TRANSFORMATIVE PEDAGOGY: CO-TEACHING COURSE CLUSTERS THROUGH COMPETITIVE TEAM DESIGNS FOR INNOVATIVE TALENT DEVELOPMENT IN AEROSPACE EDUCATION

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Abstract

The study is primarily grounded in the concept of competitive team design and co-teaching course clusters. It addresses the contemporary demand for interdisciplinary innovative personnel training in the new era of aviation development. To counteract issues such as time constraints, heavy homework, and redundant tasks associated with traditional independent lectures, the study proposes the implementation of "Five-in-One" course group joint teaching. This involves integrating course positioning, teaching objectives, and teaching progress with a certain level of coupling. This approach enables students to maintain coherence and systematization of acquired knowledge, mitigates the duplication of teachers' knowledge and teaching efforts, facilitates multi-dimensional co-construction, and encourages the sharing of "courses-teachers-resources-progress." Ultimately, it aims to foster a new mode of training innovative talents in the evolving aviation landscape.

Keywords: competitive team design; co-teaching course clusters; innovative talent development

1. Introduction

To address the challenges posed by the new wave of scientific and technological revolution and industrial transformation, China has proactively championed the establishment of "new engineering" since 2016, issuing several initiatives, such as the "Notice on Carrying out Research and Practice of New Engineering" [1]. The promotion of new engineering disciplines has gained momentum since 2016. In contrast to traditional engineering disciplines, new engineering disciplines exhibit a close integration with national industrial development, align closely with emerging fields, and place greater emphasis on enhancing students' independent learning, innovation, practical skills, and global perspective during the education process. The construction of new engineering disciplines is a significant strategic decision in China's higher engineering education, aimed at adapting to social development, economic upgrading, and industrial transformation. It represents a focal point for advancing reforms and exploring innovations in engineering education. The aerospace field, characterized by its engineering, practical, systematic, and collaborative nature, inherently involves multidisciplinary intersections [2]. This interdisciplinary aspect encompasses fields such as control, materials, energy, and information, and its knowledge system and scientific underpinnings continually evolve and expand with the ongoing developments in digitalization and informatization.

However, the existing curriculum teaching system in the aerospace field still exhibits a certain gap concerning the demand for cultivating innovative talent under the backdrop of new engineering construction. Particularly, the integration of professional theoretical knowledge and innovative practical applications faces challenges in synchronization. This paper specifically focuses on the curriculum characteristics of the core specialized course, "Aircraft Overall Design" (hereinafter referred to as "Overall Design"), within the aerospace field. It examines its relationship with the "Application of Large-scale General Software in Aeronautical Engineering" (hereinafter referred to as "Application

Software") through the sharing of teaching content, teaching modes, and methods, utilizing competitive team design as the primary approach [3]. We employ the competitive team design model to incorporate the comprehensive practical tasks of "Application Software" into the practical activities of the "Overall Design" course. The teaching content is strategically and scientifically arranged to enhance students' learning efficiency without increasing the total number of class hours, ensuring continuity in design thinking. Simultaneously, in line with the requirements of constructing new engineering disciplines and cultivating talents in the new era, we have undertaken initial exploration and establishment of a joint teaching mode for the "Overall Design" course group. This aims to stimulate students' active innovation consciousness, strengthen their global thinking abilities, and cultivate "excellent engineers" capable of comprehensively applying professional knowledge to address actual engineering problems. It also contributes to the development of a new model for training innovative talents in the evolving aviation landscape.

2. Overview of the new phase of talent development

2.1 Characteristics of the discipline

With "engineering" as its essence and "new" as its orientation, New Engineering represents a reform strategy aligning with the contemporary needs arising from the new wave of scientific and technological revolution and industrial change [4]. This strategy is not merely about establishing "new disciplines" and "new majors" but also entails embracing "new concepts" and innovative talent training methodologies in the "new era." It involves constructing a framework based on "new concepts," "new structures," "new modes," and "new systems" that align with the demands of innovative talent cultivation in the contemporary era. Regarding the characteristics of majors and disciplines, new engineering disciplines center around "Internet+," "informatization," and "intelligence." They are market-oriented, directed towards emerging industries, and responsive to major national demands. These disciplines will dynamically adapt to industrial development, social progress, and technological advancements, demonstrating strong timeliness [5]. Additionally, due to the integration of new technologies with digitalization and informatization, New Engineering is characterized by the convergence of cutting-edge disciplines and comprehensive engineering practice.

