STUDY ON EVALUATION METHODS OF UNDERGRADUATE AIRCRAFT OVERALL DESIGN COURSE BASED ON TEAM DESIGN COMPETITION

Zikun CHEN*, Hu LIU*, Chenguang YANG*
***School of Aeronautic Science and Engineering, Beihang University, Beijing 100191, China**

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Abstract

One of the most significant problem in the education of Aircraft Overall Design (AOD) is how to evaluate the learning performance of undergraduate students in the aspects of professional knowledge and practical ability. In order to solve this problem, a variety of evaluation methods have been researched in the AOD course of Beihang University (formerly Beijing University of Aeronautics and Astronautics, BUAA) in recent years, and an evaluation method based on team design competition has been come up with. The benefits of the exploration are multifaceted, including grading students more accurately and evaluating teaching effectiveness more practically. In addition, the course plan can also be refined according to the feedback.

1 Introduction

Education of AOD has increasingly been an important topic in aerospace field, additionally, many universities has relevant curriculum, such as California Polytechnic State University [1], Virginia Polytechnic Institute and State University [2], Imperial College London, Nanjing University of Aeronautics and Astronautics, and etc. [3] They have made enormous contributions to reserve talent for the development of aviation industry.

The AOD course is offered by the School of Aeronautic Science and Engineering in Beihang University, which has the history of more than sixty years. It is also elected as the National Quality Course of China. From 2011 to 2013, Beihang University has launched the Beihang-Purdue Aircraft Design Joint Courses Program. Then the Program of Aerospace Design United Courses (PADUC) [4] in early 2014, with the advantages of making more communication with other universities [5, 6] worldwide. The aim of this program is to integrate excellent resources of aerospace design courses around the world, which can increasingly promote and improve the development of aerospace design education level, what is more, lead the reform and innovation of engineering design education.

With the development of AOD course, this course has been chosen by more and more students as obligatory subject, originally elective course. At the same time, many problems have become apparent gradually, the most outstanding one is evaluation method [7]. In recent years, based on the earlier exploration, our specialized instructor team has mainly dealt with this problem, and an optimized evaluation method has been proposed. The achievement of every student is assessed from two main parts, course lecture and course project. The former uses traditional examination, while the examination content is designed based on two aspects, key points which must be emphasized in course lecture and main problems which students face in course project. The latter references three phase reviews in Purdue University [8], which consists of the System Requirements Review (SRR), the System Definition Review (SDR) and the Conceptual Design Review (CoDR).

This paper discusses the evaluation method of AOD course carried out by instructor team. It includes specific issue, course evaluation organization, course lecture program, course project competition, and undergraduate's

integrated result. In addition, according to the characteristics of the team design competition, the evaluation methods of every phase achievement, competitive selection and final scores are proposed.

Practice shows this evaluation method can not only motivate the learning initiative of undergraduate in the largest extent, but also evaluate the undergraduate learning performance more objectively.

2 Specific Issue

There are many methods can be used to evaluate the performance of an aircraft, while traditional examination is always only used to evaluate the learning performance of an AOD course. However, this traditional method is not enough in Beihang University, because there are some specific problems that seems not be frequently encountered in other universities, which can make a considerable influence on the evaluation of undergraduate AOD course. The main problems as follows:

1. The large-scale of course. More than 320 junior students participated in this course in 2017 fall semester, and the total number has been growing increasingly, comparing with 10 years ago. By contrast, there are not enough instructors of course, only 6-8 each semester. As a result, the participation rate cannot be guaranteed.

2. The large-content of course. Synthesizing multidisciplinary theory knowledge, the process of AOD is very complex, therefore more course content should be considered in class. As a result, the undergraduate learning efficiency cannot be improved if only using traditional methods.

3. The large-work of course project. Undergraduates should manipulate based on the content of course lecture in course project, and the project must be carried out with some aspects, such as market analysis, parameter determination, overall arrangement, three-dimensional model, assessment and evaluation. What is more, they need to learn and use multiple software.

Facing with this situation, an effective and workable evaluation method is necessary for this course, which can evaluate the undergraduate learning performance more objectively and accurately.

