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INTEGRATING ADDIE AND COMPETENCY-BASED ASSESSMENT FOR STUDENT PILOT PERFORMANCE EVALUATION

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Abstract: This study develops and evaluates a structured assessment model integrating the ADDIE instructional design framework with competency-based evaluation to improve student pilot performance measurement. The research applies a research and development approach involving design validation, limited trials, and implementation in flight training. The proposed model, SIM-FLIGHT, assesses both technical and non-technical competencies, including flight performance, safety awareness, and decision-making skills. Data were collected using validated assessment instruments and analyzed through pretest–post-test comparison, N-Gain analysis, and statistical testing. The results indicate a significant improvement in overall student performance, particularly in non-technical competencies, demonstrating the effectiveness of a systematic and measurable evaluation framework. The findings suggest that integrating structured instructional design with competency-based assessment enhances objectivity, feedback quality, and training outcomes in aviation education.

Keywords: ADDIE model, aviation education, competency assessment, flight training, student pilots

Introduction

The rapid development of aviation technology and increasing safety standards demand structured and measurable training systems for student pilots. Aviation education institutions are required not only to ensure technical flight proficiency but also to cultivate non-technical competencies such as safety awareness, aeronautical decision-making, and situational judgment. These competencies are essential for reducing human-factor-related incidents, which remain a dominant contributor to aviation accidents. Therefore, training evaluation systems must be systematic, objective, and aligned with competency standards. (Dattel et al., 2022)

In many flight training programs, assessment practices still rely heavily on instructor judgment without a standardized instructional design framework. Although competency-based training has been widely adopted in aviation education, the evaluation process often lacks structured development stages, measurable indicators, and validated instruments. Previous studies have emphasized the importance of competency-based assessment in improving pilot performance (Ziakkas et al., 2022), while instructional design frameworks such as ADDIE (Analysis, Design, Development, Implementation, and Evaluation) have been recognized as effective models for systematic learning development. However, limited research has integrated

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the ADDIE framework directly into competency-based assessment models specifically for student pilot performance evaluation. (Prayitno et al., 2025) (Patel et al., 2018)

The gap between structured instructional design and practical competency evaluation creates challenges in ensuring objectivity, consistency, and measurable learning outcomes. Without a clear developmental framework, assessment tools may not fully reflect competency standards or provide constructive feedback for performance improvement. This situation highlights the need for an integrated model that combines systematic instructional design with measurable competency indicators tailored to aviation training contexts.(Konrad et al., 2022)

This study proposes an integrated assessment model, SIM-FLIGHT, developed by combining the ADDIE framework with competency-based evaluation principles. The model is designed to assess both technical competencies (flight maneuver execution and procedural compliance) and non-technical competencies (safety awareness, decision-making, and situational management). By embedding competency indicators within each ADDIE phase, the model ensures alignment between training objectives, instructional strategies, and performance evaluation. (Dapica et al., 2022) (Saastamoinen & Maunula, 2021)

The objectives of this research are: (1) to develop a structured assessment model integrating the ADDIE instructional design framework and competency-based evaluation for student pilot training; (2) to validate the feasibility and reliability of the developed assessment instruments through expert judgment and limited trials; and (3) to evaluate the effectiveness of the SIM-FLIGHT model in improving student pilot performance in simulator-based training (Konrad et al., 2022). These objectives guide the development, validation, implementation, and evaluation stages of the study, and are addressed systematically in the discussion and conclusion sections.

The significance of this research lies in its contribution to aviation vocational education by providing a structured, objective, and measurable assessment framework. The integration of instructional design principles with competency-based evaluation is expected to enhance assessment transparency, improve feedback quality, and support continuous performance improvement in pilot training institutions. Ultimately, the proposed model contributes to strengthening training effectiveness and promoting higher safety standards in aviation education.(Suyatmo et al., 2025)

The conceptual integration of the ADDIE instructional framework and competency-based assessment principles in the SIM-FLIGHT model is illustrated in Figure 1.