2.2 Characteristics of human resources training

From a talent cultivation perspective, the traditional teaching mode predominantly emphasizes theoretical knowledge, often overlooking students' practical and innovative abilities. This is particularly evident in aerospace majors, which are pivotal engineering disciplines responsible for addressing the needs of social development and fulfilling national strategic demands. These majors not only demand a solid theoretical foundation but also require students to possess strong independent learning capabilities and global awareness. New Engineering places a heightened emphasis on the practicality, interdisciplinary nature, and comprehensive skills of students. It prioritizes the cultivation of "engineers of excellence" capable of adapting to the evolving landscape of science, technology, and industry. Students are expected to possess a multidisciplinary knowledge system and practical abilities that span various disciplines, enabling them to tackle complex engineering problems effectively (see Figure 1).

2.3 Dilemmas faced

2.3.1 Challenges and Shortcomings: Integrating Theory and Practice in Aerospace Courses

The integration of theory and practice poses challenges, leading to limited benefits for students, particularly in aerospace courses. Students in these courses are expected not only to grasp a robust theoretical foundation but also to cultivate strong practical abilities. However, the current integration of theory and practice for students faces two main shortcomings:

- **Emphasis on only one aspect:** Some courses focus solely on theoretical teaching, where students acquire knowledge through passive learning without hands-on opportunities. This approach results in a weak mastery of knowledge and skills, creating a theoretical understanding without practical application. Conversely, courses that concentrate exclusively on practical aspects neglect the teaching of essential theoretical knowledge. As a result, students can only

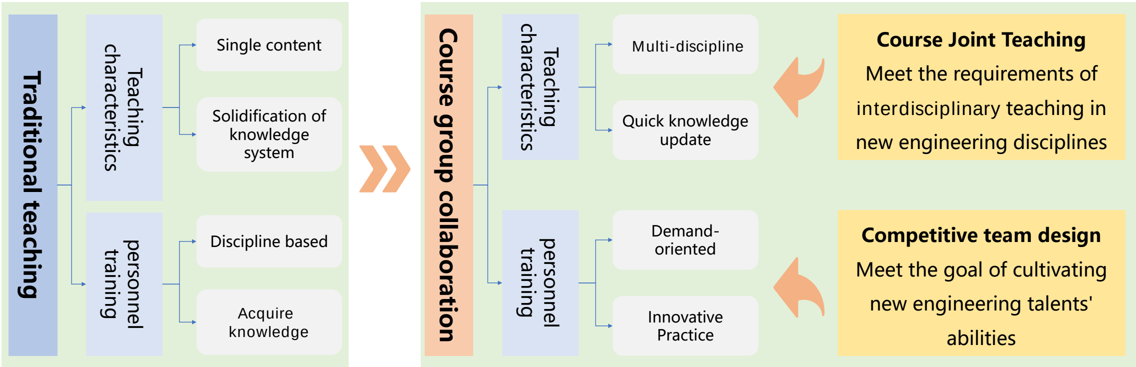

Figure 1 – The difference between traditional teaching and course group collaboration.

handle classical practice cases explained in the classroom, leaving them helpless when confronted with complex engineering problems due to the absence of theoretical support.

- **Poor balance between theory and practice:** The effective combination of theory teaching and innovative practice is essential for enhancing students' professionalism and practical abilities. However, due to constraints such as insufficient total class time, uneven distribution of class time, or suboptimal course arrangements, achieving this balance is often challenging.

Consequently, theory and practice fail to integrate fully, hindering thorough student learning and diminishing the overall teaching effectiveness.

2.3.2 Complexity Challenges: Enhancing Learning in Multidisciplinary Courses

The knowledge system is complex, placing a heavy teaching burden on instructors, and students' reports (designs) tend to be perfunctory. Particularly in topics closely related to actual engineering or cutting-edge technology, teachers often find it challenging to provide detailed explanations and extend knowledge within the limited class time. Consequently, both teachers and students may not derive sufficient benefit. Moreover, after completing a course, students, when faced with new professional courses, encounter content overlap from previous lectures. In the teaching process, teachers may not be familiar with the teaching materials system of the preceding courses, leading to similar practical assessment methods and content. As a result, students frequently submit immature reports or assignments to fulfill multiple coursework requirements. This not only unnecessarily consumes class hours across various specialized courses but also diminishes students' attention when confronted with multiple course assignments, undermining the intended goals of the curriculum and student training.