3 Course Evaluation Organization

The actual AOD process, needs not only the multidiscipline theoretical knowledge to satisfy the requirement of problem-solving capabilities, but also the team efficient cooperation to ensure that an available design plan can be obtained before every phase deadline. With the aim of making AOD course as similar as engineering practice, the instructor team combines course lecture with course project, which can highlight the significant concepts, such as trade-off, iteration, innovation thinking and teamwork in AOD for undergraduates,.

With several years of exploration, an effective evaluation method has been proposed innovatively, which can solve the specific issue listed above. The organization of AOD course evaluation is shown in Fig. 1.

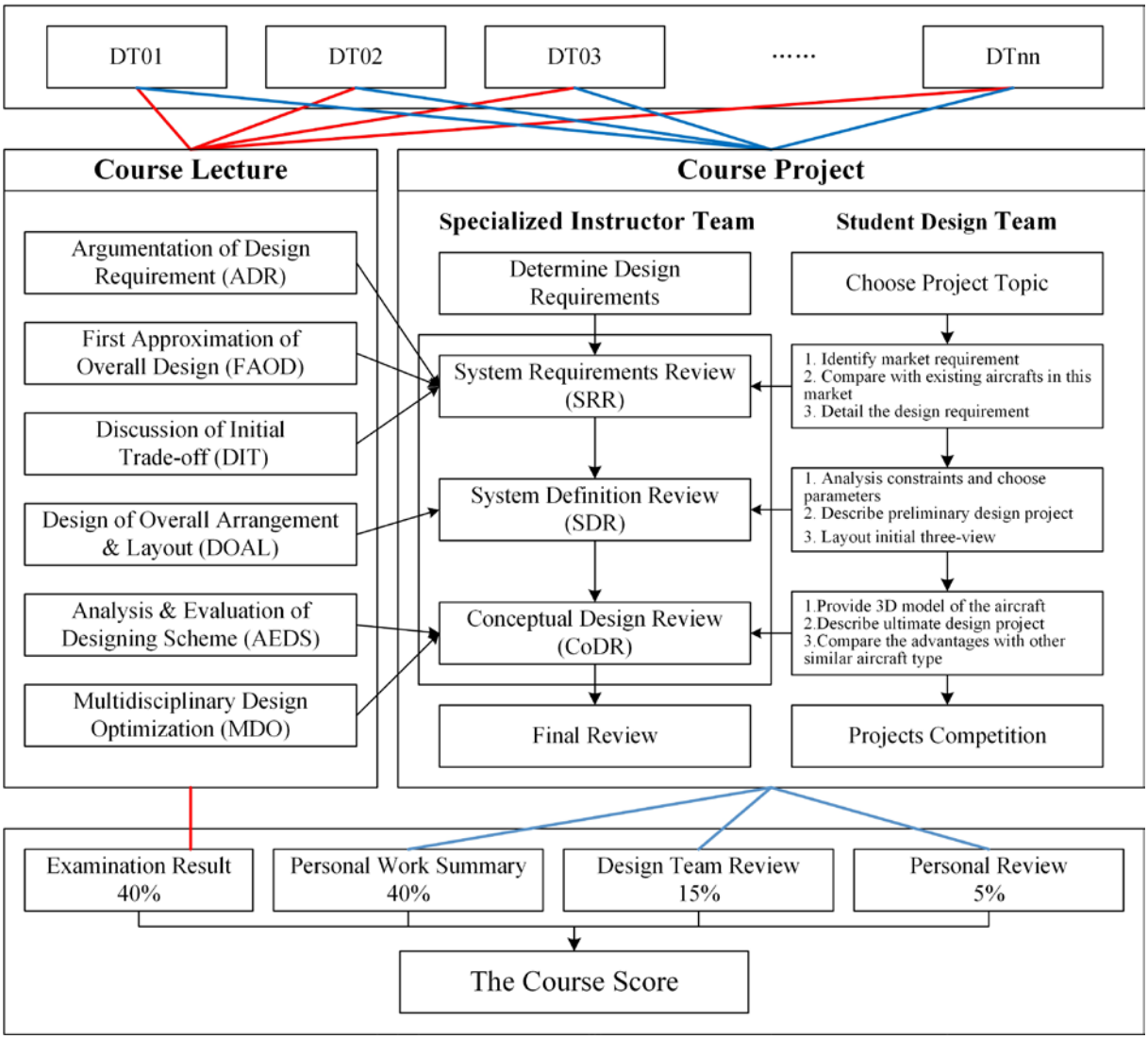


Fig. 1 Organization of AOD Course Evaluation

At the start of every semester, students can form design team (DT) freely with about 10 members, and then take the DTs as basic units to participate follow-up course. The part of course lecture emphasizes the key points in AOD by thematic lectures, and build a completed knowledge system for undergraduate. At the same time, in order to ensure the overall design of airplane can be accomplished during course cycle, the part of course project divides the design work into three phases, and sets objects of each phase. These two parts supplement each other. What is more, the instructor team arranges lecture content according to the requirements of every phases, and optimizes the follow-up lectures based on the feedback form SRR, SDR, CoDR, by which the AOD course learning performance will be improved.

