CDIO BASED PRELIMINARY ENGINEERING DESIGN COURSE IN CHEMICAL ENGINEERING

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ABSTRACT

The globalization of economy and the rapid development of technology call for the reform of engineering education to meet the social need for talents. Since 2009, the CDIO engineering education model has been implemented in the major of Chemical Engineering at Beijing Institute of Petrochemical Technology (BIPT). Starting from the first academic year, CDIO projects are planed every year in the curriculum of chemical engineering program, such as Preliminary Engineering Design in the first year, Secondary Engineering Design in the second year, Chemical Engineering Design in the third year and graduation project in the forth year.

This paper mainly introduces the implementation of the first design course for chemical engineering students, the Preliminary Engineering Design course, including course objectives; implement process and outcome assessment, and also several typical project examples. The course objectives are ability-oriented, aiming to develop their abilities of comprehensive use of technology, skills and modern engineering tools to tackle problems, learning ability, the sense of lifelong learning, team organization, effective interpersonal communication and presentation skills. The implement process is mainly comprised of project proposal, medium-term inspection and project defense, and at each stage, conception, design and implementation should be accomplished, accordingly. The outcome assessment is based on the participation of the teamwork, presentation, report and project. The score related to participation is given by his/her supervisor and his/her teammates, and the score related to presentation, report and project is given by committee members.

The Preliminary Engineering Design course is popular with students, and most of them like this course. They think the course stimulates their active learning, and they need to search some new knowledge or self-study modern engineering tool to solve the problem, in addition to the knowledge studied in the classroom.

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KEYWORDS

CDIO, Engineering Design, Active Learning, Chemical Engineering, Standards: 5, 6, 7, 8, 11

INTRODUCTION

With the rapid development of global economy and technology, the traditional engineering education can not meet the modern social need for talents any more (Lynch, 2007; McMasters, 2004). It is highly desirable to reform the engineering education model (Diaz Lantada, 2016). As an innovative initiative, the Conceive-Design-implement-Operation (CDIO) approach has been considered as one of the greatest achievements of an international collaborative endeavor for engineering education in the last decades (Ostlumd, 2003). CDIO is ability-oriented and project-based education model, which stimulates active learning. It offers alternative educational framework for producing better-prepared and highly skilled engineers and has brought about significant impact on engineering education of many universities worldwide through adoption of the CDIO initiative (Edward, 2011). Since 2009, the CDIO engineering education model has been implemented at Beijing Institute of Petrochemical Technology. For the students majoring in the Chemical Engineering, CDIO projects are planed every year in the curriculum of four-year Chemical Engineering program starting from the first academic year, such as Preliminary Engineering Design in the first year, Secondary Engineering Design in the second year, Chemical Engineering Design in the third year and graduation project in the forth year.

This paper mainly introduces the implementation of the Preliminary Engineering Design course, including course objectives; implement process and outcome assessment, and also several typical project examples. The Preliminary Engineering Design course is the compulsory course for chemical engineering students, which lasts for the whole academic year (32 weeks) for freshmen. The assignment for students is to design and implement a project in groups. Since this course starts from the first academic year, and students haven't studied any specialized courses in Chemical Engineering, the project does not have to be related to chemical industry, and it can come form the needs of our modern life. Design-Implement Experiences (**Standard No. 5**) and integrated learning experiences (**Standard No. 7**) are involved in this course. The labs and the engineering training center are available for the students according to **Standard No. 6**. The outcome assessments include five aspects, which covers both individual and team evaluation (**Standard No. 11**).

COURSE OBJECTIVE

Our main aim, when planning the course of Preliminary Engineering Design, is to let

students conceive a project based on literature review and questionnaire, and the project should be technically feasible and cost effective when implementing. Hence, **the first objective of the course is to employ various search tools to search related literature, define custom needs and the key issue, propose a project and analyze the technical and economic feasibility**. When doing practical projects, teamwork, coordination and communication skills are required and engineering ethics should be taken into consideration in real world engineering situations. With this in mind, **the second objective was set as encouraging and cultivating students learn how to communicate, coordinate, organize a project as well as give a presentation, and make them aware of engineering ethics.** The course objectives are associated with **CDIO Learning Skills** such as introducing a framework for engineering fundamentals and practice, building personal and interpersonal skills, communication skills, and professional skills, which is implemented in various stages of the course.

STAGES OF THE COURSE

This course lasts for one whole academic year (32 weeks) and can be structured as seven stages which include three check points to ensure the students are maintaining progress, as described below.