2.3.3 Challenges in Assessment Formalization: Balancing Inquiry-Based Learning and Traditional Approaches

Formalization of assessment methods remains a challenge. The traditional independent course assessment method, initially centered around exams, has evolved to include "exam + personal report (design)" for final evaluations. While this approach seemingly promotes engaging "inquiry-based" learning, the majority of students still prioritize completing established course tasks as their primary goal [6]. Despite the appearance of rich and interesting "inquiry-based" learning, most students tend to focus on meeting examination requirements, resulting in reports that are generally descriptive and rely on conventional design approaches. This approach diminishes the effectiveness of learning and practical application. Even with the incorporation of various digital teaching tools to assess complex and scattered knowledge points incrementally, the lack of control over the macro knowledge system makes it challenging to truly gauge students' learning effectiveness. Consequently, the assessment method becomes a mere formality. Additionally, this form of assessment fails to stimulate active learning among students and does not contribute to enhancing their understanding of knowledge or their ability to solve practical problems.

3. Co-Teaching Course system for course clusters

3.1 Top-level design of teaching models

The cultivation of interdisciplinary innovative talents advocates for the cross-fertilization of demand-driven disciplines, resources, mechanisms, and systems [7]. By exploring the teaching and practice modes of specialized courses, we aim to facilitate the integration of "top-level design" in teaching content, objectives, means, and modes with the national development strategy. This integration is further aligned with the specific requirements and measures of the transformation and reform of "double first-class" colleges and universities. The joint teaching system of course clusters under competitive team design primarily explores collaborative and shared teaching methods for multiple specialized core courses and practical courses. It achieves a seamless connection between "learning" and "use" without increasing the number of class hours. Ultimately, this approach establishes a national first-class teaching system based on the national first-class course "Aircraft Overall Design." This course serves as the leading component in the joint teaching of the research and development of an aircraft course group. This innovative approach addresses the issue of wasted teaching and learning time caused by similarities between courses, enhances students' interest in learning, and improves the utilization rate of teaching hours. The result is a more focused knowledge system for students, fostering systematic ideas and perspectives in learning and practice during the educational process.

3.2 Implementation process

The joint teaching of course clusters represents an effective approach and a developmental trend for addressing the dispersion of students' knowledge systems and avoiding the duplication of teaching content. The "General Design" course, being a comprehensive course built upon various specialized courses, enables students to apply knowledge from aircraft structure design, fluid mechanics, aerodynamics, finite element methods, elasticity mechanics, large-scale aeronautical engineering software, engines, and other related fields in the process of course practice through project-based learning. The integration of professional knowledge for overall design becomes a key focal point in the joint teaching of the course group. Implemented through the competitive team design, the joint teaching of the course group, without increasing the total number of hours, is realized through the principles of "three combinations" and "five unions." This approach effectively resolves issues related to the dispersion of students' knowledge systems and prevents the duplication of teaching content. Ultimately, it achieves true integration of "learning" and "use."

3.2.1 Revolutionizing Team-Based Learning: Adapting Aerospace Education to the Information Era

Reform of the Competitive Team Design Model: The teaching of courses such as "Application Software" and other software-related subjects still lacks synchronization with the state of learning and application. In the current era of information explosion, independent learning, teamwork, and active exploration are integral aspects of talent cultivation. Drawing from the successful operational experience of over a decade in the "General Design" course and other application-oriented courses, we are exploring a shift from the existing model to a reformed competitive team design mode. This transformation aims to actively respond to and adapt to the challenges posed by the evolving landscape of talent cultivation. The reform focuses on three key aspects:

- **Combination of Team and Project:** The class is linked to the classroom, with students grouped around specific goals (such as an aircraft program). These groups engage in practical exercises aligned with the course content.
- **Combination of Process and Results:** Emphasizing the importance of both process and project outcomes, the assessment comprises 40% for the process and 60% for the guided project. This includes classroom tests and regular homework, ensuring an organic blend of process and project design.
- **Combination of Group and Individual:** To reinforce teamwork and enhance student engagement, a mechanism for mutual evaluation within the group is established. The total points

allocated to the group correlate with the total score and the number of individuals in the group project.

