Interdisciplinary Course Reform and Practice of Emerging Engineering Education Major for Ability Cultivation

Taking the course of "Aircraft Health Management and Prediction" as an example

Shuyu Cai*, Xuan Wang

College of Aeronautical Engineering, Civil Aviation University of China, Tianjin, China

*sycai@cauc.edu.cn

Abstract. With the digital and intelligent transformation of the civil aviation industry in the new era, it is particularly important to cultivate college students that are adaptable to industry demands, interdisciplinary integration, and technological innovation. Taking the course "Aircraft Health Management and Prediction" as an example, the effective pathways for the reform of interdisciplinary courses in the aircraft manufacturing engineering emerging engineering education are explored. In response to the problems in the course, such as a complex knowledge system, lack of case-based teaching, and outdated assessment methods, this paper carries out the innovation and exploration from the core content of the course, the expansion of cutting-edge technology, the design of advanced experiments, and the reform of assessment methods. It provides a reference for interdisciplinary courses of aircraft manufacturing emerging engineering education.

Keywords: Ability cultivation, Interdisciplinary courses, Emerging engineering education, Aircraft manufacturing engineering, Aircraft health management and prediction

1 Introduction

In the current era, we are witnessing a new wave of technological revolution and industrial transformation, with emerging intelligent technologies such as artificial intelligence, big data, and cloud computing rapidly permeating various industries. Cultivating interdisciplinary talents capable of meeting the demands of the intelligent era has become an unprecedented challenge for higher education. The Massachusetts Institute of Technology (MIT) in the United States has launched the "New Engineering Education Transformation" initiative, while the Technical University of Munich in Germany integrates information technology into traditional engineering disciplines against the backdrop of "Industry 4.0". In China, the Ministry of Education initiated the implementation of the "Emerging Engineering Education" construction in 2017, forming the Fudan

M. F. A. Ghani et al. (eds.), *Proceedings of the 2024 4th International Conference on Education, Language and Art (ICELA 2024)*, Advances in Social Science, Education and Humanities Research 907,
https://doi.org/10.2991/978-2-38476-364-1_15

Consensus [1], Tianjin University Action Plan [2], and Beijing Guidance [3], which propels our country from a large engineering education nation to a powerful one [4-5].

Relying on the first batch of national-level "Emerging Engineering Education" projects, our university's Aircraft Manufacturing Engineering closely follows the development trend and talent needs of the digital and intelligent transformation in the civil aviation industry. It incorporates cutting-edge science and technology into its training programs, constructing an interdisciplinary curriculum system centered on cultivating innovative capabilities. This system is designed according to a three-tier progression: application ability, practical ability, and innovation ability, integrating various modules within the curriculum framework. Through general education courses and basic professional courses, students build a solid foundation in fundamental knowledge and essential skills. Project-based practical courses focus on real engineering problems, guiding students through progressive scientific research projects to creatively develop interdisciplinary engineering solutions, thereby effectively enhancing their innovation abilities [6]. Core professional courses and specialty courses play a crucial bridging role [7], aimed at: ① expanding students' knowledge and skill boundaries from single disciplines to interdisciplinary integration; ② shifting the focus from idealized theoretical problems to practical engineering cases; ③ promoting a change in thinking from analytical application to innovative optimization, providing a vital intermediate link in building a systematic, progressive innovation capability training system.

This paper takes the specialty course "Aircraft Health Management and Prediction" as an example to discuss how it fosters engineering practice abilities and innovative awareness, combining the interdisciplinary characteristics of specialized courses for curriculum reform practices.

2 Analysis of Course Issues

"Aircraft Health Management and Prediction" is an elective course for the Aircraft Manufacturing Engineering program (Emerging Engineering Education). The course covers key theoretical methods related to essential technologies such as aircraft state monitoring, fault diagnosis, performance trend prediction, health status assessment, and maintenance decision support. Its aim is to enable students to deeply understand the basic concepts of aircraft health management, systematically master the fundamental principles, technical methods, and applicability of its key technologies, and develop professional competencies and innovative awareness oriented towards the forefront of engineering.

The issues with this course can be summarized as follows:

(i) Complex Knowledge System Hindering Efficient Interdisciplinary Skill Expansion.