The course score of every undergraduate consists of four components: final examination result (FER, 40%), personal work summary (PWS, 40%), design team review (DTR, 15%) and personal reply review (PRR, 5%), in the hundred-mark system. The FER integrates main focuses from both course lecture and course project, the PRR requires each member illustrate their division work content and achievements, the DTR and PRR are based on the composite result of three phase reviews.

This organization and implementation of AOD course evaluation, have integrated final result with each review, in addition, made theory and practice combined. By this way, the completed AOD knowledge system can be created through actual practice, and the learning performance can be evaluated more objectively.

4 Course Lecture Program

Because of the limited class hour, it is impossible and unnecessary to detail all of the tasks of AOD in course lecture. Therefore, based on the requirements of undergraduate course syllabus, thematic lectures for special topics have been used to emphasize the key points. [9] As shown in Fig. 2. The left part is the main circle of topics, and the right parts are further descriptions for the Design of Overall Arrangement & Layout (DOAL) and the Analysis & Evaluation of Designing Scheme (AEDS), which is the most important parts of the former.

At the same time, some digital design experiment classes have been set up, considering that many assistant software will be used in the process of course project, such as OpenCADS, SEACD, Collaborate Client. [10, 11] The aim of it is to make DTs speed up the process more conveniently, and introduce some significant method [12, 13] in project.

