

Reform Practice of an AI-Enabled Integrated Model for "Flight Principles" Experimental Teaching



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Abstract: Traditional experimental teaching in Flight Principles is constrained by site, equipment, airspace, and safety conditions. It often suffers from single experimental scenarios, poor parameter controllability, limited data acquisition, and superficial understanding of principles, making it difficult to meet the needs of high-precision, inquiry-based, and innovative experimental teaching in aviation-related majors. Artificial intelligence offers advantages such as simulation, data collection, intelligent analysis, and personalized tutoring, which can effectively compensate for the shortcomings of traditional experiments. Focusing on AI-enabled teaching reform, this paper clarifies practical teaching objectives, analyzes factors affecting reform, constructs a systematic implementation method for AI-integrated experimental teaching, and builds a new experimental teaching model that combines virtual and real environments, is data-driven, and intelligently empowered. The study aims to improve students' ability to inquire into flight principles, their aviation engineering thinking, and their innovative practical ability, thereby providing a reference for intelligent teaching reform in aviation majors.

Keywords: artificial intelligence, flight principles, experimental teaching, intelligent simulation, teaching reform

1. Introduction

Flight Principles is a core professional foundation course for aviation and flight test technology engineering majors. Its theory is abstract, its formulas are complex, and its logic is rigorous. Experimental teaching is intended to help students understand aerodynamic laws and the core elements of flight mechanics. With the widespread application of intelligent education, AI simulation, and big data analytics in university engineering courses, using artificial intelligence to enhance professional experimental teaching has gradually become a new direction in educational reform. With its strengths in intelligent simulation, data computation, intelligent diagnosis, and personalized guidance, AI can break through the bottlenecks of traditional experiments and deepen students' understanding of flight mechanics, aerodynamics, and flight control laws. On this basis, this study carries out reform and research on an AI-enabled integrated experimental teaching model for the Flight Principles course, hoping to provide a practical path for intelligent, precise, and deep experimental education in aviation majors.

2. Practical Goals of the AI-Enabled Integrated Reform of "Flight Principles" Experimental Teaching

2.1 Intelligent simulation breaks condition constraints

With the support of AI intelligent simulation technology, the construction of virtual flight experiment scenarios can completely break the constraints of site, equipment, safety, and environmental conditions. It enables free reproduction of high- and low-altitude flight, complex airflow, extreme weather, special flight attitudes, and various real operating conditions, achieving full-parameter, full-condition, and full-dimensional experimental reproduction. Students can independently adjust core parameters such as angle of attack, airspeed, altitude, and rudder deflection, and can repeatedly conduct extreme-condition tests, fault simulation tests, and comparative verification tests, thereby avoiding the risks of physical experiments and the troubles of equipment loss (Wang & Yu, 2022). Through AI simulation, the breadth and depth of experiments are expanded, the variety of experimental projects is enriched, and the bottleneck of traditional experimental teaching is overcome. A new experimental teaching environment that is unrestricted, repeatable, highly safe, and low-cost is established, fully expanding students' exploration of flight principles experiments.

2.2 Data-driven approaches deepen understanding of principles

AI technology has advantages such as

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high-speed data acquisition, automatic computation, intelligent fitting, trend analysis, and error diagnosis. It can capture a large amount of flight experimental data in real time and automatically generate parameter variation curves, dynamic law maps, and variable correlation models. The visual presentation of big data makes abstract aerodynamic laws and flight mechanics trends intuitive and clear, helping students accurately capture different flight states caused by subtle parameter changes (Yin et al., 2023). Relying on AI data comparison, variable analysis, and causal reasoning, students are guided from "observing phenomena" to "analyzing data, summarizing laws, and deriving principles." This deepens their understanding of the essential logic of flight principles, develops their data thinking, engineering analysis ability, and scientific inquiry ability, and achieves the teaching goal of transforming surface-level cognition into deep principle construction.