The "Aircraft Health Management and Prediction" course features a significant interdisciplinary integration. The theoretical methods of its key technologies are based on mathematical disciplines such as advanced mathematics, linear algebra, probability, and statistics. Additionally, current practical engineering methods involve extensive use of machine learning and deep learning techniques from computer science. The content thus presents a cross-disciplinary integration of "mathematical foundation + professional knowledge + intelligent methods," making the knowledge system overly vast. With limited class hours, it only allows for broad and superficial learning, dispersing students' time and energy, hindering in-depth thinking to integrate different disciplinary knowledge, and preventing the formation of systematic thinking to establish intrinsic connections between disciplines. Consequently, students' learning merely becomes an accumulation of different disciplinary knowledge, making it difficult to effectively internalize and achieve interdisciplinary integration.

(ii) Lack of Case Teaching Impedes Development of Engineering Practice Abilities.

Case teaching is a crucial method for developing students' engineering practice abilities [8-9].

The course aims to closely integrate theoretical methods with engineering practice applications by introducing case teaching tailored to various key technological scenarios of aircraft health management, thereby cultivating students' professional competencies and innovative awareness geared towards the forefront of engineering.

For intelligent methods based on machine learning and deep learning, which introduce new methodologies driven by data for modeling, training, and predicting aircraft systems, there are significant changes in case data collection, engineering case design, and case teaching equipment requirements compared to traditional case teaching.

The implementation of case teaching for aircraft health management based on intelligent methods demands high standards for both the quality and quantity of case data. As shown in Figure 1, differences between the distribution of collected case data samples and the overall data distribution of engineering problems significantly impact the training and prediction results of case models, potentially invalidating subsequent optimization methods and thus affecting the application effectiveness of engineering cases. The complexity of designing engineering cases for aircraft health management using intelligent methods has increased. Engineering cases need to be customized according to the application scenarios and technical characteristics of each key technology in aircraft health management.

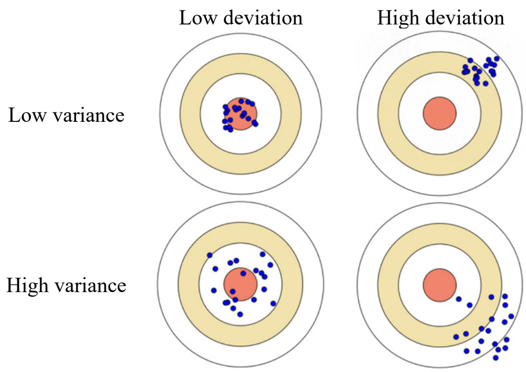

Fig. 1. Diagram of Differences in Distribution of Case Data

Intelligent methods often involve complex model structures, necessitating consideration of more technical details and implementation steps during case design, such as model structure selection, feature engineering design, and parameter optimization. Intelligent methods typically require machine learning frameworks and deep learning libraries to support the implementation of case teaching. These tools vary in versions, compatibility is complex, and environment configuration poses challenges. Moreover, intelligent methods usually require substantial computational resources for support.

(iii) The assessment methods are outdated, which hinders the transformation of innovative consciousness.

Traditional assessment methods emphasize memorization of knowledge and test-taking skills [10], focusing solely on the final learning outcomes, with examination scores as the primary evaluation criteria. This approach overlooks students' performance in innovative thinking and practical abilities, as well as their efforts and behaviors during the learning process. Consequently, it fails to comprehensively evaluate students' innovative awareness and capabilities. This disconnect from the innovative educational objectives of the curriculum means that these methods do not effectively guide and motivate students toward innovative practices, thus failing to foster and transform an innovative mindset.

3 Course Reform Measures

3.1 Design of an Online-Offline Hybrid Theoretical Teaching Plan Based on Interdisciplinary Teaching Modules

(1) Design of Interdisciplinary Teaching Modules

To address the complexity of the course knowledge system, we have organized the curriculum and related interdisciplinary knowledge systems. Centering around each knowledge point of the course, we have constructed teaching modules that include "Mathematical Foundations + Professional Knowledge + Intelligent Methods + Typical Applications", as shown in Figure 2. This approach ensures that the teaching content focuses on core professional knowledge and engineering applications, supplemented by closely related interdisciplinary knowledge such as mathematical foundations and intelligent methods, thereby guaranteeing the systematic coherence of knowledge within the teaching module and across the entire course.