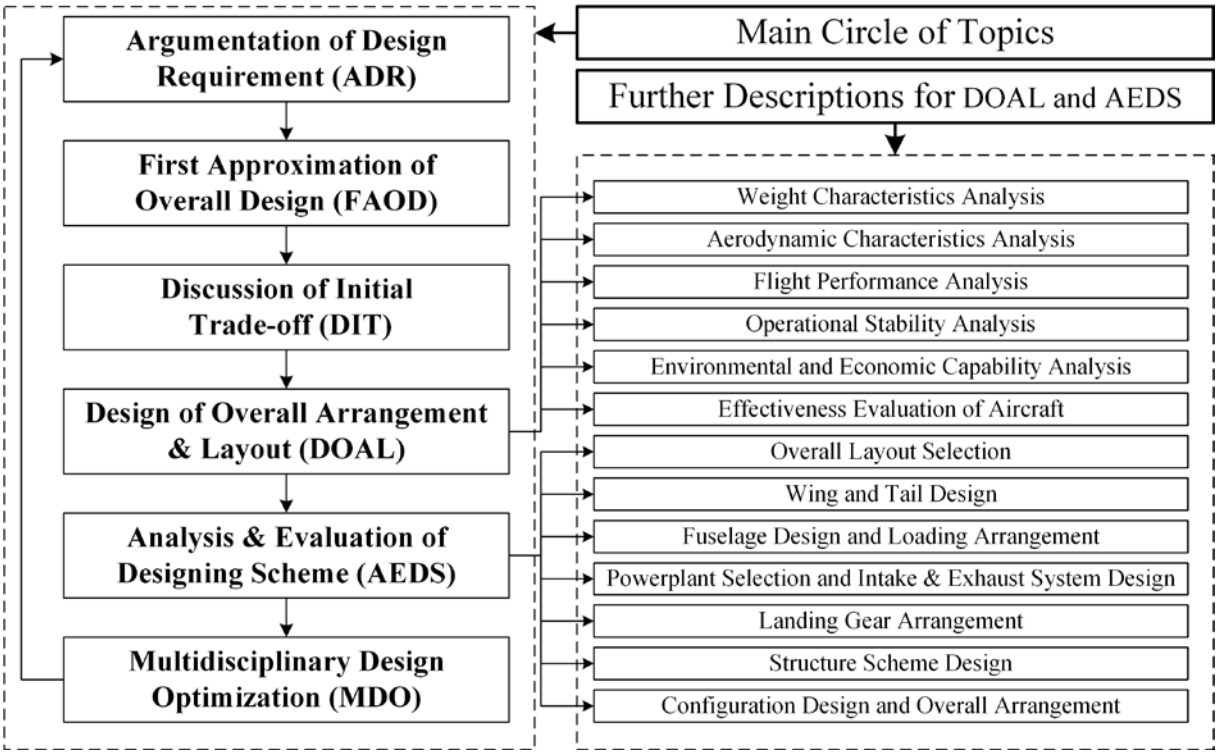


Fig. 2 Relationship of Special Topics in Course Lecture

5 Course Project Competition

Military and Civilian Integration (MCI) as a developing strategy has been emphasized all the time, especially in the field of AOD. Even though there are many differences in design parameters and actual application between civil and military aircraft, their AOD process are almost the same. Thus the course project topics of every semester are separated into two aspects, military and civilian aircraft, for every DT's choice. And the aim of it is making them master the necessary knowledge system and understand the AOD process by analyzing the design requirements.

From the original organization of instructor team and the beginning of course project in 2006[14], the competition system has been continuously perfected nearly decade. Especially in later 5 years, the special study of it has been carried out, with the purpose of reproducing actual AOD process, and an available course project competition system has formed gradually.

5.1 Group and Subarea

The organization of course project is carried out through 'group' and 'subarea'. The 'group' refers to DT, which is combined by 10 members freely. And the 'subarea' refers to an agreed

partition of all DTs, which is based on the configuration of instructors and make sure every two instructors can be responsible for as the same amount as possible. This way will balance the difference amount of student and instructor, and promote the participation of every DT members to the maximum extent.

The implementation of course project is carried out through competition system. Firstly, the project topics is ensured according to the recent focus of aviation industry, and the design requirements of every topic is analyzed based on course lecture content, as a result DTs can choose military and civilian subareas freely. Next, through SRR, SDR, CoDR, the instructor team reviews the milestone achievements of every DT, which can not only ensure that they can complete the project in time, but also supervise the details from requirements analysis, preliminary design and initial trade-off to improve the quantity of final achievements. Finally, the outstanding DTs of military and civilian subareas will be evaluated by integrating three phase results, and the champion reviewed by both instructor team and industry experts invited will produce.

This organization and implementation of course project duplicate the actual AOD process in industry, using team design competition. The aim is making undergraduate comprehend the transformation from professional knowledge to engineering application, furtherly integrating theory with practice.

5.2 Competition System

According to specific situation of each semester, competition system is determined considering the number of students, class, major, and project topic. In order to add team competition into the course project, the final review will be set after three phase reviews, and then the champion DTs of this semester will be selected.

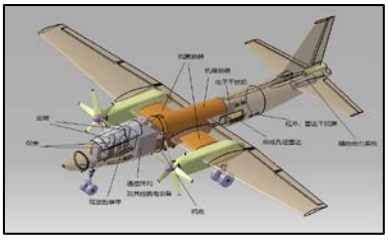
Course Project Competition System (CPCS) of nearly five semesters (including the number of DTs, the information of subareas, the DTs in final review and the champion DTs selection) are discussed as shown in Fig. 4.

The figures show that although competition system of each year is different, all the course project has undergone three phases: SRR, SDR, CoDR and the champion is chosen by the finial. It is worth noting that, the AOD course of Beihang University is not only a course of giving classical design method to students, it also play a significant role in promoting the communication with other organizations. For example, in the spring semester of 2006, the AIAA partition was set and students were organized to participate in Future Flight Vehicle Innovation Competition. Moreover, students and teachers keep academic exchange with other colleges academic exchanges by PADUC.