This reform aims to bridge the gap between theoretical knowledge and practical application, promoting a more dynamic and collaborative learning environment in response to the demands of contemporary talent development.

3.2.2 Synergizing Learning: Co-Teaching Courses for Integrated Course Clusters

Co-Teaching Course of Course Clusters: Leveraging the project design of the "General Design" course as a catalyst, the "Application Software" course's substantial assignments are integrated into the project design process. This integration transforms these assignments, providing them with more practical application value and detaching them from the nature of simple tasks. The objective is to align the learning and practice process of Application Software courses more closely with the project design processes in the industrial world, fostering interest in learning and narrowing the gap between learning and engineering application. The approach involves studying the progress, requirements, and evaluation system of the project design process and large-scale assignments of large-scale software. It introduces a mode and method of staged assessment during the project, facilitating the assessment and evaluation of different courses within the same process. Key elements of the Co-Teaching Course include:

- **Joint Model:** Both courses adopt the same competitive team design project model (see Figure 2), encouraging students to actively engage in learning, discussions, and problem-solving throughout the project design process.
- **Joint Topics:** The two courses share identical design project topics. "General Design" emphasizes professional knowledge in aircraft design, design iteration, and design trade-offs, while "Application Software" focuses on the application of design support tools, supporting the expression and improvement of design solutions.
- **Joint Team:** Both courses cater to junior students, with students from the "Application Software" course each year originating from the "General Design" course. This overlap ensures a common foundation for joint course work and maintains consistency in the design teams.
- **Joint Progress:** The three design project phases of "General Design" are closely integrated with the multiple software learning progress of "Application Software," synergistically promoting the smooth progress of students' design projects.
- **Joint Resources:** Teachers, courseware, and video resources from both courses are shared. Particularly, challenges encountered by students during the overall design of the aircraft, such as aerodynamic analysis problems, can be addressed by teachers and teaching assistants from the "Application Software" course.

These Co-teaching courses aim to enhance the coherence of students' knowledge systems and provide a comprehensive and integrated learning experience.

3.2.3 Gradual Integration of Civics and Politics: Nurturing Soulful Course Clusters through Joint Teaching

Incorporating Civics and Politics gradually and establishing soulful course clusters through joint teaching. The comprehensive promotion of ideology and politics courses in colleges and universities is deemed "a strategic initiative that affects and even determines the issue of succession, the long-term stability of the country, and the revitalization of the nation and the rise of the country" [8]. This initiative is also recognized as an effective means to realize the central link and fundamental task of "the foundation of colleges and universities lies in establishing morality and nurturing people," as articulated by General Secretary Xi Jinping [9]. Classroom teaching, being the "main channel" for implementing this fundamental task, should leverage the leading role of teachers, teaching teams, schools, society,

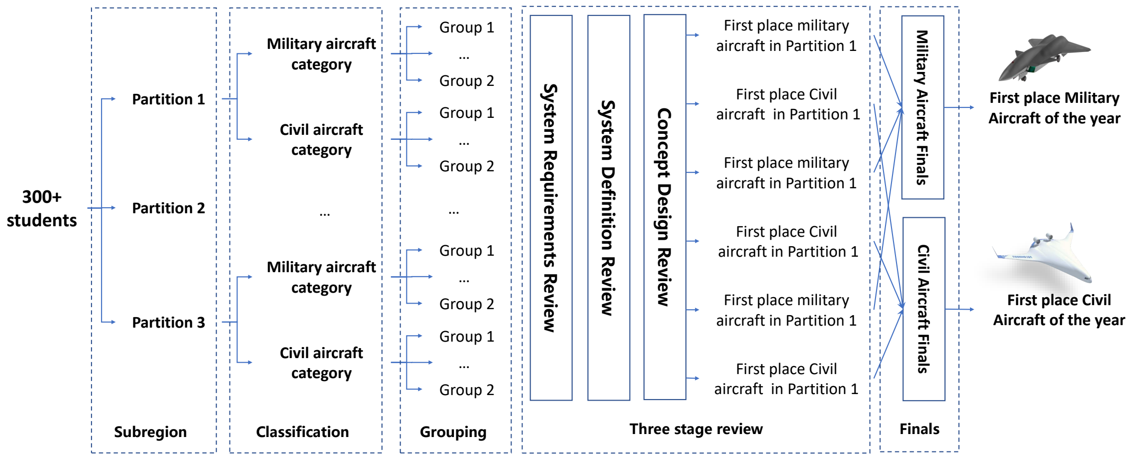

Figure 2 – Competitive team design project model.

