PROJECT-BASED LEARNING BASED ON COMPREHENSIVE ENGINEERING TRAINING

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ABSTRACT:

Comprehensive engineering training is the engineering education program to realize the overall development of engineering practice abilities (technical operation ability, engineering management ability, etc.), engineering thinking abilities (innovative thinking ability, self-directed learning ability, etc.), and other relevant abilities of the students through actual engineering practice training and comprehensive engineering thinking training. As project-based learning (PBL) is one of the key approaches to carry out comprehensive engineering training, PBL based on comprehensive engineering training will provide a fine platform for the students to accumulate engineering experience. Hence, the integrated PBL model based on CDIO, namely, C-DREAM model, is proposed. The whole series of training solutions offered by this model provide reference path for the students to master disciplinary knowledge, improve comprehensive abilities and develop career awareness.

KEYWORDS:

Engineering training, PBL (project-based learning), talent

The booming economy of China requires engineering talents with a strong theoretical knowledge, good engineering practice ability, innovation and entrepreneurship. However, it’s generally shown that the students’ engineering practice ability remains poor, which the colleges and universities, the key training bases of talents, shall be addressed. Overcoming the three shortcomings of emphasis on systematic disciplinary knowledge, importance to simple verification of disciplinary principles and pursuit of one-way acquisition of professional engineering theories in the previous engineering talent training in China, comprehensive engineering training provides ideas on how to integrate knowledge, ability and career awareness, and how to combine practice training with theory learning in innovative and enterprising talent training.

I. The Core Meaning of PBL based on Comprehensive Engineering Training

Comprehensive engineering training is the engineering education program to realize the overall development of engineering practice abilities (technical operation ability, engineering management ability, etc.), engineering thinking abilities (innovative thinking ability, self-directed learning ability, etc.), and other relevant abilities of the students through actual engineering practice training and comprehensive engineering thinking training. Comprehensive engineering training is composed of theory knowledge learning and engineering practice training. Theory knowledge learning focuses on the transmission of knowledge and development of thinking ability while engineering practice training emphasizes on the application of knowledge, the acquisition of ability and development of career awareness. It's worth noting that the development of engineering thinking ability relies on not only engineering practice training, but also theory knowledge learning.

Oriented towards talent training objectives and based on real engineering environment, comprehensive engineering training is to integrate the acquisition of knowledge, ability and career awareness and thus improve the engineering thinking ability and engineering practice ability of the students. The core meaning of comprehensive engineering training can be interpreted from three perspectives:

- From the perspective of knowledge. In addition to attaching importance to systematic disciplinary knowledge, PBL based on comprehensive engineering training focuses more on interdisciplinary knowledge, optimizes and restructures the knowledge structure of the students instead of pursuing how much they learn.

- From the perspective of process. Three aspects shall be noted. Firstly, it is a solution to guide the students to conduct engineering training, which answers the questions of how to integrate knowledge, ability and career awareness and how to acquire integrated learning experience; secondly, it pursues engineering environment that is as real as possible; lastly, integrating engineering practice ability and engineering thinking ability, it takes the impact of aesthetics, environment, cost and culture into consideration in addition to solving engineering problems with scientific and technological knowledge.

- From the perspective of value. PBL based on comprehensive engineering training aims for three values: firstly, the personal ability development of the students is pursued, in which the students will take engineering as a way of thinking and a way of life and integrate it into their personal development process while acquiring engineering practice ability and engineering thinking ability; secondly, market value is emphasized through pursuing the optimal balance of technology, cost and commercial value of the engineering products; thirdly, the internal value of engineering is targeted which is reflected on the engineering timeliness, aesthetics and safety, impact on natural environment and human environment, and contribution to social harmony and sustainable development.

II. The Approaches of PBL Based On Comprehensive Engineering Training

Student-focused, PBL based on comprehensive engineering training develops the actual operation ability, team spirit and adaptability of the students through PBL and encourages the students to put forward, analyze and solve problems based on multidisciplinary knowledge and from multi-angle perspective. Hence, diversified and flexible approaches are available.

Firstly, select an appropriate project and establish a project team. Despite of the huge advantage of PBL in knowledge, ability and career awareness integration, it's necessary to select an appropriate project based on different students and learning phases to respect individual differences in learning phases and knowledge acquisition. Furthermore, the increasingly complicated engineering problems in the industry have formed the practice of project team. Hence, the students must develop their comprehensive abilities in communication, teamwork and leadership to prepare for the increasingly intense competition in the society.

Secondly, set PBL phases. The main purpose of guidance in different learning phases in the process of PBL is to have the students to learn about self-management and self-directed learning. After identifying the main objective and learning method in each learning phase, the students will have improved learning initiative and develop the sense of achievement and satisfaction in learning more easily.

Thirdly, combine PBL with theory knowledge learning. Theory knowledge learning divorcing from practice training is one of the crucial pressing problems to be addressed of Chinese higher engineering education. With learning experience divorcing from practice training, the students will find it hard to recognize the interaction between theory knowledge learning and practice training, and develop waning interest in learning. As one of the effective approaches of combining theory knowledge learning with practice training, PBL based on comprehensive engineering training will enable the students to acquire integrated learning experience.