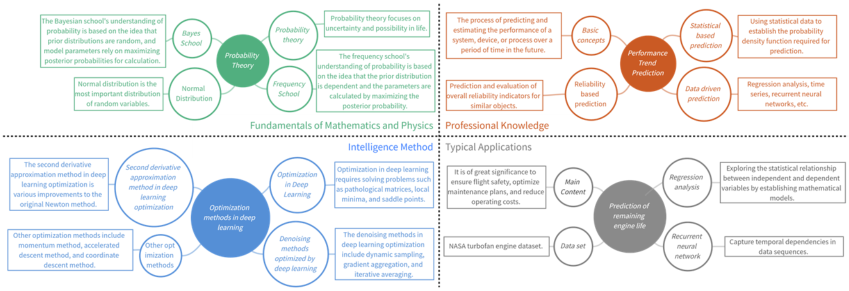

Fig. 2. Example of Teaching Module

(2) Design of Online-Offline Hybrid Theoretical Teaching Plan

Leveraging AI open-source platforms, we have designed an online-offline hybrid theoretical teaching plan that integrates theoretical instruction, interdisciplinary knowledge, cutting-edge technology, and student self-learning.

The hybrid theoretical teaching for this course consists of online learning and offline classroom sessions. The overall plan is illustrated in Figure 3.

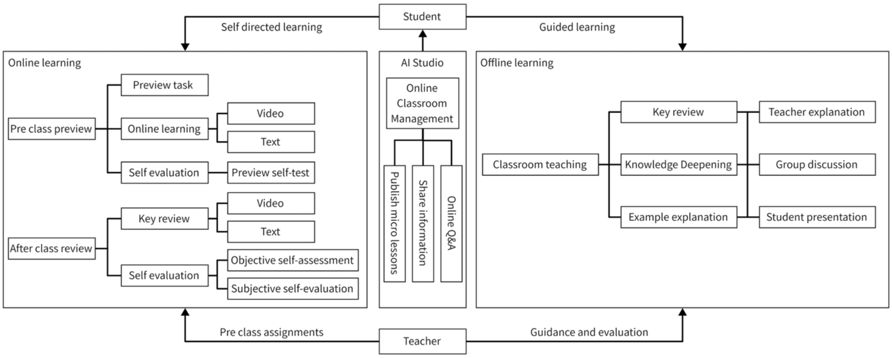

Fig. 3. Overall Plan of Online-Offline Hybrid Theoretical Teaching

a) Online Learning

Online learning is divided into pre-class preparation and post-class review.

i) Pre-class Preparation

Before class, teachers use AI open-source platforms to push mathematical foundational content required for the current teaching module to students. Students can independently preview based on their mastery of prerequisite courses and complete a pre-class mathematical foundation assessment.

ii) Post-class Review

After class, students can revisit summaries of all knowledge points in the current teaching module and complete online homework to evaluate their theoretical learning outcomes. Additionally, in-course engineering cases corresponding to the teaching module are provided as practical assignments. These help students review typical applications of professional knowledge and further optimize and improve their understanding. By engaging students' initiative, this approach fosters active thinking and enhances their ability to identify and solve problems.

b) Offline Learning

The physical classroom sessions for theoretical courses consist of teacher explanations, case studies, and student discussions.

i) Teacher Explanations and Case Studies

Teachers explain professional knowledge and intelligent methods while demonstrating with in-course engineering cases. This makes the specific functions and typical applications of intelligent methods more intuitive and understandable. Through AI open-source platforms, students learn the problem-solving process and visualize results, gaining the most direct understanding. Finally, the teaching returns to theory, analyzing application processes and effects to form a "Theory Explanation—Case Study—Application Analysis" teaching model.

ii) Student Discussions

Each teaching module reserves 10 minutes for discussion. Students can bring unresolved issues from their preview or questions encountered during the teacher's explanation to the discussion session. Teachers guide students to analyze problems independently, attempt to propose solutions using existing knowledge, and discuss the feasibility of methods.