and other dimensions in "Civics." This entails forming a Civics teaching system characterized by the attributes of new engineering disciplines. The competitive team design under the joint teaching mode of the course group aligns with national major needs and industry cutting-edge directions. It combines school teaching objectives with the goal of nurturing students into Civic and Political leaders. Internally, students engage in the joint teaching mode of course clusters (see Figure 3), gaining practical experience to understand the fundamental aspects of domestic aircraft, fighter jets, and domestic industrial software. This cultivates national self-confidence and pride, establishes a robust theoretical and practical foundation, and exemplifies the spirit of the new era in college students, characterized by self-reliance, innovation, and vitality. Externally, leveraging the characteristics of Beihang, such as "Beijing No. 1" and the "Museum of Aeronautics and Astronautics," the program extends from internal to external contexts. With support from entities like COMAC, Aeronautical Research Institute, and other research units, it connects with the most cutting-edge industry developments and social needs. This approach aims to cultivate outstanding engineers with a strong sense of familial and national identity, embodying the fusion of "ideology and politics + professionalism." These efforts contribute to a holistic educational experience, aligning with the overarching goals of ideological and political education, fostering well-rounded individuals who contribute to the long-term stability and prosperity of the nation.

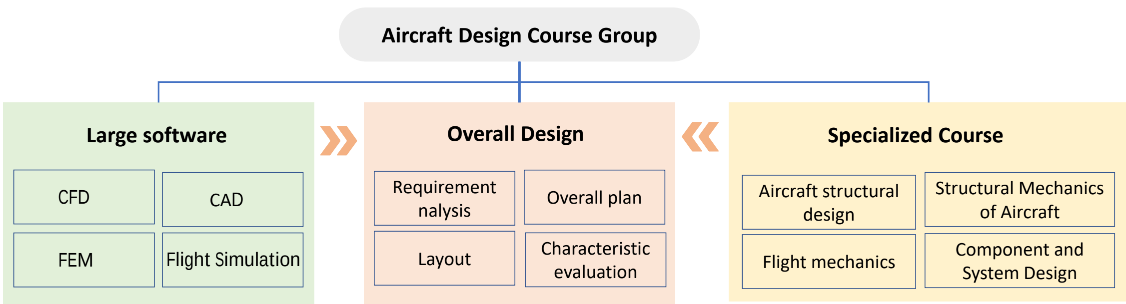

Figure 3 – Schematic diagram of aircraft design course group.

4. Actual effects of teaching

4.1 Improvement of students' learning capacity

The joint teaching of course clusters guided by competitive team design dismantles the barriers between courses, addressing the traditional issue of teacher-centered teaching in independent lectures of a single course. It optimizes the classroom approach, moving away from the teacher's lectures striving for completeness in teaching time, content, and method. This transformation expands opportunities for students to acquire knowledge, exercise creativity, and engage in innovation. The approach aims to maximize the reduction of time redundancy resulting from overlapping knowledge and, concurrently, maximize the expansion (not prolongation) of students' independent learning time. This ensures the continuity of innovative practice. Under the guidance of projects, students can extend their learning and practice from classical design cases to the industry's frontiers, aligning more closely with the nation's needs. By focusing on a "project" for learning and communication, the approach narrows the gap between learning and engineering applications. Students are liberated from the constraints of examinations and formalized assessments, allowing for a more natural course assessment rooted in the inherent nature of homework. In the context of a "project," students operate as a single team, concentrating on a singular task that requires meticulous attention. This fosters the development of a cohesive knowledge system and ensures constant pressure and motivation derived from peer leadership. Both inside and outside the classroom, students become more active and conscientious, their learning interests fully stimulated, and their active learning ability and global thinking comprehensively enhanced.