3. Factors Influencing the AI-Enabled Integrated Reform of "Flight Principles" Experimental Teaching

3.1 Compatibility between AI tools and content

The degree of compatibility between AI teaching tools and the experimental teaching content of Flight Principles is a core factor affecting the effectiveness of intelligent teaching reform. Existing general-purpose AI teaching platforms lack professional specificity. Most intelligent simulation software cannot accurately match the standards of experimental parameters related to aviation flight principles. Common problems include insufficient accuracy of aerodynamic models, deviations in flight mechanics algorithms, and low compatibility with working-condition scenarios. If AI tools lack modeling accuracy, have incomplete parameter databases, and lack professional modules, the results of virtual experiments will deviate from real flight laws. This not only fails to assist teaching but may also mislead students' professional cognition (Yin et al., 2024). At the same time, different experimental projects have different requirements for AI simulation computing power, modeling accuracy, and data functions. Some complex aerodynamic experiments and dynamic control experiments have extremely high requirements for the accuracy of AI algorithms, and ordinary intelligent tools can hardly meet the needs of deep teaching.

3.2 Teachers' ability to use intelligent technology

Teachers' level of AI technology application and ability to integrate intelligent teaching are key human factors in promoting AI experimental teaching reform. Traditional Flight Principles teaching mainly relies on theoretical lectures and physical equipment demonstrations. Most professional teachers have long depended on traditional teaching models and are not

sufficiently proficient in operating intelligent simulation platforms, AI data analysis systems, and smart teaching tools. They also lack experience in AI instructional design, virtual-real classroom organization, and intelligent data-guided teaching (Yang, 2024). Some teachers merely use AI software for basic demonstrations and cannot use AI platforms for in-depth teaching activities such as variable inquiry, data review, personalized question answering, and intelligent error correction. It is difficult for them to deeply integrate AI technology with the key and difficult points of experiments and students' cognitive patterns. At the same time, teachers are also insufficient in using AI big data to analyze students' weak points in experiments, accurately diagnose learning problems, and dynamically optimize teaching content, resulting in low utilization of intelligent equipment resources and insufficient technology empowerment. The lack of teachers' intelligent teaching literacy directly restricts the depth of integrating AI technology with Flight Principles experimental teaching and affects the quality of intelligent teaching reform and educational outcomes.

4. Practical Methods for the AI-Enabled Integrated Reform of "Flight Principles" Experimental Teaching

4.1 Build an intelligent simulation experiment platform

Supported by AI modeling, virtual reality, and aerodynamic simulation algorithms, an exclusive AI intelligent simulation experiment platform for Flight Principles has been established. It completely breaks the limitations of traditional experimental equipment and scenarios and builds a high-precision, adjustable, full-condition virtual experimental teaching environment. Based on actual aircraft aerodynamic parameters, flight mechanics equations, and atmospheric environment models, the platform establishes a high-precision model. It accurately reproduces various flight states and aerodynamic variation laws of fixed-wing aircraft and covers actual flight conditions such as low speed, subsonic speed, high and low altitude, complex airflow, and turbulent weather (Zhang, 2024). The platform opens full-dimensional parameter control permissions, allowing students to independently adjust core variables such as flight altitude, flight speed, wing angle of attack, elevator deflection, and flap state. Students can freely conduct single-variable controlled experiments, multi-variable coupling experiments, extreme-condition inquiry, and fault simulation experiments. For nonlinear aerodynamic experiments such as stall, spin, and high angle of attack, as well as complex control response experiments that are difficult to conduct in traditional teaching, the AI simulation platform supports safe,

repeatable, and intuitive implementation, effectively filling teaching blind spots that physical experiments cannot cover. The platform also has built-in standardized experimental procedures, principle knowledge prompts, and operation specifications, guiding students to independently complete experimental design, parameter tuning, process observation, and phenomenon summary. Through the construction of this exclusive intelligent simulation platform, flight principles experiments can be conducted without risk, repeatedly, in all scenarios, and with high precision, providing core technical support for deep inquiry-based experimental teaching. The platform supports multi-terminal access, so students can log in to the classroom laboratory and after-class self-study environment at any time for simulation experiments, breaking the limitations of experimental time and place (Xiong et al., 2025). The system includes an experiment version saving function, allowing students to retain flight state data under various parameter combinations for multiple comparisons and analyses. A simulation result verification module is also built into the platform to compare virtual simulation output with classic wind tunnel experimental data, ensuring the engineering credibility of the simulation results.