3.2 Design of Practice Teaching Plan Based on Engineering Cases

(1) In-Course Engineering Cases

The course introduces application cases based on engineering backgrounds and combines them with teaching modules. We design hierarchical in-course engineering cases to help students deepen their understanding of theoretical knowledge and proficiently apply appropriate methods to solve engineering problems, achieving the goal of applying what they have learned.

Focused on core course content, we have designed three types of in-course engineering cases: airplane fault diagnosis and performance comparison, airplane system performance trend prediction analysis, and airplane system remaining useful life prediction analysis, as shown in Table 1. These cases provide basic programs for eight typical intelligent methods, including decision trees, neural networks, support vector machines, clustering analysis, convolutional neural networks, regression models, recurrent neural networks, and gated recurrent units, supporting 8 hours of in-course teaching content.

Table 1. In-Course Engineering Cases

In-Course Engineering Cases	Intelligent Methods of In-Course Engineering Cases
Aircraft Fault Diagnosis and Performance Comparison	Neural Network Support Vector Machine
Aircraft Systems Performance Trend Prediction and Analysis	Clustering Convolutional Neural Network Regression Analysis
Aircraft Systems Remaining Life Prediction and Analysis	Recurrent Neural Network

(2) Extracurricular Expansion Cases

Targeting cutting-edge engineering methods and combining theoretical knowledge points, we set extracurricular expansion cases. These include fault diagnosis and classification based on VGG and GoogleNet; performance trend prediction based on LSTM and CNN-LSTM; data generation based on generative adversarial networks; and performance anomaly detection based on faster R-CNN, as shown in Table 2.

Extracurricular expansion cases are intended to broaden and deepen course content. Students can choose to work on these cases based on their professional background, knowledge level, and interests, aiming for personalized training and uncovering individual potential.

Table 2. Extracurricular Expansion Cases

Extracurricular Expansion Cases	Intelligent Methods of In-Course Engineering Cases
Aircraft System Performance Abnormal Detection and Classification	Faster Region-based Convolutional Neural Networks Visual Geometry Group Google Inception Network You Only Look Once
Performance Data Visualization and Trend Prediction	Long Short Term Memory Deep Auto-encoder Deep Belief Network
Aircraft System Performance Data Generation	Generative Adversarial Network

Each engineering case is supported by practical teaching guidance, including practice objectives, an introduction to the practice, and steps (data description, data preparation, data analysis, modeling, model testing, and model application practice). Each case provides basic program implementations, facilitating student operation verification and imitation applications to quickly obtain preliminary results and achieve a sense of accomplishment. Students can also further optimize and improve based on initial results, stimulating sustained interest in exploration.

Practice teaching based on engineering cases is conducted on AI open-source platforms. As shown in Table 3, the platform's cloud computing capabilities, ample computational power, and well-configured environment effectively support the teaching of engineering cases.

Table 3. Comparison of AI Open Source Platforms

Compare projects	Baidu AIstudio	Google Colab	Amazon Segamaker Studio
Support library	Paddle framework only	Preinstalled with various libraries	Need to install
GPU usage	Need computing power points	Backend scheduling	4 consecutive hours
GPU type	V100	Cannot specify	Cannot specify
File store	Support	Associate with Google Drive	Support
Number of terminals	One	One notebook	Multiple

3.3 Construction of Multidimensional Assessment Methods Emphasizing Process

(1) Open Course Competition Design

Relying on AI open-source platforms and targeting key application scenarios of airplane health management technology, we have designed an open course competition to reform the final assessment method.

Students apply the knowledge and methods they have learned to complete a project that includes modeling, optimization, evaluation, and application, submitting the project results and analysis report. Teachers can write evaluation standard programs through the platform interface to score and rank student submissions in real-time. Students can continuously optimize their models within the competition deadline to achieve higher rankings.

During the 2021 grade course competition, students averaged 9.2 rounds of optimization, as shown in Table 4. The open course competition effectively stimulates students' comprehensive innovative application potential in connecting learned knowledge with practical problems, enhancing their ability to identify and solve engineering practice problems.