Introductory Class (Week 1)

In the first week, students are assembled to be introduced the basic background and requirement of the class. The course objectives and learning outcomes are clearly stated in order that they have the goal in mind before they start a project. The process of the course is also introduced to let them know the stages and due time of each task. Afterwards, the specific scientific requirements for reporting and documenting the project proposal, interim report and final report are stated, followed by the introduction of how the project is assessed and the proportion of each assessment in total grade.

Project Proposal (Week 2-7)

There is a feature in the cultivation program of chemical engineering major that around 120 students are divided into study groups in teams of four and each team is assigned a teacher to, regarded as the academic adviser to guide their four years of undergraduate study. Thus, each study group naturally becomes a team, and their academic adviser takes the responsibility for instructing them and gives necessary advice when practical difficulties exist. Also, each team has a ream leader who is responsible for organizing and coordinating the project work. There are 6-7 weeks for students to *conceive* a proposal. The project proposal can be from the needs of our daily life or to solve the practical problems of the existing products. Students need to review literature or make a questionnaire survey to

conceive a project. They also need to propose several approaches to fulfill the project, and the evaluations of technical feasibility and economic efficiency are also required. During this stage, they have to meet with their adviser once a week, and discuss with him about the feasibility of the proposal and the possible problems that may exist. Based on the discussion, a feasible project proposal should be finalized and documented.

Proposal Presentation (Week 8)

Three check points are set to ensure they are maintaining progress and also to develop their writing and presentation skills. The first check point comes in the 8th week. Students need to make a proposal presentation in groups to state the background, objective, plan, key issues and approaches of their projects. Their advisers are invited as the committee members to give suggestions, feedback and comments on their proposals. All the teams are divided into three big groups to take turns to give presentation in three classrooms, separately, and each group has five committee members (Figure1). Before the presentation, the documented project proposal should be submitted to the committee members. The presentation can be given by either only a team member or four of them together. After presentation, committee members are required to give the group assessment based on not only the technical content, but also the writing, presentation and communication skills.

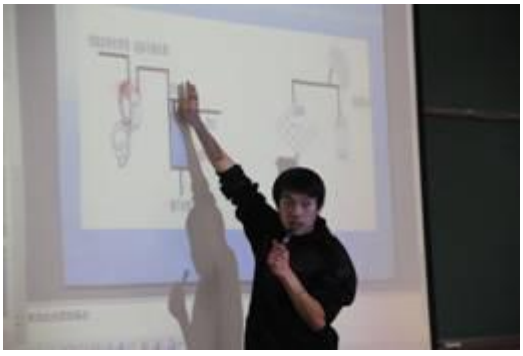


Figure 1. Proposal presentation

Project Design (Week 9-15)

From the 9th week to 15th week, students should accomplish the design of the product. The detailed structure of the product needs to be designed and drawn with the accurate sizes. At this stage, students are also encouraged to meet their advisers once a week for technical suggestions. Students are not required to submit independent documents for medium inspection, but the drawing and in-depth functions description of each component of the product should be provided in the final report. Functions description should be written in order to make it understandable for users.

Medium-Term Inspection (Week 16)

Medium-term inspection is carried out in the 16th week following the same procedure with the proposal presentation except that students do not need to submit a documented report. Each team presents the design of their project, and committee members assess the technical and economic feasibility of the design and also give some constructive suggestions on the following implementation stage.

Implementation (Week 17-31)

Hand-on project work is performed in the lab or at the engineering training center at BIPT. The lab is always open to the students, but the engineering training center should be reserved in advance for the available time because the engineering training center takes on some practice courses and is not available all the time. The staff at the engineering training center may offer them instructions when they encounter some technical problems. It should be noted that some dangerous hand-on work must be conducted under the supervision of the experienced staff. Hand-on project work is divided into parts and a part can be performed by a single student or by the cooperation of several students depending on the specific task.

Students are required to meet with their supervision once a week to discuss about the progress, the existing problems and future plan. Sometimes, some creative ideas may come up during discussion, and the changes and adjustment in planing and approaches are unavoidable. Moreover, their communication skills can be improved in the weekly meeting. The hand-on work stimulates their **Active Learning** (**Standard No. 8**) and is a valuable **Integrated Learning Experience** with personal and interpersonal skills, corresponding to **Standard No. 7.**

Project Defence (Week 32)

At the end of the project, a final report need to be written, including the background, literature review, proposed approaches, design description as well as the economic calculation. Economic calculation is very important in the practical production, so engineering students not only need to grasp the technical knowledge but also should have the sense of the economic calculation. Hence, the economic calculation is included in all the design courses in the curriculum of the chemical engineering major. A poster is also produced and exhibited during project defence to present an overview of their work. The project defence is given by students in groups following the same procedure with proposal presentation. Students need to present all contents in their final reports. Committee members give the group grade based on their presentation performance, technical contents and report quality. Figure 2 shows some pictures of the project defence and poster exhibition, as well as a group photo of committee members and students in a big group.

