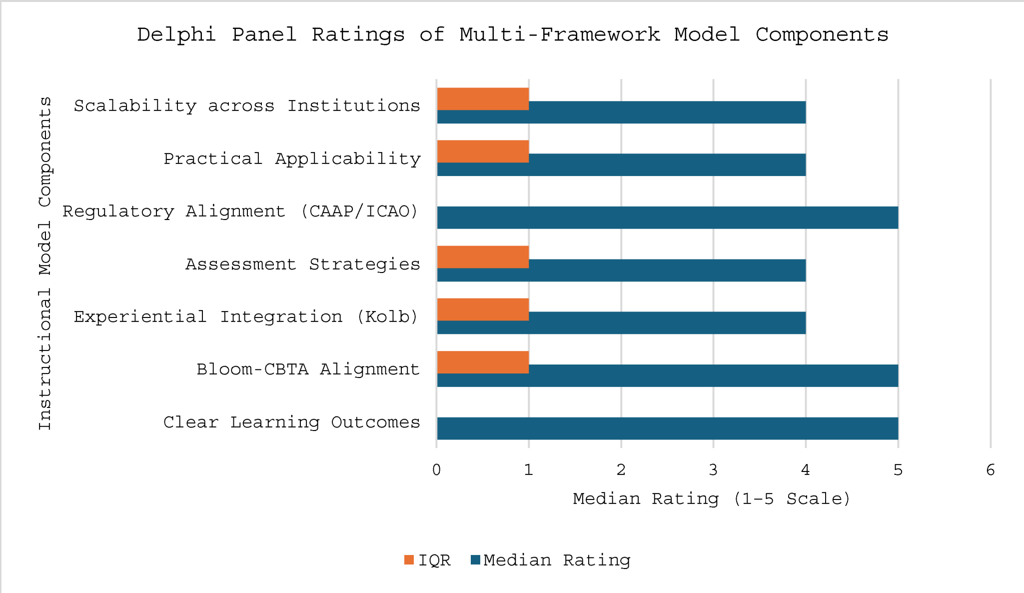
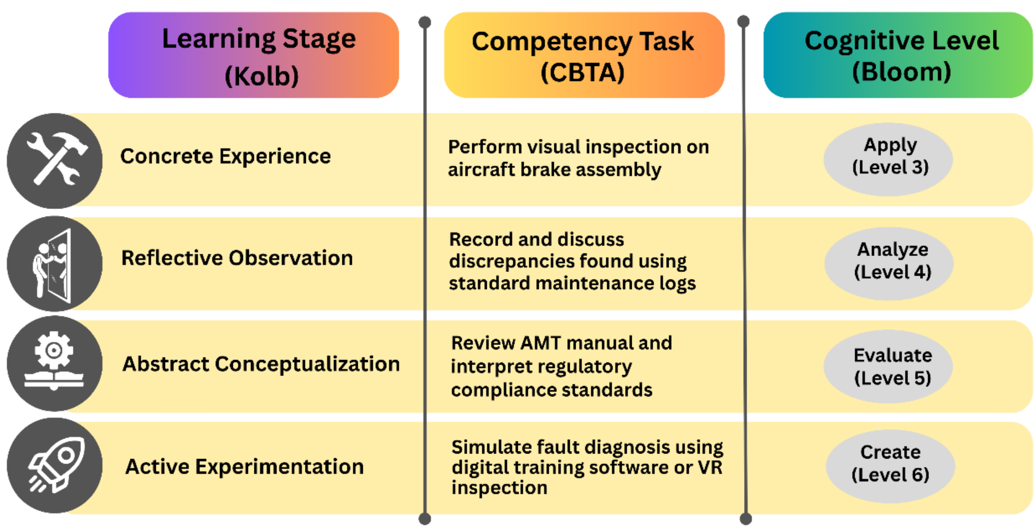


Table 4 shows strong Delphi panel agreement on key instructional components. Clear learning outcomes and regulatory alignment received the highest consensus (median = 5, IQR = 0). Bloom-CBTA alignment, experiential integration, assessment strategies, practical applicability, and scalability were rated positively (median = 4–5, IQR = 1), confirming the model's relevance and feasibility.