Table 4. 2021 Grade Course Competition Results Table

Student ID	Final Score	Final submission time	Optimization rounds	Final ranking
***662	100	2024-05-30 09:39:24	2	1
***472	100	2024-05-30 10:18:04	33	2
***295	100	2024-05-30 10:18:17	18	3
***032	100	2024-05-30 10:41:16	16	4
***349	100	2024-05-30 11:51:25	31	5
***241	100	2024-05-30 17:34:43	2	6
***291	100	2024-05-30 21:02:55	4	7
***678	100	2024-05-30 21:57:36	3	8
***205	100	2024-05-30 22:46:35	6	9
***012	100	2024-05-30 23:06:59	15	10
***534	100	2024-05-30 23:07:03	10	11
***090	100	2024-05-30 23:10:08	15	12
***656	100	2024-05-30 23:28:22	7	13
***466	100	2024-05-30 23:44:26	3	14
***262	100	2024-05-31 10:19:30	29	15
***410	100	2024-05-31 10:48:46	2	16
***068	100	2024-05-31 11:54:15	3	17
***299	100	2024-05-31 12:48:37	3	18
***080	100	2024-05-31 13:36:39	2	19

Student ID	Final Score	Final submission time	Optimization rounds	Final ranking
***503	96.67	2024-05-21 22:14:23	1	20
***775	96.67	2024-05-22 21:29:19	8	21
***409	96.67	2024-05-24 13:13:10	13	22
***745	96.67	2024-05-30 20:26:59	16	23
***054	96.67	2024-05-30 21:47:16	5	24
***558	96.67	2024-05-30 22:03:02	2	25
***498	96.67	2024-05-30 22:04:43	8	26
***413	83.33	2024-05-31 17:22:56	2	27
***406	83.33	2024-05-31 23:54:18	5	28
***665	83.33	2024-05-31 23:58:45	3	29

(2) Multidimensional Assessment Methods

The course assessment methods emphasize the combination of practical application ability evaluation and learning process evaluation. The course integrates assessment into various implementation stages of teaching, examining students from multiple dimensions.

The comprehensive course grade consists of process-based assessment scores and final assessment scores. Process-based assessment scores account for 30% of the total grade, while final assessment scores account for 70%.

Process-based assessment scores are composed of regular attendance scores and assignment scores. Regular attendance scores are determined by the instructor based on attendance and classroom performance; assignment scores are evaluated by the instructor based on the completion of assignments.

Final assessment scores consist of open course competition scores and analysis report scores. Open course competition scores are determined by the final project ranking on the AI open-source platform; analysis report scores are evaluated according to the "Analysis Report Scoring Standard (as shown in Table 5)."

Table 5. Scoring Criteria for Analysis Reports

index	A	B	C	D
The processing of the dataset is scientific. (20 points)	20-16	15-11	10-6	5-0
The selection of analysis methods is applicable. (15 points)	15-12	11-8	7-4	3-0
The analysis process is rigorous and sufficient. (20 points)	20-16	15-11	10-6	5-0
The optimization method design is rigorous and innovative. (20 points)	20-16	15-11	10-6	5-0
The analysis conclusion is correct. (10 points)	10-8	7-5	4-2	1-0
The format specification meets the requirements for writing scientific papers. (15 points)	15-12	11-8	7-4	3-0

4 Conclusion

This paper delves into the effective pathways for the reform of interdisciplinary courses in the Emerging Engineering Education major of Aircraft Manufacturing Engineering through the reform and practice of the "Aircraft Health Management and Prediction" course. By designing teaching modules, online and offline blended teaching plans, hierarchical engineering cases, and multidimensional assessment methods based on course competitions, we have optimized the knowledge system of interdisciplinary courses, significantly enhancing students' engineering practice abilities and innovative awareness. In the future, we will continue to deepen course reforms and constantly explore and improve interdisciplinary teaching models to meet the demands of the digital and intelligent transformation of the civil aviation industry for scientific and technological innovation talents in the new era.

Acknowledgments

This work was supported by the Research Programme on Undergraduate Teaching Reform and Quality Construction in Tianjin Universities (Grant No. B231005909).

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