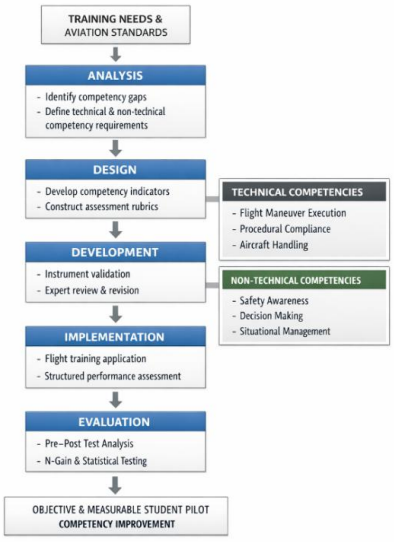

Figure 1. Integrated SIM-FLIGHT Conceptual Model

Method

This study employed a Research and Development (R&D) design with a quantitative approach to develop, validate, and evaluate the SIM-FLIGHT (Simulated Integrated Model for Flight Competency Training) assessment model. The R&D process was organized using the ADDIE framework, consisting of Analysis, Design, Development, Implementation, and Evaluation phases. This design was selected because it allows the assessment model to be developed systematically, validated by experts, and tested empirically in an authentic simulator-based aviation training context. (Rotger et al., 2024)

The research was conducted at the Indonesian Aviation Academy Banyuwangi during the implementation period of the Private Pilot License (PPL) simulator training program. The research subjects were 60 cadet pilots enrolled in the PPL program, selected using total sampling because all cadets participating in the relevant simulator training cycle were included in the study. The object of the research was the SIM-FLIGHT assessment model, which integrates ADDIE-based instructional design with competency-based assessment indicators for evaluating student pilot performance. (Prayitno et al., 2024)

The Analysis phase was conducted to identify gaps in conventional simulator training and assessment practices, particularly the limited use of structured instruments for evaluating both technical and non-technical competencies. The Design phase focused on formulating competency indicators, simulator-based learning scenarios, assessment rubrics, and instructor guidance. The Development phase involved preparing the SIM-FLIGHT instructional modules, standardized simulator scenarios, performance assessment rubrics, and validation sheets. Content validation was carried out by three experts, consisting of a senior flight instructor, a vocational aviation education academic, and a Redbird FMX1000 simulator practitioner. Expert feedback was used to revise the model, improve the clarity of competency indicators, strengthen the measurability of rubric items, and enhance the objectivity of instructor assessment.

The Implementation phase was conducted through structured simulator training using the Redbird FMX1000 full-motion simulator. Each cadet completed simulator-based training totalling 10 hours, consisting of briefing, scenario execution, performance observation, and debriefing sessions. Instructor procedures were standardized to ensure consistency in the delivery of training scenarios and the use of assessment rubrics. The assessed competency indicators consisted of Safety Awareness (SA), Decision Making (DM), and Flight Performance (FP), representing both non-technical and technical aspects of student pilot performance. (Ziakkas et al., 2022)

Data were collected using several techniques. Observation was used to assess cadet performance during simulator training based on structured performance rubrics. Documentation was used to record pretest and post-test scores, simulator training records, and expert validation results. Expert judgment was used to evaluate the content validity and feasibility of the SIM-FLIGHT model and assessment instruments. In addition, instructor feedback obtained during the limited trial was used to refine the model before full implementation.

A pretest–post-test design was used to measure changes in cadet competency before and after the implementation of the SIM-FLIGHT model. The pretest was administered prior to the intervention to determine baseline competency levels, while the post-test was conducted after completion of all simulator training sessions using the same assessment indicators and scoring criteria. The use of identical indicators in the pretest and post-test ensured comparability of performance improvement across the three competency domains (Mahsun et al., 2025)

The data were analysed using descriptive statistics, normalized gain (N-Gain) analysis, and paired-sample t-tests. Descriptive statistics were used to present mean scores for each

competency indicator before and after implementation. N-Gain analysis was used to determine the magnitude of competency improvement, while paired-sample t-tests were used to examine whether the differences between pretest and post-test scores were statistically significant. The statistical significance level was set at $p < 0.05$. Ethical approval was obtained from the institutional authority, and all participants provided informed consent. Cadet performance data were anonymized and used solely for academic research purposes.