4.2 Develop an AI data acquisition and analysis system

Supported by AI big data technology, an intelligent data acquisition and analysis system adapted to the experimental teaching of Flight Principles has been developed. It establishes an automatic, high-precision, and visual experimental data processing system and solves the pain points of traditional experiments, such as limited data, large errors, difficult analysis, and vague laws. The system can collect a large amount of dynamic data in real time, at high frequency, and across the full domain throughout the entire experimental process, including lift coefficient, drag coefficient, pitching moment, roll response, control displacement, and airflow parameters, thereby achieving full coverage, no omission, and high-precision acquisition of experimental data (Zhao, 2023). The AI system has built-in professional aviation data analysis algorithms that can automatically perform data denoising, error correction, curve fitting, variable correlation analysis, and dynamic trend inference. It generates two-dimensional and three-dimensional visual variation maps in real time to intuitively display the variation laws of flight parameters and the coupling relationships among variables. After the experiment, the system automatically generates an experimental data analysis report and accurately annotates abnormal points, causes of experimental errors, parameter variation laws, and corresponding knowledge points. Students can use the AI data comparison function to intuitively analyze

differences in aerodynamic characteristics under various working conditions and parameters, and abstract flight mechanics laws from large amounts of data. Teachers can summarize all students' experimental data in the background, accurately grasp the overall experimental problems and knowledge weak points of the class, and achieve the goal of data-driven learning, data-driven teaching, and data-empowered precise teaching.

4.3 Design virtual-real integrated experimental projects

Based on the advantages of AI intelligent simulation and traditional physical experiments, a "physical operation plus virtual inquiry" virtual-real integrated, layered, and progressive experimental project system has been designed. It aims to complement the authenticity of traditional experiments with the depth of AI experiments. Verification experiments based on physical wind tunnels and flight simulation equipment help students master real equipment operation procedures, become familiar with basic experimental phenomena, and establish intuitive professional cognition, ensuring the development of basic practical ability. Supported by the AI intelligent simulation platform, expansive, inquiry-based, and innovative experimental topics have been designed. For difficult and key issues such as high-risk and extreme conditions and complex multi-variable coupling, virtual simulation is relied upon for in-depth inquiry (Yang et al., 2025). The experimental system is built at three levels: basic verification, comprehensive inquiry, and innovative design. The basic level completes conventional aerodynamic parameter tests with the support of physical equipment. The comprehensive level uses AI simulation to conduct multi-variable comparative experiments, complex weather flight experiments, and control response law experiments. The innovation level guides students to independently design experimental schemes, use the AI platform to explore new working conditions, optimize flight parameters, and verify ideas for aerodynamic improvement. The virtual-real integrated experimental model retains the advantages of traditional practical education while using the flexibility, safety, and inquiry potential of AI simulation to effectively solve problems such as fixed content and lack of depth in traditional experiments, expand limited problems, and integrate the hierarchy and innovation of experimental teaching.

4.4 Intelligent tutor supports personalized guidance

Supported by AI intelligent guidance, intelligent question answering, and learning diagnosis technologies, an intelligent virtual tutor guidance system has been constructed to provide personalized, precise, and all-weather guidance for students'

experimental learning. The AI intelligent tutor has a complete knowledge base of flight principles, an experimental operation question bank, a common error case bank, and resources for analyzing key and difficult points. It can provide services related to students' experimental operation processes and parameter settings, realize real-time intelligent monitoring of experimental results, automatically identify students' operational errors, inappropriate parameter settings, and deviations in understanding principles, and provide real-time pop-up error correction, dynamic question answering, and step-by-step guidance. For students with weaker foundations, the AI tutor automatically simplifies experimental difficulty, gradually guides operations, and refines principle analysis to consolidate basic experimental ability. For students with stronger abilities, it intelligently pushes expansion experimental tasks, complex-condition inquiry projects, and innovative design topics that meet the requirements of differentiated cultivation. After class, students can log in to the intelligent guidance system at any time to independently review the experimental process, replay principle explanations, redo wrong questions, and conduct special training, achieving all-weather independent learning. The AI intelligent tutor breaks the constraints of the traditional uniform classroom teaching model and solves teaching shortcomings such as limited teacher tutoring, inadequate personalized tutoring, and untimely question answering. It enables a personalized experimental teaching model in which everyone can receive guidance, progress step by step, and improve layer by layer.