4.2 Reducing the teaching load of teachers

The existing model effectively alleviates the heavy workload previously borne by teachers, who were responsible for organizing, presenting, explaining, summarizing, and assessing all the contents of a course. Through the collaborative effort of several teachers in the course cluster for joint teaching, teaching arrangements can sidestep the redundancy of content presentation, thereby reducing the unnecessary burden of lesson preparation. This collaborative teaching model enables experienced teachers to explain each chapter of the course, diminishing the need for "performative" teaching solely designed to attract attention [10].

The teaching methods become more flexible with the synchronization of theoretical and practical courses. This approach avoids the unnecessary investment of teachers' energy in practical teaching during theoretical lectures. In terms of assessment arrangements, the volume of homework at all stages is effectively controlled, leading to a more centralized assessment process and a substantial reduction in the time required for correcting homework. The "mechanical" teaching component of teachers has been diminished, while the instructive component has been enhanced. Teachers' roles have transitioned from delivering single lectures and indoctrination to guiding students' learning, thereby reducing the burden on teachers in the teaching process.

4.3 Enhancing the precision of assessment

The phased assessment model addresses the limitations of the previous assessment system, which relied on factors such as the number of assignments, the content of examination questions, and performance on the spot. The new model ensures more accurate and less accidental assessment scores. Phased assessment facilitates the integration of "learning" and "use" by aligning the three-phase assessment of the "General Design" course (System Requirements Review, System Definition Review, and Conceptual Design Review) with the "Application Software" course. The organic coordination of the three-phase evaluation of the "General Design" course with the software-focused "Application Software" course (see Figure 4) encourages students to proactively engage in learning, discussions, and problem-solving in the project design process. This creates an environment fostering teacher-student interaction, student-student interaction, cooperation and competition, and initiative and innovation. "General Design" emphasizes aircraft design expertise, design iteration, and design trade-offs, while "Application Software" focuses on the application of design support tools, supporting the expression and refinement of design solutions. The final team presentation serves as an intuitive reflection of the project team's communication quality and innovative research. Moreover, it provides a reasonable quantification of students' individual learning situations and practical abilities. This comprehensive assessment approach enhances the overall evaluation accuracy and reflects the students' capabilities more authentically.

4.4 Enriching the results of teaching practice

After multiple rounds of teaching practice, the CAD modeling proficiency of "General Design" students has notably improved. The expression of their designs has become more complete and comprehensive, showcasing advanced CAD functions such as animation and mechanism motion simulation.

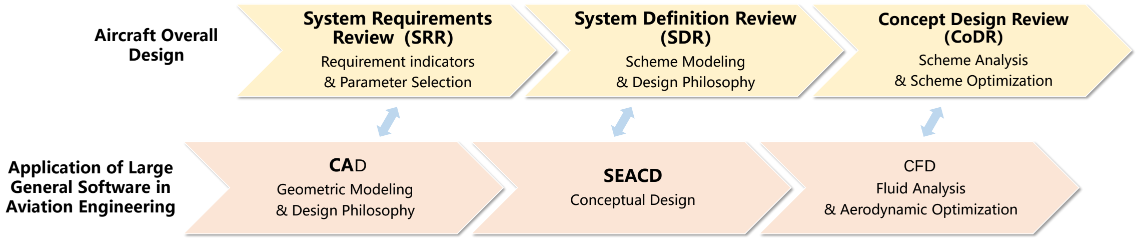

Figure 4 – Joint progress of two courses.

Virtually every group utilized CFD for overall or localized simulation analyses, offering vital support for optimizing and enhancing the design schemes. Taking the Beihang "White Nue" team as an example, though consisting of only 10 students, the team covered five disciplines, including aircraft design, man-machine and environmental engineering, and engineering mechanics. Engaging in competitive team design, the team embarked on the pioneering design of the "White Nue," the first of its kind in China. Throughout this process, the team conducted 32 focused cross-seminars, underwent four major revisions of the program design, completed over 70 iterations of RCS analysis, and conducted more than 300 CFD simulations. Ultimately, they successfully executed a feasible program. The "Red Sky" team, representing the project team, secured the first-place gold medal in the 2021 China University Students' Engineering Practice and Innovation Competition for Aircraft Design and Simulation (Professional Group of Platform Design Competition). The "Interdisciplinary Joint Team Graduation Design," formed around the core of the project-led joint teaching mode of course clusters, achieved recognition as the "Outstanding Undergraduate Graduation Design (Thesis) of Beijing Ordinary Schools of Higher Education (Team Category)" in both 2022 and 2023. So far, over 400 student teams have completed nearly 1,000 aircraft conceptual designs (see Figure 5), significantly enhancing students' sense of active learning and innovation ability. Furthermore, teachers under this mode have guided students in the course group to win gold medals, national final champions, and special prizes in provincial and ministerial competitions within the same industry. The students' innovative and practical abilities have received high praise from the China Industrial Competition. This demonstrates the success and effectiveness of the interdisciplinary joint teaching model in nurturing competent and accomplished students in the field.