Instructor team think that students can realize the development trend of aviation industry, with more communications.

5.3 Demonstration of excellent projects

With the Combination of course lecture and project, and the advantages of special topics and competition system, many excellent projects have been made by many DTs, and the common characteristics of them are effective, cooperative and competitive. The picture (a) to (i) in Fig. 3 are some of the excellent projects.



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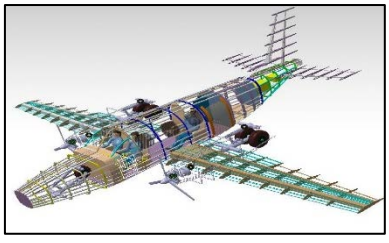

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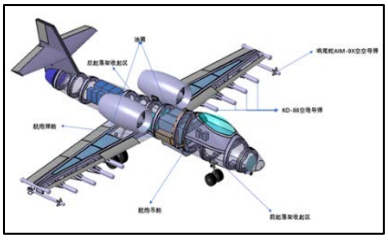

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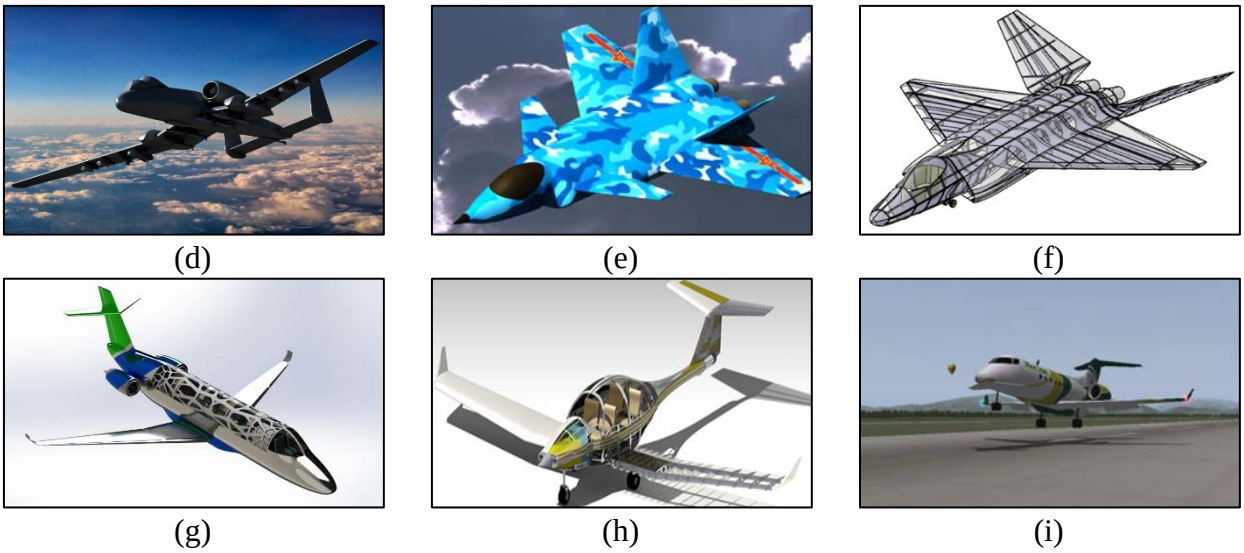
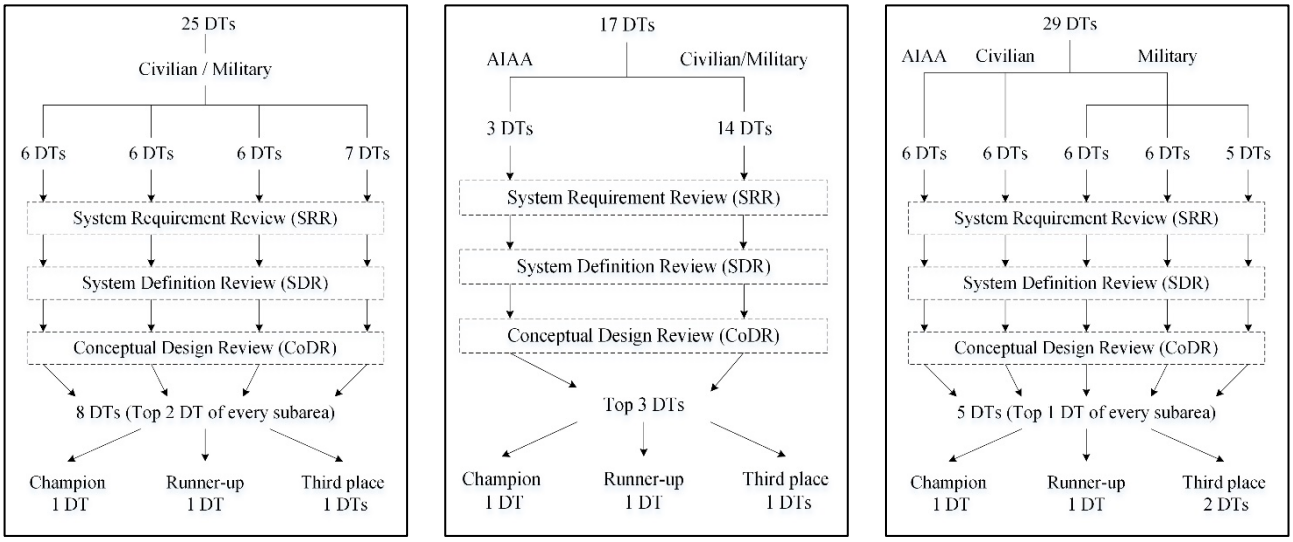