4.5 Dynamic adjustment driven by data feedback

An AI big data learning feedback and teaching dynamic adjustment mechanism supported by the platform has been constructed. It collects whole-process data on students' experimental operations, parameter settings, experimental results, wrong-question data, and knowledge weak points, and establishes students' personal learning profiles and a class-level teaching quality database. The AI system uses intelligent big data analysis to accurately judge students' insufficient grasp of core knowledge points such as the angle-of-attack lift principle, drag characteristics, control moments, and stall principles. It accurately locates misunderstandings in experimental operations, blind spots in principle understanding, and weaknesses in inquiry thinking. The system automatically generates learning analysis reports that intuitively show common problems in the class and individual student characteristics. Based on data feedback results, teachers dynamically adjust the key and difficult points in classroom teaching, conduct special explanations and concentrated reviews for common weak principle content and high-frequency incorrect operations, and provide

targeted strengthening training. According to students' learning in different semesters and their level of experimental mastery, the difficulty of experimental projects, teaching process, teaching rhythm, and practical training focus are dynamically adjusted. This implements a closed-loop teaching improvement mechanism in which "data diagnoses problems, problems optimize teaching, and teaching promotes quality," continuously improving the accuracy of experimental teaching and the actual effect of education.

4.6 Build a multiple evaluation mechanism

Supported by AI intelligent data statistics and whole-process recording functions, a process-oriented, diversified, and intelligent experimental teaching evaluation system has been established, breaking through the traditional evaluation method based on a single experimental report and a one-time final score. The new evaluation system covers eight dimensions: experimental preview, intelligent simulation operation, parameter design ability, data analysis ability, experimental inquiry and innovation, classroom performance, experimental report, and after-class expansion, achieving whole-process, all-round, and all-factor assessment. The AI system automatically records whole-process quantitative data such as students' experimental operation duration, number of parameter adjustments, number of incorrect operations, accuracy of experimental data, completion of inquiry projects, and innovative design results, forming an objective intelligent score. Teachers integrate qualitative evaluation of students' experimental thinking, principle expression, classroom interaction, and report quality, thereby achieving an organic combination of intelligent quantitative evaluation and manual qualitative evaluation. On this basis, the evaluation weight of innovation ability, inquiry ability, and problem analysis ability has been increased, encouraging students to independently design experiments and conduct innovative exploration. The multiple intelligent evaluation mechanism comprehensively, objectively, and accurately reflects students' experimental practical ability, level of principle understanding, and engineering innovation literacy. It effectively guides students from focusing on scores and reports to focusing on process, inquiry, and thinking, comprehensively improving the overall educational quality of Flight Principles experimental teaching.

5. Conclusion

Deeply integrating artificial intelligence technology with Flight Principles experimental teaching is an important development direction for intelligent teaching reform in aviation majors in the new era. It effectively breaks through the main

problems of traditional experimental teaching, such as condition limitations, insufficient inquiry, superficial understanding, and single assessment. The AI-integrated teaching model effectively expands the dimensions of experimental teaching, deepens understanding of professional principles, and promotes the cultivation of students' engineering inquiry and innovation abilities. In the future, it is necessary to continuously optimize the accuracy and teaching adaptability of AI simulation, strengthen the cultivation of teachers' intelligent teaching ability, and continuously improve the intelligent experimental education system, so as to promote aviation professional experimental teaching toward intelligent, precise, and innovative high-quality development.

Conflict of Interest

The author(s) declare that there is no conflicts of interest to this work.

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