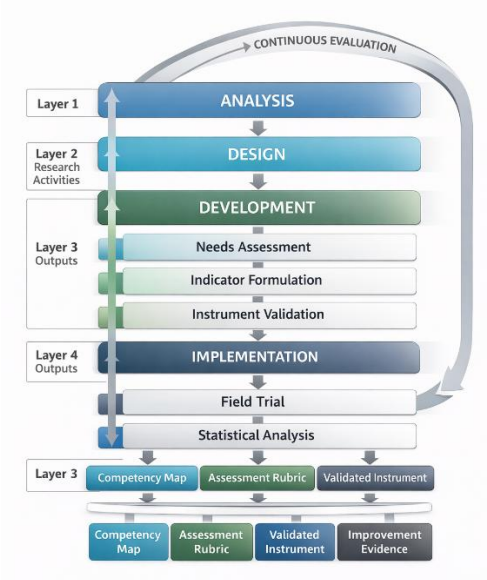

Figure 2. Integrated ADDIE and Competency-Based Assessment Framework

All research procedures were conducted in accordance with institutional training regulations. The structured development and validation process was intended to ensure that the SIM-FLIGHT assessment model was systematic, objective, and aligned with competency-based aviation education standards. (Thulasy et al., 2022)

Discussion

The findings of this study should be interpreted in relation to the three research objectives: developing a structured assessment model, validating the feasibility of the assessment instruments, and evaluating the effectiveness of the model in improving student pilot performance. First, the study successfully developed the SIM-FLIGHT assessment model by integrating the ADDIE instructional design framework with competency-based assessment principles. The Analysis phase identified the need for a more structured and measurable assessment system in simulator-based flight training, particularly because conventional assessment practices often depend heavily on instructor judgment. The Design and Development phases translated this need into simulator scenarios, competency indicators, standardized rubrics, and instructor guidelines. By embedding Safety Awareness, Decision Making, and Flight Performance into the assessment structure, the model provides a systematic mechanism for evaluating both technical and non-technical competencies. This finding confirms that the first objective of the study was achieved, namely the development of a structured assessment model aligned with aviation training requirements and competency-based education principles.

Second, the feasibility of the SIM-FLIGHT assessment instruments was supported through expert validation and limited trial procedures. The involvement of a senior flight instructor, a vocational aviation education academic, and a Redbird FMX1000 simulator practitioner ensured that the model was reviewed from operational, pedagogical, and technical

perspectives. Expert feedback contributed to the refinement of the instructional scenarios, assessment indicators, rubric clarity, and instructor guidance. The use of standardized rubrics and consistent instructor procedures also supported the reliability of the assessment process by reducing subjectivity and promoting consistency across performance evaluations. This validation process strengthened the content relevance, practical applicability, reliability, and objectivity of the instruments. Therefore, the second objective of the study was addressed by demonstrating that the developed assessment tools were feasible and reliable for implementation in simulator-based pilot training.

Third, the implementation results demonstrated that the SIM-FLIGHT model was effective in improving cadet pilot competencies. The pretest results indicated moderate baseline performance, with mean scores of 57.2 for Safety Awareness, 56.7 for Decision Making, and 66.2 for Flight Performance. These results suggest that prior to the intervention, cadets showed relatively stronger technical performance than non-technical competencies, particularly in cognitive and safety-related domains. This condition supports the need for an integrated assessment model that does not only evaluate maneuver execution but also emphasizes judgment, awareness, and decision-making processes.

Following the implementation of the SIM-FLIGHT model, post-test mean scores increased substantially to 81.8 for Safety Awareness, 81.4 for Decision Making, and 81.5 for Flight Performance. The observed increases of 24%, 25%, and 15%, respectively, indicate meaningful competency development across all indicators. The largest improvement occurred in Decision Making, suggesting that structured simulator-based scenarios, guided briefing, and systematic debriefing were particularly effective in strengthening cadets' analytical and judgment capabilities in dynamic flight situations.

