Synthesis Courses of project-based and Knowledge-based in Engineering Programms

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***Abstract* - In this paper we will introduce a reformation in engineering programs in Nanjing University of aeronautics & astronautics. For enhance students' competences and abilities to solve problems in an engineering project, we had developed a kind of synthesis courses by combined knowledge-based lectures with a problem-based project. In synthesis courses, there are two learning paths. One is the regular knowledge learning path, by which students would attend lectures and do experiments in laboratories as usual. The second one is a synthesis path on which students would take and finish a design project in a work team. After we have practiced for three years, new synthesis courses have shown great advantages in inspiring learning interesting, enhancing undergraduate experience and competence to solve problems. In this paper, we will analyze the synthesis course in detail by comparing the traditional course design method and new course design method, and we will introduce a synthesis course of Aircraft Design and Engineering also.**

Index Terms - Engineering Education, Knowledge-based, Project-based, Synthesis Course.

BACKGROUND

After coming into the 21th century, China Government has stated that china will become a creative country and build an innovation-based economy development model in a not long future. In this campaign, the most important is to enhance the creative competence of new generation. Universities have to reform curricula, such as building interdisciplines and developing project-based courses, to meet these needs.

In china, the higher engineering education was traditionally a narrow discipline education. For example, there were approximately 200 disciplines in the higher engineering education before 1998. In 1999, State Ministry of Education issued a new catalogue of higher education disciplines, the number of the engineering disciplines reduced to 75 [1]. With the reforming in higher engineering education, we reformed the engineering programms in our university. We have increased the foundation courses and experiments in the engineering programmms. As an example, in the Airspace Engineering programm, there were 40 to 45 weeks for a student to get trained at a factory, to do sociality survey, to attend a workshop course, to finish his or her final project and so on [2].

Since 2002, we have reformed curricula wildly and deeply. For undergraduate students, we have developed some project-based courses, research-based projects and special training courses, and a series of design contests have also been developed to enhance experiences [3]. In reforming, we found that students were often in a state that they did not know why they had to learn a theorem, and that some of them lost interests in learning after entering the university. Especially, when they faced a real problem, they did not know which of theorems could be adopted, did not know how to solve it. There was a gap between theory learning and practice. It separated learning from actual works.

For solving these problems appeared in traditional courses, we introduced a problem-based project into a course to combine theory lectures with designing practices in 2004. After four years exploring, we have developed a kind of synthesis courses. In this course, theory lectures were in parallel with a problem-based project.

FORM TRADITION COURSE TO SYNTHESIS COURSE

Traditionally, we designed a course based mainly on the knowledge structure. As we redesigned courses in the Aircraft Design and Engineering programm in the Mid of 1990s, we firstly built a knowledge matrix in which knowledge was arranged based on the knowledge structure， showed in Figure 1.

Math / Tech	Differential-integral	Vector-algebra	………	Stochastic-variables
CAD/CAM	2	2		0
Plat mould	0	2		0
………	X=			
Aircraft digital make tech	0	2		2

Note:
X=0, means a Math knowledge was not adopted in the Tech course.
X=2, means a Math knowledge was adopted in the Tech course.

FIGURE 1. KNOLEDGE MATRIX

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By the knowledge matrix, we had set courses for undergraduate students [4]. Courses designed based on the knowledge matrix reflected the knowledge structure and the generally cognizing process. In this kind of courses, student studied theorems step by step according to the knowledge structure, and they did exercise at any knowledge point by adopting it to a theoretical question. A teacher gave a lecture and students attended in a classroom. Students did their homework after a lecture to review what they had even learnt in the lecture. This was a regular process we used to. The advantages of this course were that students could build a knowledge structure in their minds simply. But we had also found that students often complained they did not know why they had to learn some courses arranged by the university and how to adopt the theorems they had learnt in courses to solve a real problem. These were the reasons why students would lose interests after they had mad a decision to take a course.

Faced to these questions, we deeply analyzed the process of a regular course by holding students and teachers colloquia in 2001-2002. In summary, the reasons causing these questions were as below:

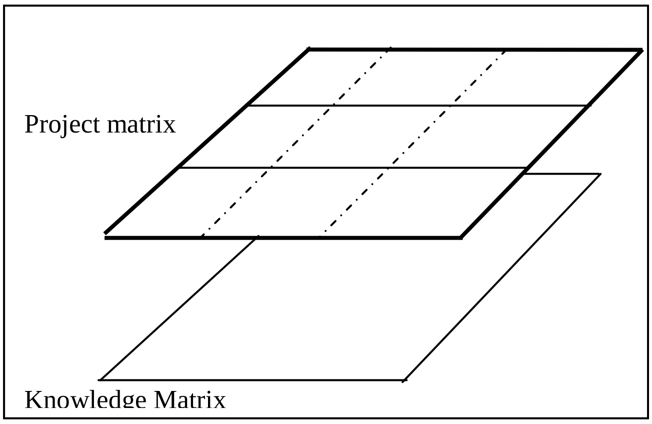
- Students learnt theorems in a lecture or in a book, and they did exercises to review theorems. Their learning activities did not refer to a real problem.
- Experiments in a course were mainly designed to verify theorems or nature phenomena. The Course grade was mainly based on a theoretical examination.
- The relations between courses or knowledge points were clear, but they did not reflect the needs to solve a real problem or a project. After finished a course, they were also lack of the competence to integrate theorems to solve a complex problem.