To demonstrate its practical application, a curriculum map excerpt was developed showing how the proposed multi-framework model can be implemented in a typical AMT lesson. The example integrates Kolb's learning cycle, CBTA performance tasks, and Bloom's cognitive levels in a structured competency unit (see Figure 6).

Figure 6

Sample Application of the Integrated Bloom–CBTA–Kolb Model in an Aircraft Maintenance Competency Unit



5. Discussion

5.1 Cognitive Gaps in AMT Curriculum

The mapping analysis exposes a systemic reliance on lower-order cognitive outcomes within AMT curricula, with most learning objectives restricted to the "Remember" and "Understand" domains of Bloom's Taxonomy. This pattern, corroborated by both the mapping matrix (Figure 3) and content analysis (Table 1), reflects a broader trend in technical-vocational education, where mastery of factual knowledge is prioritized over the cultivation of analytical, evaluative, and creative skills (Kurukwar, 2022; Swart & Daneti, 2019). Crucially, this cognitive stagnation undermines graduates' capacity for complex troubleshooting and decision-making in high-stakes maintenance environments. The persistent focus on foundational knowledge may be rooted in both historical curriculum design and entrenched instructional norms, suggesting that systemic change requires not only updated syllabi but a shift in institutional culture toward valuing higher-order thinking as essential for aviation safety and operational excellence.

5.2 Assessment Misalignment

The interviews reveal a pronounced disconnect between stated learning outcomes and assessment practices. While instructors are nominally aware of OBE principles, assessment remains heavily weighted toward traditional written exams and rote knowledge recall. This disconnect is not simply a pedagogical oversight, but a structural issue: the absence of clear rubrics for practical tasks and limited exposure to authentic performance-based assessment create a gap between regulatory aspirations and classroom realities (Akella, 2018; Ramsoonder et al., 2020). This finding signals that effective reform cannot be achieved by curricular mandates alone; rather, targeted faculty development and capacity-building in assessment literacy are urgently needed. Moreover, without robust mechanisms to ensure that assessments genuinely measure critical thinking and hands-on competencies, efforts to advance OBE in AMT risk superficial compliance, failing to deliver meaningful improvements in student learning or industry readiness.

5.3 Framework Integration and Instructional Blind Spots

Analysis across data sources uncovers how isolated implementation of educational frameworks perpetuates instructional blind spots. Bloom’s Taxonomy, when used alone, structures cognitive development but leaves practical and behavioral outcomes underemphasized. Conversely, CBTA strengthens regulatory compliance and performance assessment but may neglect the cultivation of reflective or innovative thinking required in emergent maintenance scenarios. Kolb’s Experiential Learning Theory, despite its proven value in hands-on domains, often operates at the periphery of formal curricula, lacking integration with cognitive progression and regulatory benchmarks. The high consensus among Delphi panelists (median = 5.0; IQR $\leq$ 1) on the value of an integrated model underscores a critical insight: no single framework suffices. Only by synthesizing cognitive, performance-based, and experiential elements can instructional design in AMT achieve the coherence necessary for producing workforce-ready, adaptable graduates in a safety-critical industry.

5.4 Implications for Curriculum Designers

These findings call for a fundamental shift in curriculum development and instructional strategy. The evidence suggests that merely updating content or introducing sporadic practical tasks is insufficient. Instead, AMT programs must operationalize an integrated model that intentionally aligns higher-order cognitive objectives, authentic assessments, and experiential learning cycles. Such alignment supports not only compliance with CHED, CAAP, and ICAO standards but also enhances students' adaptive capacity in unpredictable operational contexts. For curriculum designers, this means prioritizing faculty training in multi-framework instructional design, investing in assessment literacy, and embedding reflective and problem-based learning throughout the curriculum. In the long term, this integrated approach can serve as a template for broader reforms in technical education, supporting both regulatory mandates and industry transformation.