5. Conclusion

By delving into the teaching content, mode, and methods of course synergy sharing and considering the unique characteristics of the "General Design" course and its relationship with the "Application Software" course, we leverage the project design tasks in the "General Design" course that mirror the engineering development process. This becomes the focal point, integrating the substantial assignment tasks from the "Application Software" course into the overall design teaching and practice activities. This approach tightly intertwines students' knowledge learning and practicing processes with the project design process. It facilitates the swift application and verification of acquired knowledge, fostering a deeper understanding and mastery of the subject matter. Through the judicious and timely embedded organic integration of course content, the teaching content is arranged in a rational and scientific manner without increasing the total number of hours, thereby enhancing students' learning efficiency and ensuring continuity in design ideas. The initial step involves establishing an aircraft overall design course group, exploring the teaching mode, content, and methods of the course group, and catalyzing the formation of a new mode for cultivating innovative talents in the evolving stage of aerospace development. This initiative aims to create a comprehensive and integrated educational approach that aligns with the demands of the current aerospace landscape.

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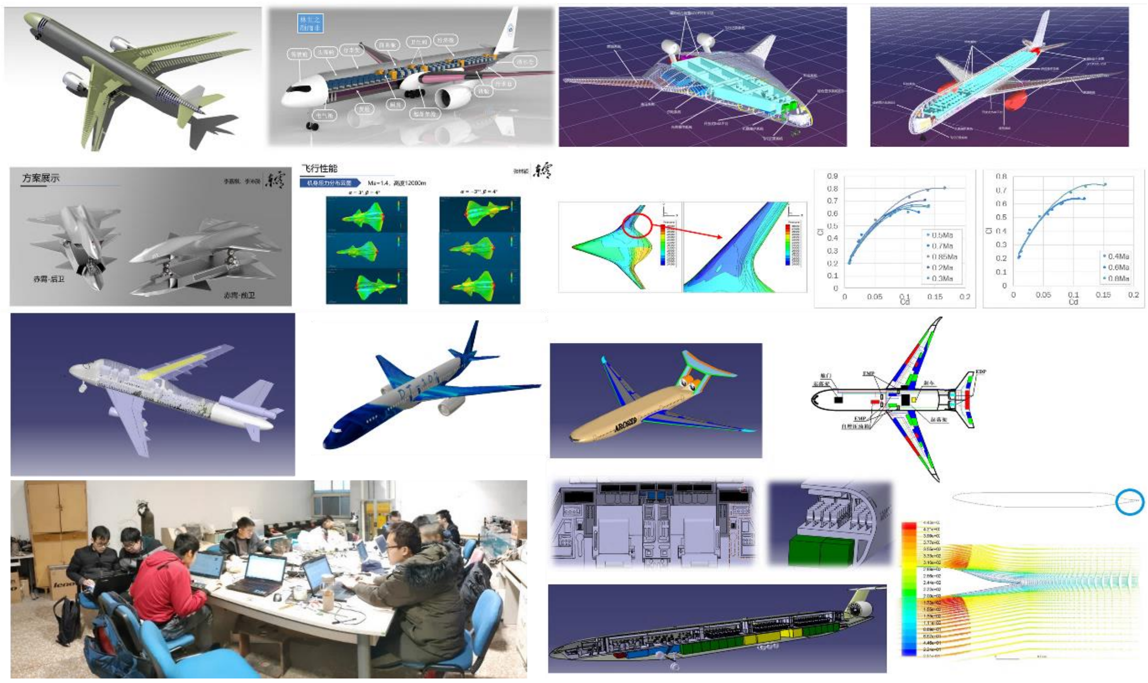

Figure 5 – Conceptual Design/Simulation Plan for Aircraft Formed under the Joint Course Group (Part).

7. Copyright Statement

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