For keeping students motivated and enhancing students' competence to integrate theorems to solve complex problem, we tried to introduce some problem-based project into engineering programs in 2002. In a Problem-based project, students learnt in solving a problem process by searching suitable knowledge, adopting theorems they had mastered. In a problem-based course:

- Students always learnt theorems in a motivated mood and with a clear goal. In the process of a project, students wanted to learn some new theorems for solving the problem met in the project, and they had to solve questions by integrating theorems learnt in different courses. Problem solving was a challenge to students.
- Experiments were parts of a project, they were done to test a design or to verify a proposal, not only to verify a theorem or a nature phenomenon.
- Student Knowledge systems were not organized only on a theoretical structure. Students built their knowledge systems based on their experience. So that a student knowledge system always reflected the needs to solve a real problem or a project.

But in a problem-based course, we also met a problem that students often learnt for a practical utilization and their knowledge system was not very systematical.

In 2004, following the four guiding principles of constructivism [5], we tried to connect the knowledge matrix and the process of a project to establish a double matrix course design model, showed in Figure 2.



Skill / Work	CAD	Digital Wing Tunnel	………	Cost-analysis
Conceptual-design	0	0		0
Draw crafts	2	0		0
………	X=			
Select an Engine	0	0		2
Air Dynamic Analysis	0	2		0

Note:
X=0, means a skill was not adopted in the work.
X=2, means a skill was adopted in the work.

FIGURE 2. DOUBLE MATRIX MODEL

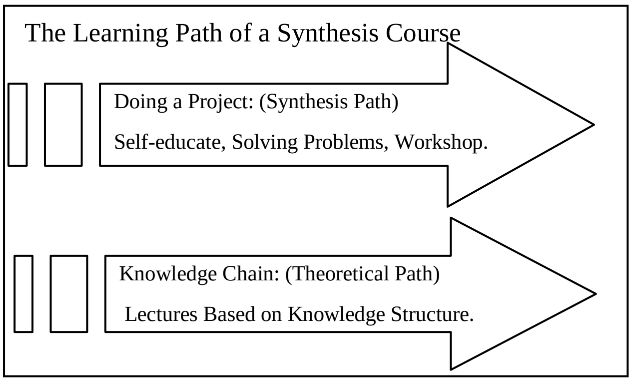


FIGURE 3. LEARNING MAP

By the double matrix course design model, we designed a new kind of courses which we called as the synthesis courses. In the synthesis course, there were two parallel learning paths, showed in Figure 3. One was the regular knowledge chain. We also called it as a theoretical path by which lectures were organized based on the knowledge structure of a special subject as regular courses.

The second one was a synthesis path that was parallel with the theoretical path. Students adopted knowledge learnt in lectures to solve problems in the path, and they got trained in data analysis, parts or system design, system test and self-educated. They would also search for new resources to get knowledge which is needed in solving problems in the project but beyond the courses in their major programms.

As students took this kind of courses, they would take lectures of the courses listed in their major programms to form a regular concept chain, they would do a project based-on a problem during the same period to adopt them and construct their meaning, and they would learn other courses beyond their major programms or learn by themselves to construct their own knowledge systems. They learnt and did in the synthesis courses.

REFORMING EXAMPLE

Since 1996, the Aircraft Design and Engineering being as a core course in the Airspace Engineering programm for undergraduate students has come through three periods of reformation. During 1996-1999, we reformed the knowledge structure by the knowledge matrix [6]. We finished the work as below:

- Introduced some new courses into the programs, including the digital design technology, stealth technology and cost-effect analysis, according to the development trend of airspace science and technology in the 21th century.
- We adjusted the structure of knowledge, according to the aircraft design process composed of the Conceptual Design, Preliminary Design, Modern Design Technology, and System Engineering.

In 2002, we introduced a problem-based project, being called as the Chief Designer Presiding over Project as the final project [7], into the Airspace Engineering programm to enhance students' competence of undergoing design works. Students had shown a great interest in it, and their works had got some awards in national wide and international future aircrafts design contests. Students who toke the project had shown also a progress in team work, in self-education, in making a system design, and in solving complex problem.

In 2004, we redesigned the course of Aircraft Design and Engineering again by moving the Chief Designer Presiding over Project into the course to develop a synthesis course [8].

The new course had traits as followed:

- Two path for students to learn and do exercise which being showed in Table 1.
- Knowledge structure and lectures were reorganized according to the process of the project to harmonize with the project work.