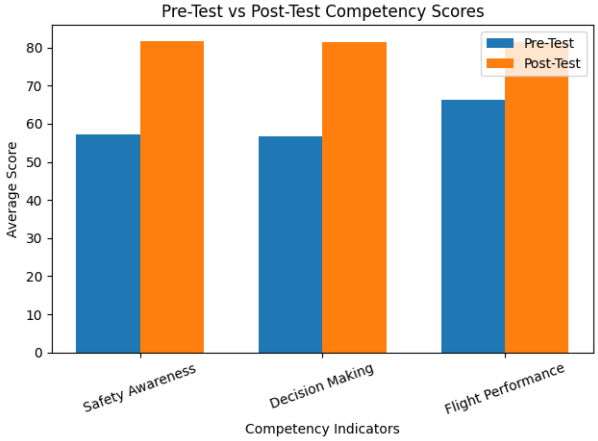

Figure 3. Comparison of Pretest and Post-test Scores

The N-Gain analysis further supports the instructional effectiveness of the model. Safety Awareness achieved an N-Gain of 0.57, Decision Making 0.59, and Flight Performance 0.45, all of which indicate moderate improvement. The higher gain in Decision Making confirms that the SIM-FLIGHT model was especially effective in strengthening higher-order cognitive competencies, while the improvement in Flight Performance mainly reflected the refinement and consolidation of previously acquired technical skills.

Statistical testing using paired-sample t-tests revealed p-values < 0.001 across all indicators, confirming that the differences between pretest and post-test scores were statistically significant. This indicates that the observed improvements were not due to random variation but were associated with the structured intervention implemented through the SIM-FLIGHT

framework. Thus, the third objective of the study was achieved by demonstrating the empirical effectiveness of the model in improving student pilot performance.

From a pedagogical perspective, these findings reinforce the importance of integrating technical and non-technical competencies within a competency-based training and assessment (CBTA) framework. (Ziakkas et al., 2022) The relatively balanced post-test scores (all exceeding 81) suggest that the model successfully reduced the initial gap between technical performance and non-technical competency domains. The structured use of rubrics, standardized instructor guidance, and systematic debriefing likely contributed to greater objectivity and consistency in performance evaluation.

Overall, the results show that integrating the ADDIE instructional framework with competency-based assessment provides a structured, validated, and measurable approach to improving cadet pilot performance. Unlike conventional models that focus primarily on technical skill execution, SIM-FLIGHT enables the quantitative assessment of both technical and non-technical competencies using validated rubrics and statistical evaluation. The significant improvements in all competency indicators demonstrate that the model provides empirical operationalization of competency-based training and assessment principles in vocational aviation education.

Conclusion

This study achieved its first objective by developing the SIM-FLIGHT assessment model, which integrates the ADDIE instructional design framework with competency-based evaluation principles for student pilot training. The model was structured through the Analysis, Design, Development, Implementation, and Evaluation phases and translated into simulator-based scenarios, competency indicators, standardized rubrics, and instructor guidelines. This structure enables the assessment of both technical and non-technical competencies in a systematic and measurable manner. The second objective was achieved through the validation of the SIM-FLIGHT model and its assessment instruments by aviation training and education experts. The validation process confirmed the feasibility and reliability of the model in terms of content relevance, instructional clarity, indicator measurability, assessment consistency, and objectivity. Expert feedback strengthened the quality of the rubrics and ensured that the model was appropriate for implementation in simulator-based pilot training. The third objective was achieved by demonstrating the effectiveness of the SIM-FLIGHT model in improving student pilot performance. The post-test results showed substantial improvement in Safety Awareness, Decision Making, and Flight Performance, with moderate N-Gain values across all indicators and statistically significant differences between pretest and post-test scores. These findings indicate that the model effectively enhances both technical proficiency and non-technical competencies, particularly safety awareness and aeronautical decision-making. In conclusion, the integration of ADDIE-based instructional design and competency-based assessment provides a structured, objective, and empirically supported framework for evaluating student pilot performance. The SIM-FLIGHT model can serve as a practical reference for aviation training institutions seeking to improve assessment transparency, feedback quality, and continuous performance development. Its implementation may contribute to stronger training effectiveness and higher safety standards in aviation education.

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