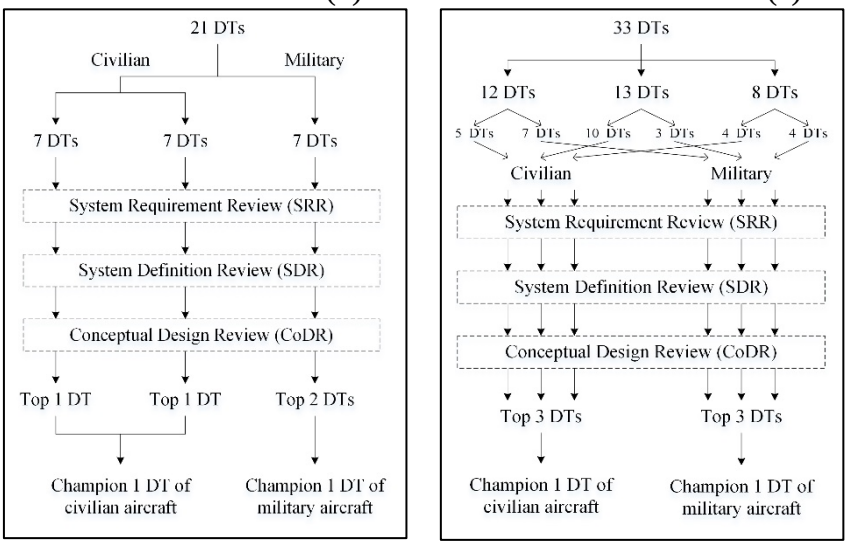
(d) (e) (f)

(g) (h) (i)

Fig. 3 Demonstration of excellent project



(a) 2014 CPCS (b) 2015 CPCS (c) 2016 CPCS



(d) 2017 (Spring) CPCS (e) 2017 (Fall) CPCS

Fig. 4 Course Project Competition System (CPCS) of Each Semester

6 Undergraduate's Integrated Result

6.1 Course Lecture Evaluation

After all course lectures ended, the teaching effect is evaluated by final examination paper. The content of this paper refers to the emphases and difficulties of course lecture on one hand, and refers to feedback of course project on the other hand. Exam questions can be broadly divided into two types, fill-in-the-blank questions (20%) and short-answer questions (80%). The former examines students' mastery degree of AOD basic concept, and the latter examines students' comprehensive and practical ability of AOD important design method.

6.2 course project evaluation

Taking AOD process and course lecture plan as a reference, the content of three phase reviews are set as following shows:

1. SRR: This review and report will identify the segment of the military/civilian aviation market that the team has chosen to focus upon.

2. SDR: Based upon the market analysis and the subsequent aircraft design requirements, this review and report should include constraint diagrams and results from initial sizing studies for the aircraft.

