Effectiveness of Synthetic Training Device in Enhancing Student Competence in Digital Instruments

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Abstract— Aviation training has continuously evolved alongside the shift from conventional analog instruments to highly integrated digital avionics, increasing the demand for students to develop strong competence in interpreting and troubleshooting digital instruments. Traditional classroom instruction alone often provides limited hands-on exposure to real-time system responses and fault scenarios. This study assessed the effectiveness of a synthetic training device (STD) in enhancing the competence of second-year Avionics students of Air Link International Aviation College (ALIAC) in digital instruments. Using a one-group pretest–posttest experimental design combined with a descriptive survey, students underwent a structured test before and after exposure to the STD and completed a perception survey. Results showed that competence rose from a pretest mean of 5.10 (Low Mastery) to a posttest mean of 10.45 (Closely Approaching Mastery), a statistically significant improvement, $t(39) = 8.811$, $p = .000$. Students also strongly agreed (general weighted mean = 3.89) that the STD was an effective, safe alternative to actual aircraft exposure for building learning, confidence, and engagement. The findings support the continued use and expansion of synthetic training devices in avionics education.

Index Terms— Avionics Education, Digital Instruments, Simulation-Based Learning, Student Competence, Synthetic Training Device.

I. Introduction

Simulation has become a cornerstone of modern aviation education, allowing learners to experience realistic operational environments without risk [1]. As aircraft systems have transitioned from conventional analog instruments to highly integrated digital avionics, the demands placed on aviation education and student competence have grown [1]. Modern aircraft increasingly rely on glass cockpit displays, integrated navigation systems, and automated avionics technologies, requiring students to interpret and troubleshoot digital instruments with confidence. Traditional classroom instruction, while foundational, often lacks the hands-on experience needed to build these skills, since students have limited opportunities to interact with real-time system responses, instrument behavior, and fault scenarios.

Synthetic training devices (STDs) have therefore become vital tools for bridging the gap between theoretical learning and actual aircraft operation, offering a realistic and controlled environment where students can practice instrument interpretation, system operation, and troubleshooting without the risks associated with real aircraft use [2]. This study, conducted among second-year Avionics students of Air Link International Aviation College (ALIAC), assessed the effectiveness of an STD in enhancing student competence in digital instruments, examined students' perceptions of its effectiveness relative to actual aircraft exposure, and proposed recommendations for strengthening its use in avionics education.

II. Related Literature

The FAA's Pilot's Handbook of Aeronautical Knowledge identifies flight instruments such as the pitot-static system, gyroscopic instruments, and the magnetic compass as fundamental to safe flying [1], underscoring the need to give students structured opportunities to master such instruments. The ICAO's Manual of Criteria for the Qualification of Flight Simulation Training Devices formally recognizes simulators as tools whose fidelity allows skills learned in training devices to transfer directly to real-world flying [2]. Beyond hardware fidelity, Salas, Bowers, and Rhodenizer argue that a simulator's effectiveness depends on how training is structured, how feedback is given, and how tasks are designed, rather than on the technology alone [3]. Related work on digital-avionics curriculum design [4] and on the broader safety, cost, and training benefits of simulation [5], [6] similarly frames synthetic training as both a technical and an educational tool.

Empirical studies reinforce these claims. Flight-simulator-based instruction has been found to deepen students' grasp of navigation and new technologies while improving learning satisfaction [7]. Virtual-reality-based training has produced skill gains comparable to traditional flight training [8] and measurable academic benefits over conventional two-dimensional instruction [9], while also supporting pilot-skill development at lower cost and risk [10] and boosting learner motivation and engagement [11]. At the same time, actual aircraft experience remains a strong predictor of competence, with simulators adding the greatest value when combined with real flight time [12]; even low-cost, microcomputer-based avionics trainers have been shown to bring trainees to proficiency faster while reducing training costs [13].

In the Philippine setting, CAAP Advisory Circulars 02-005 and 02-006 formalize the approval, use, and skill-testing procedures for aviation training devices, embedding simulator-based assessment into national regulatory practice [14], alongside broader regulations governing pilot and flight-

instructor licensing [15]. Local aviation schools such as Alpha Aviation Group and CAE Philippines likewise operate Level D and glass-cockpit simulators to deliver hands-on digital-instrument training. Local studies further support simulation's role in improving student performance, whether in aviation programs [16], maritime cadet training [17], science instruction [18], or computer-engineering laboratories [19]; manufacturer documentation for integrated avionics suites such as the Garmin G1000 further underscores the complexity of the digital systems students must learn to operate [20].

Taken together, the literature establishes synthetic training devices as globally recognized, regulator-endorsed tools whose effectiveness depends on sound instructional design, providing a strong basis for examining how an STD can enhance avionics students' competence in digital instruments.

III. Objectives

This study aimed to determine the effectiveness of a synthetic training device in enhancing avionics students' competence in digital instruments. Specifically, it sought to: (1) describe the demographic profile of the respondents in terms of age, gender, and year level; (2) determine students' level of competence in digital instruments before, and (3) after, exposure to the STD; (4) determine whether a significant difference exists between the pretest and posttest results; (5) assess students' perception of the STD's effectiveness compared to actual aircraft exposure; and (6) propose recommendations to strengthen the use of STDs in improving students' competence in digital instruments.