Figure 2. Project defense and the exhibition of posters and products

TYPICAL PROJECT EXAMPLES

Example Ⅰ: Vacuum Blackboard Eraser

The background of the Vacuum Blackboard Eraser project is that large amounts of chalk dust are produced when using the traditional blackboard eraser (left picture in Figure 3) to clean the blackboard. The chalk dust can penetrate into the lung and cause pneumoconiosis disease when sucked in. Students came up with a good idea that they planed to connect a small vacuum (right picture in Figure 3) with the traditional blackboard eraser to vacuum the generated chalk dust when cleaning the blackboard. Figure 4 shows the implementation of the project. Firstly, the traditional blackboard eraser was cut into pieces, which were then pasted on a waste computer box. After fitting all the components together, the vacuum blackboard eraser was done, as shown in bottom right corner of Figure 4. Students also calculated the expense of the project, which is shown in Table 1. The expense included a vacuum which was bought online, two vacuum blackboard eraser from a grocery store and a waste compute box obtained for free. The total expense was 162 RMB, which did not exceed the budget of 300 RMB.

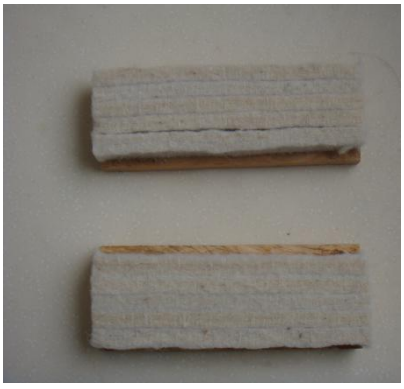


Figure 3. Tentative plan of the vacuum blackboard eraser project

Figure 4. Implementation of the project

Table 1. Expense of the vacuum blackboard eraser

Items	**Expense (RMB)**
Vacuum	150
Blackboard erasers	12
Waste computer box	0 (free)
Total	**162**

Example Ⅱ: Manual Spin Dryer

The purpose of the manual spin dryer project is to spin-dry the towel in the office or lab manually. Students proposed an approach of using a waste bicycle and a waste spin dryer to make the manual spin dryer, and the tentative plan is shown in Figure 5. Figure 6 shows the design drawing of the manual spin dryer. At first, they planed to design a bicycle-driven spin dryer, and the drying of towel could be realized when riding a bicycle. However, the initial plan was very hard to implement due to some dangerous cutting and electric welding work. Later on, students changed the design to a hand-cranked spin dryer. They used three gears and a belt to realize the transmission. The sizes of the gears and the relative position between the gears had to be accurately designed. After several months of hand-on work, the hand-cranked spin dryer was competed, as shown in Figure 7. Table 2 shows the expense of the project, including a waste spin dryer costing 60 RMB , a free waster bicycle, three gears provided by the grocery store, a belt and other components. The total expense was 160 RMB, which was under budget.

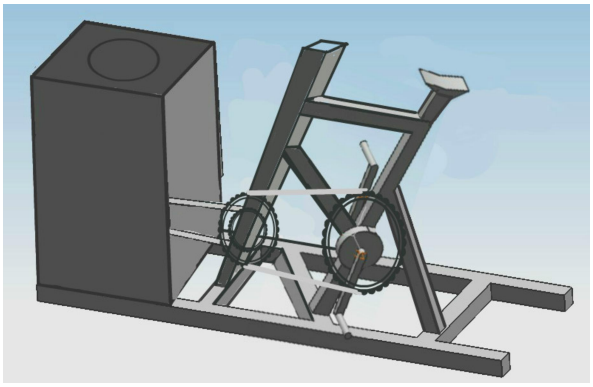
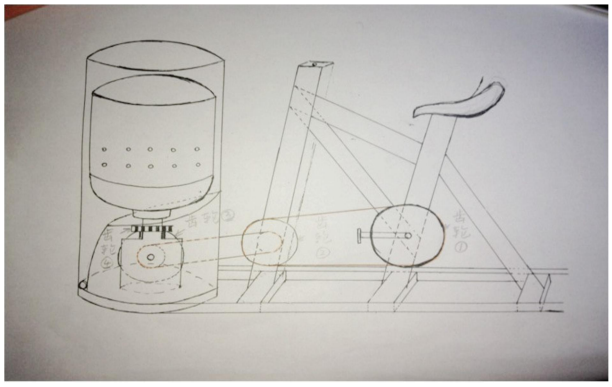