3. CoDR: This report and review needs to present the best available description of the environmentally-sensitive aircraft concept, and should contain additional details about the aircraft that do not appear in the system definition review.

The instructor team has designed detailed scoring tables of every phase to evaluate the stage work of DTs, which are shown in Tab. 1 and Tab. 2. At least two instructors are in charge of reviewing the design teams in the three phases. The review includes phase achievement of every team and job content of every team member, and the phase score is the average score. When three phase reviews are finished, the design teams which enter final review are chosen based on the result of reviews, and course project champion will be selected.

The scoring contents of SRR and SDR are the same, including team work, accomplishment, workload, correctness & scrupulousness, innovativeness and report format specification. In addition, CoDR has some adjustment and supplement compared with former two phases, which turn team work into member review and report format specification into Presentation and reply, and add feasibility. Setting five points per item, SRR and SDR are both 30 points, and CoDR is 35 points, the last 5 points is calculated by attendance rate of DTs.

It is necessary to emphasize that the member review refers to that each team member has to answer the questions raised by instructors, and the score of it is the average of every member result. There is a column of instructor feedback to DT in scoring tables, which is written by instructors after reviews. The purpose of it is to point out problems and shortcomings for DTs in time, so that they can perform subsequent project work better.

Tab. 1 Phase Review Scoring Table of SRR and SDR

Scoring Items	Score	Instructor Feedback to DT
1. Team Work		
2. Accomplishment		
3. Workload		
4. Correctness & Scrupulousness		
5. Innovativeness		
6. Report Format Specification		
Total Score		

Tab. 2 Phase Review Scoring Table of CoDR

Scoring Items	Name	Student ID	Assignment	Score	Instructor Feedback to DT
1. Member Review					
	Average Score of Members				
2. Accomplishment					
3. Workload					
4. Correctness & Scrupulousness					
5. Innovativeness (design solution, method and thought)					
6. Feasibility (design solution, method and thought)					
7. Presentation and Reply					
Total Score					

Because each judge has different standards of evaluation for scoring items, the achievement of each item has five levels, taking the scale method as reference, and the description of every level has been unified to reduce the scoring differences. The details are shown in Tab. 3.

Tab. 3 five scale assessment method

Score	Description
5	Perfect
4	Complete
3	Normal
2	Insufficient
1	Very Bad

After detailed evaluation of three phases, the DT ranking of each subarea has been calculated. Then the DTs in final review will be selected. In the competition of final review, each DT has limited time to make a presentation and answer questions. Then the instructors and other professors select the champion, based on design content and question-and-answer performance.

6.3 Final Score Evaluation

As shown in Tab. 4, student achievements collecting table is designed to solve the special problem that multi-component of undergraduate course score and large-magnitude of statistical information. The FER is used to evaluate mastery degree of relevant theory knowledge in course lecture, the PWS to mastery degree of AOD process in course project, the DTR to team work of DTs and the PRR to work capability of undergraduate.

The evaluation of final score focus more on the course project, as a result, only 40 percent of score belongs to FER, and another 60 percent consists of PWS, DTR ,PRR. The FER is calculated from final examination paper score; the PWS is determined by the personal work report submitted by undergraduate at the end of semester, the evaluating items of which include specification, achievement and suggestion; the DTR is ensured according to DT ranking of each subarea after three phase reviews, and the score is proportional to it; the PRR is equal to the member score in phase review scoring table of CoDR.

Tab. 4 Student Achievements Collecting Table

DT number	Student ID	FER (40%)	PWS (40%)			DTR (15%)	PRR (5%)
			Specification	Achievement	Suggestion		

7 Conclusion

In conclusion, the course evaluation method introduced in this paper can not only stimulate the learning interest of undergraduates, but also integrates teaching content into design project. It helps the instructor team grade undergraduate more accurately and evaluate their teaching effectiveness more actually. Duplicating actual AOD process, the competitive selection method highlights the significant roles for undergraduate students of the trade-off, iteration, teamwork and innovative thinking. The course evaluation method based on the three phrase review competition is an innovation of the AOD course in Beihang University, which has valuable reference for the AOD course evaluation in other university at the same time.

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