IV. Research Methodology

The study used a quantitative, one-group pretest–posttest experimental design combined with a descriptive survey method to measure improvement in students' competence and to determine their perceptions of the STD's impact on learning. Respondents were Avionics students of Air Link International Aviation College (ALIAC) selected through purposive sampling, limited to students with direct exposure to the training device; 40 of them completed both the pretest and posttest.

Data were gathered using a structured test administered before and after STD exposure, together with a short survey questionnaire on students' assessment of the device's effectiveness relative to actual aircraft exposure. The instrument was reviewed and validated by three experts in avionics instruction and graduate research prior to use to ensure technical accuracy, relevance, and clarity. Data were analyzed using mean, standard deviation, frequency and percentage, weighted mean—interpreted on a four-point Likert scale (3.25–4.00, Strongly Agree; 2.50–3.24, Agree; 1.75–2.49, Disagree; 1.00–1.74, Strongly Disagree)—and a paired-sample t-test to determine whether the difference between the pretest and posttest scores was statistically significant.

V. Results and Discussion

A. Demographic Profile of Respondents

Table 1. Demographic Profile of the Respondents

Variable	Category	f	%
Age	18–21	41	87.20
	22–25	6	12.80
Gender	Male	30	63.80
	Female	17	36.20
Year Level	First Year	1	2.10
	Second Year	44	93.60
	Third Year	2	4.30

As shown in Table 1, most respondents (87.20%) were 18 to 21 years old, male students comprised 63.80% of the group, and 93.60% were second-year students. This profile indicates that most participants were young adult learners at the stage of their program where hands-on, simulator-based training is most heavily emphasized.

B. Level of Competence Before and After STD Use

Table 2. Competence in Digital Instruments Before and After STD Use

Score	Description	Pre f	Post f	Pre %	Post %
13–15	Mastered	0	6	0.00	15.00
10–12	Closely Approaching Mastery	3	23	6.52	57.50
7–9	Average Mastery	13	8	28.26	20.00
4–6	Low Mastery	23	0	50.00	0.00
0–3	Very Low Mastery	7	3	15.22	7.50
Mean		**4.96 (LM)**	**10.45 (CAM)**		

Before STD exposure, half of the students (50.00%) fell under Low Mastery, with a computed mean of 4.96. After exposure, more than half (57.50%) reached Closely Approaching Mastery and none remained at Low Mastery, raising the mean to 10.45. The shift toward the higher mastery bands indicates that simulator-based practice strengthened students' understanding and operation of digital instruments.

C. Significant Difference Between Pretest and Posttest

Table 3. Paired-Sample T-Test Results

Test	N	Mean	t	df	p-value
Pretest	40	5.10	8.811	39	0.000
Posttest	40	10.45	—	—	—

The paired-sample t-test yielded $t(39) = 8.811$, $p = .000$, which is below the 0.05 level of significance. The null hypothesis of no significant difference was therefore rejected,

confirming that the improvement in students' competence following STD exposure was statistically significant and not attributable to chance. This finding supports the value of simulator-based instruction in developing both the theoretical understanding and the practical skill of avionics students.

D. Students' Assessment of STD Effectiveness

Table 4. Assessment of STD Effectiveness Compared to Actual Aircraft Exposure

Dimension	Mean	SD	Interpretation
Learning and Skill Acquisition	3.90	0.25	Strongly Agree
Confidence and Readiness	3.87	0.26	Strongly Agree
Engagement and Learning Experience	3.88	0.26	Strongly Agree
Overall Perception	3.91	0.21	Strongly Agree
General Weighted Mean	**3.89**		**Strongly Agree**

Across all four dimensions, students strongly agreed that the STD was an effective substitute for actual aircraft exposure, with a general weighted mean of 3.89. The highest-rated indicator was that simulator use "enhances both the safety and learning efficiency of avionics students" (mean = 3.95), while students most frequently cited improved familiarity with cockpit instruments and controls as the STD's most helpful contribution. The most commonly noted limitation was that the simulator could not fully replicate the realism of actual digital instruments, followed by occasional technical or accessibility constraints—concerns that, despite being present, did not outweigh students' overall positive assessment of the device.

VI. Conclusion

Most respondents were young, second-year Avionics students actively engaged in practical and simulator-based coursework. Before using the synthetic training device, students showed limited mastery of digital-instrument operations; after exposure, their competence improved to a statistically significant degree, confirming that the STD was effective in strengthening both theoretical understanding and practical skill. Students strongly agreed that the device improved their understanding, confidence, and engagement, and that it served as a safe, effective alternative to actual aircraft exposure, even though it could not fully replicate real-world realism. Overall, the study concludes that synthetic training devices are a highly effective tool for developing avionics students' competence in digital instruments, and recommends that the avionics department continue and expand their use, develop structured modules on modern systems such as the Garmin G1000, schedule simulator sessions regularly, maintain and calibrate devices consistently, and coordinate with the Civil Aviation Authority of the Philippines to standardize simulator-based training guidelines.

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