5.5 Policy, Regulatory Alignment, and Benchmarking

Table 5

Comparative benchmarking of CBTA/OBE implementation in aviation training across selected countries

Country	Key CBTA/OBE Practices	Relevance to Proposed Model
Philippines	Multi-framework approach integrating Bloom's Taxonomy, CBTA, and Kolb's ELT into AMT curricula	Serves as a pilot model for unified OBE-CBTA implementation in technical programs
Singapore	ICAO Regional Training Centre of Excellence; ISO-certified CBTA programs at SAA	Demonstrates structured competency frameworks and international certification
Malaysia	IATA CBTA Center alignment for Dangerous Goods and aviation training providers	Highlights standardized competency mapping and modular curriculum implementation
Canada	Integration of CBTA and Evidence-Based Training (EBT) with emphasis on human factors and adaptive learning	Reinforces multi-framework alignment with performance-based, flexible assessments

Sources*:* Authors (2025); CAAP (2023)

The multi-framework model directly addresses the intersection of national and international policy priorities in technical education. By grounding the benchmarking analysis (Table 5) in original data from curriculum mapping, faculty interviews, and policy review, the study not only clarifies the source and relevance of each country case but also demonstrates the evidentiary basis for the Philippine approach. Comparative benchmarking with Singapore, Malaysia, and Canada reveals that successful systems integrate cognitive progression, competency mapping, and experiential strategies to foster both compliance and innovation. The study's integrated model positions Philippine AMT education as globally relevant and adaptable, providing a roadmap for harmonizing training standards across ASEAN and beyond. Institutionalizing this model within ATO manuals and quality assurance protocols supports audit readiness and regulatory compliance while simultaneously driving pedagogical innovation and continuous improvement.

In addition to national reforms, the proposed model presents strong export potential. It can be incorporated into Part 147 Approved Training Organization (ATO) manuals as a structured reference for aligning teaching, learning, and assessment with internationally recognized competency standards. This integration ensures that instructional materials meet the required benchmarks for certification and licensing, thereby enhancing audit readiness and instructional quality. Moreover, the adaptable and modular design of the framework supports its adoption by other ASEAN-based AMT institutions, particularly those undergoing curricular reforms aligned with the ASEAN Qualifications Reference Framework (AQRF). By demonstrating alignment with global best practices, this study reinforces the broader applicability of the proposed instructional model to improve curriculum design and workforce readiness in aviation education worldwide.

6. Conclusion

This study proposed and validated a multi-framework instructional model that integrates Bloom's Taxonomy, Competency-Based Training and Assessment (CBTA), and Kolb's Experiential Learning Theory to enhance the design and delivery of Outcome-Based Education (OBE) in Aircraft Maintenance Technology (AMT) programs. Through curriculum mapping, qualitative interviews, and Delphi expert validation, the findings revealed systemic cognitive imbalances, assessment misalignments, and limited experiential scaffolding in current AMT instruction. The integrated framework offers a cohesive structure that connects theoretical knowledge with practical application, regulatory standards with instructional delivery, and cognitive development with hands-on proficiency. It enables curriculum designers to align syllabi with ICAO and CHED mandates while simultaneously cultivating higher-order thinking, critical evaluation, and workplace readiness, core competencies in safety-critical aviation environments.