For introduced a project into the course, the assessment of course outcomes was also reformed. The grading was composed of four parts:

- Homework and Exercise 20%
- Final Exam 30%
- Oral Presentation 20%
- Project Work 30%

Course objectives and outcomes were assessed by the homework and exercises, the final examination, the project work, and the oral presentation of the project work.

TABLE I
SYLLABUS OF AIRCRAFT DESIGN AND ENGINEERING

Week	Content of Lecture	Work of Project
1th	Introduction	
2th	Premier Design Standard	Set Demands of the Project
3th	Aircraft Structure DesignⅠ	
4th	Aircraft Structure DesignⅡ	Calculate Factors
5th	Premier Parameters calculateⅠ	Select an Engine
6th	Premier Parameters calculateⅡ	Design the Aircraft Outline Ⅰ
7th	Engine Selection	Design the Aircraft Outline Ⅱ
8th	External Configuration Design of the Fuselage	Design the Aircraft Outline Ⅲ
9th	External Configuration Design of Wings	Design Undercarriages
10th	External Configuration Design of the Tail Fin	Draw crafts in Three Dimension
11th	Undercarriages Design	Set Inner Disposal
12th	General Arrangement of Devices	Air Dynamic Analysis
13th	Flight Function Analysis and Evaluation	Fly Performance Analysis
14th	Premier Optimizing Principles	Write a Design Report
15th	Example of a Aircraft Design (Course Summarize, Project Work Assessment, Examination)	Deliver an Address on Project Work

As an example, in 2006 fall term, the project work in the course of Aircraft Design and Engineering was to design a civil jet plane. The figure 4 showed a project work of a four students group.

The project task description was as bellow:

- To finish a principle design work of a jet plan for business. It would provide a seating capacity of 8 and could bear a cargo weight of 8*20 kilograms. The highest cruise speed of it was not below M 0.75, and the longest voyage was 3500 kilometers.
- Or To finish a principle design work of a civil passenger-plane. It would provide a seating capacity of 70 and could bear a cargo weight of 70*20 kilograms. The highest cruise speed of it was not below M 0.7, and the longest voyage was 2300 kilometers.
- The design work had to be finished by a 4 students group. They had to work in a team in which one would act as the general designer, and each one of other three would act as a sub-system designer respectively.
- Four students, as a design group, could select one of tow design works described above as their task. At the course end, the group had to hand in a design work report and to deliver an oral presentation to the instruct teachers.

FIGURE 4. A STUDENTS WORK

Paralleled with project, Lectures were re-organized. Some of relative knowledge had been introduced into the course, such as cost analysis and engineering management, to meet the needs of the project. At the end of the course, students had to hand in the project report and also to take a tow hours examination on the design theory and relative knowledge.

EVALUATION OF COURSE OUTCOME

Since 2004, about 70 students have attended the course of Aircraft Design and Engineering, they have benefited from the synthesis course. As an evaluation result in 2006, there were four distinct advantages.

- Students got obvious progresses in innovation competence. For examples, a group of students built a prototype of a mini flapping flight, and it had get the special award in the national wide college innovation contest in 2004. Another group of students built a prototype of a solar energy aircraft with 3.5 m width of wages.
- Students got obvious progresses in solving engineering problem. For in the course, students would finish a design task, so they had to solve complex problems by adopting synthetically knowledge learnt in different courses.
- The student' work experience was enhanced and Student' communication ability was improved. Because of working in a work team, every one had to finish a design work of a sub-system, and the general designer had to take charge of whole design work. In the designing process, they had to communicate with each other to solve conflicts and to ensure the system optimization.
- The student' interest in learning was inspired. Students showed great interests in learning and working, they were more active in classes than those not attend this synthesis courses.

As a senior aircraft designer Mr. Li Wenzheng, who worked in a famous aircraft design institute, said [9], "In the course of Aircraft Design and Engineering, the new structure of lectures paralleled with a project combined the theory teaching and practicing well, students could get a comprehensive understand of the aircraft design engineering. The outcomes of the course had shown that students had got more progress than formers in adopting knowledge to solve real problem, in innovation competence and in dealing with engineering problems."

CONCLUSION

As described above in this paper, the double matrix model is an effective approach to design courses for providing a substantial knowledge base, improving students' innovative ability, self-educated ability and the capability of solving engineering problem.

In evaluating the outcomes, we also found if we wanted to keep the lectures to be consistent with the project process, we had to design the content of the course according to the needs and features of engineering projects, and we had also to reform teaching methods in the course. For example,

- To reform teaching methods to focus on inspiring students to innovate in thought.
- To develop a convenient knowledge resource on internet to help students learning out classes.

Now, we have built a Website for the course of Aircraft Design and Engineering. It provides for students the design tools, analysis software, and resources links of aircraft design materials on internet. Students can search for materials and learn on it [10].

For meeting the developing needs, students have to be equipped with advanced knowledge and abilities to solve complex engineering problems to meet the challenge of labor market in the future. We have also a lot of work to do the course reformation.

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