Figure 5. Tentative plan of the manual spin dryer project



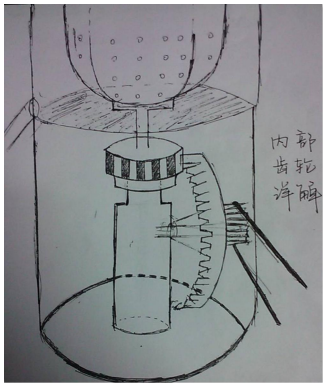


Figure 6. Design drawing of the manual spin dryer

Figure 7. Pictures of the completed manual spin dryer

Table 2. Expense of the manual spin dryer

Items	**Expense (RMB)**
Waste spin dryer	60
Waster bicycle	0 (free)
Gears	60
Chain	40
Other components	0 (free)
Total	**160**

ASSESMENT

The assessment of this course contains four items, which are participation, project proposal, medium-term inspection, and the final defence exhibition and report. The assessments covers both individual and team evaluations. The grade of participation is based on his/her participation in the weekly meeting and the project work, which is given by his/her

adviser (10% of the total grade) and teammates (10% of the total grade). The other three assessments are based on the technical content, presentation performance and writing skills. It is worth noting that it is hard for committee members to assess the individual performance of team members. Thus, the grade of the individual performance is given by his/her adviser and teammates who are more familiar with his/her participation in the project, and it occupied 20% of the total grade. The scores of each team member should be different according to his/her contribution. The final report should be written formally according to the guidelines and templates.

Table 3. Course Assessment

Assessment	Percentage of Total grade	Type
1. Participation	20%	Individual
2. Project Proposal	15%	Group
3. Medium-term inspection	15%	Group
4. Project defense, Exhibition and Report	50%	Group

POSITIVE RESULTS AND CHALLENGES

BIPT has an online course assessment system, and students can give the scores and comments on the course. The survey shows that the average score of the course every year is above 98 marks in the hundred-mark system. Some students comment that this course stimulates their active learning, and they need to look up a lot of literature and self-study modern engineering tool to solve problems, which are not or haven't been taught in class. This is helpful when they start to learn the professional courses.

However, some challenges of the course also exist. For example, the team leader and some capable students are very motivated and take on most of the project work, while the students who are less motivated have little chance to practice and cope with their weakness. It is also hard to give a relatively fair individual grade on each student because 80% of the assessments are based on the team performance. There is another challenge that it is difficult for students to propose entirely different projects each academic year, and some students may copy the projects from previous years. These problems are very common and have been also stated by Lantada (2017) and Torre (2017), which could be avoided if the advisers know more about the students and keep an eye on the project progress. It is also very challenging and time-consuming for the advisers to instruct different projects every year, but they can learn while teaching.

CONCLUSION

We have described Preliminary Engineering Design course for the first-year chemical engineering students at BIPT. *Conceive-Design-implement-Operation* model is introduced into this course. This course includes introductory class, project proposal, proposal presentation, project design, medium-term inspection, implementation, and final defence. The outcome assessment is based on the participation of the teamwork, project proposal, medium-term inspection, and the final defence exhibition and report, which covers both individual and team evaluation according to CDIO Standard No. 11. This course is popular with students and received good comments. It can stimulate students' active learning and establish a good basis for the study of the following Secondary Engineering Design, Chemical Engineering Design, and Graduation Design courses.

REFERENCES

Lynch, R., Seery, N., & Gordan, S. (2007). *An evaluation of CDIO approach to engineering education*. Paper presented at the International Symposium for Engineering Education, ISEE-07, Dublin, Ireland.

McMasters, J. H. (2004). Influencing Engineering Education: One (Acrospace) Industry Perspective. *International Journal of Engineering Education*, *20*(3), 353-371.

Diaz Lantada, A. (2016). Engineering Education For All: Strategies and Challenges. *International Journal of Engineering Education*, *32-B*, 2255-2271.

Berggren, K. F., Brodeur, D., Crawley. E. F., Ingemarsson., I., Litant, W. T., Malmqvist, J., & Ostlumd, S. (2003). CDIO : An International Initiative For Reforming Engineering Education. *World Transactions on Engineering and Technology Education*, *2*(1), 49-51.

Edward Crawley, Johan Malmqvist, William Lucas, Doris Brodeur. the CDIO Syllabusv2.0-An Updated Statement of Goals for Engineering Education. *Proceedings of the 7th International CDIO Conference*, Technical Universitiey of Denmark, Copenhagen, 2011.

Andrés Díaz Lantada, Juan de Juanes Márquez Sevillano. (2017). Ten Yeas Of CDIO Experience Linked To Toy Design. *Proceedings of the 13th International CDIO Conference.*

Patrick Van Torre, Jo Verhaevert. (2017). A Design-Implement Capstone Project In Electronics Engineering. *Proceedings of the 13th International CDIO Conference.*

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