Beyond AMT, this model holds promise for broader application in other technical domains within aviation education, including avionics, pilot training, and airport operations, where performance-based standards and experiential learning are equally vital. Its modular and scalable design allows for contextual adaptation across disciplines while maintaining fidelity to international training standards. Importantly, while the present study is situated in the Philippine context, the framework is grounded in globally recognized CBTA and OBE principles, ensuring its transferability to other ICAO- and EASA-aligned jurisdictions. The benchmarking comparisons with Singapore, Malaysia, and Canada demonstrate that similar CBTA practices are already embedded in advanced aviation training systems. These parallels reinforce that the proposed model can serve as a template for institutions seeking to strengthen regulatory compliance, outcome alignment, and competency-based instruction in diverse settings.

In the European and broader global context, the model contributes to ongoing efforts to harmonize engineering education with international quality frameworks such as the European Qualifications Framework (EQF) and EASA Part-66 requirements. By integrating experiential and competency-based approaches with cognitive progression, the framework provides a replicable and adaptable blueprint for enhancing curriculum design and workforce readiness. It addresses both pedagogical alignment and regulatory compliance, supporting evidence-based reforms in aviation and other technical education programs worldwide that face similar pressures of globalization, industry alignment, and accountability for student outcomes.

To implement the validated multi-framework instructional model and address gaps in AMT curriculum design and delivery, four key actions are recommended.

First, prioritize faculty development through sustained training on cognitive domain progression and competency-based instructional design. Educators should be equipped to integrate Bloom’s higher-order thinking skills into lesson planning, practical activities, and assessments while becoming familiar with ICAO CBTA standards, including performance criteria and evidence-based assessment.

Second, redesign assessment systems to ensure alignment with both cognitive levels and competency outcomes. Traditional knowledge-based exams should be complemented or replaced with authentic, performance-based assessments that reflect real maintenance tasks, as demonstrated by the sample outcome realignments in this study.

Third, formally integrate the validated model into institutional quality assurance frameworks. Adoption may include policy updates, curriculum committee endorsement, inclusion in accreditation documents, and regular evaluation of implementation effectiveness to strengthen compliance with CHED's OBE policies and ICAO/CAAP requirements.

Finally, pilot and validate the framework in other ASEAN and ICAO-recognized training institutions to enhance its generalisability. Cross-institutional application would enable benchmarking, adaptation to diverse regulatory contexts, and evidence gathering on effectiveness, supporting alignment with the ASEAN Qualifications Reference Framework (AQRF) and global standards set by ICAO and EASA.

Collectively, these actions will help produce AMT graduates who are academically prepared, operationally competent, and globally aligned, while establishing a transferable model for broader aviation education reforms.

While this study offers a validated multi-framework instructional model with substantial practical and theoretical implications, several limitations must be acknowledged. The research was conducted as a single-case study, situated within a single region and a limited number of Aircraft Maintenance Technology (AMT) institutions in the Philippines. As such, the findings, although rich in contextual depth, may not be immediately generalizable to broader national or international settings. The qualitative nature of the study, centered on document analysis, stakeholder interviews, and Delphi validation, also limits the capacity to quantify the effectiveness of the proposed model in terms of learning gains or performance metrics.

Future research should focus on piloting the validated multi-framework model in real classroom and laboratory environments to assess its impact on student learning outcomes, instructional quality, and regulatory compliance. Quantitative validation through experimental or quasi-experimental designs is recommended to measure gains in cognitive performance, competency attainment, and graduate readiness. Additionally, integration with digital learning platforms and simulation-based instruction should be explored to enhance engagement, practical realism, and performance tracking.

To broaden applicability, international benchmarking studies should compare curriculum alignment and instructional practices across ICAO-aligned and ASEAN-based aviation institutions. Longitudinal investigations that monitor model implementation and sustainability over time can also offer insights into policy integration, institutional adoption, and instructional refinement. These research directions help establish the model's generalizability and support evidence-based advancements in global aviation education.

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Institutional Review Board Statement

The institution where this study was conducted does not maintain a formal Institutional Review Board. Nevertheless, the research followed established ethical principles including the Declaration of Helsinki and complied with national data privacy laws. Informed consent was obtained from all participants, and confidentiality was strictly maintained throughout the research process.

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