Fourthly, integrate PBL with other practice training. PBL is an effective approach yet not the only approach to realize comprehensive engineering training. Other practice training like course project, graduation project and internship will help improve the engineering thinking ability and engineering practice ability of the students. The integration of theory knowledge learning and engineering practice training is not conventional inclusion but sequence correspondence of time and learning phases, and expected learning results. Therefore, the course project, graduation project, internship and other practice training shall be designed based on PBL. Manifold engineering training will help the students gain and thoroughly grasp diversified learning experience, and subsequently ensure the coordinated development of engineering thinking ability and engineering practice ability of the students.

Fifthly, combine PBL with extracurricular activities. Different from PBL, extracurricular activities come from yet not limited to the textbooks. In lively forms, they serve as a new interactive platform for the teachers and students. Offering an open, scientific, healthy space for personal development, extracurricular activities will help the students become “engineers” and become socially responsible “men”. The prerequisite of training the students as innovative and enterprising talents is to make them real “men”. Hence, it is necessary and important to blend PBL with extracurricular activities.

Lastly, establish and improve quality evaluation procedure. Learning-focused, the evaluation of PBL will combine learning evaluation with learning results (including expected and actual learning results), adopt diversified evaluation methods, and attach importance to gathering evidence of the students’ proficiency in problem-solving, innovation and teamwork. Quality evaluation shall prioritize combination with learning results, and then integrate the learning results to integrated course project and PBL to improve teaching and learning experience. Furthermore, the consistency of evaluation methods and learning results shall be noted to categorize different learning results based on different projects, and choose appropriate evaluation methods.

III. The Operational Design Of PBL Based On Comprehensive Engineering Training

The key problem of PBL based on comprehensive engineering training is how to acquire PBL experience, which involves the objectives of PBL, contents of PBL, conditions for implementing PBL and process of PBL.

1. The Objectives of PBL: The Innovative and Enterprising Talents Shall Acquire Multi-project Integrated Learning Experience.

Integrated learning experience refers to the development of innovation and entrepreneurship of the students in addition to expanding disciplinary knowledge. As one of the main features of CDIO model, it drives the overall development of knowledge, ability and career awareness. With comprehensive abilities, career awareness and disciplinary knowledge highly integrated, PBL activities will further the students’ understanding of disciplinary knowledge. Through grouping and sequencing disciplinary knowledge, comprehensive abilities and career awareness required by the engineering talents, multi-project integrated learning experience coordinately develops different abilities in different groups and projects. Projects are grouped by size and complexity. The larger and more complex of the projects, the more comprehensive and extensive of the integrated learning experience acquired.

2. *The Contents of PBL: Project Level Design*

As PBL is to understand and apply knowledge through simple or complex engineering problems according to a certain sequence and level, projects shall be designed based on level. There are three key factors of project design. Primarily, elementary projects are to lay a foundation for future study and arouse the learning interest of the students. Hence, the less complex elementary projects are designed for further knowledge learning and training of single or several abilities. Furthermore, projects of different levels and different projects of same level are coordinated and connected, posing challenges to interdisciplinary learning. Last but not least, the more complex advanced projects in the end of teaching require extensive interdisciplinary knowledge and comprehensive abilities, self-directed learning ability in particular.

Although it is hard to measure the learning results of comprehensive abilities and career awareness, it is certain that these abilities must be developed through multiple projects. For example, career awareness can be developed through consecutive projects in the first-year, second-year and third-year study. In view of that, the projects are categorized into elementary projects, intermediate projects and advanced projects based on complexity. Every project in each layer is composed of sub-projects of same level.

Elementary projects: mainly offered in the first-year study, elementary projects can be virtual projects, virtual simulation projects or real projects. There’s no need to overemphasize real projects. The main purpose of elementary projects is to develop the students’ conception and thinking on how to resolve engineering problems through guidance, provide the students with the opportunity to apply the disciplinary knowledge they learn, realize the usefulness of project results to the society, and arouse their learning enthusiasm.

Intermediate projects: mainly available in the second-year and the first semester of the third-year study, intermediate projects shall be relatively real. The main purpose of intermediate projects lies in integrating disciplinary knowledge learned with corresponding ability training. There are two approaches to realize the synergic integration of multiple disciplines and abilities. One approach is project design based on two practical courses. The other approach is integration of one practical course and theoretical course to make intermediate projects relatively complex.

Advanced projects: mainly offered in the second semester of the third year and the fourth-year study, advanced projects shall be as real as possible. Connected with one or multiple projects and combining theory with practice, advanced projects are designed to enable the students to understand the practicability and limitation of theories, appreciate social and commercial background, and take environment, cost and other factors into consideration in resolving engineering problems.

3. The Conditions for Implementing PBL: The Challenges of Integrated Learning Experience

Integrated learning experience poses three challenges to PBL: firstly, the people in project implementation, meaning that what role shall the students and teachers play in PBL; secondly, the objects, that is what impact will the site of engineering practice have on the project implementation and what site design will help project implementation; lastly, the project itself.

As PBL requires the students' involvement in thinking and problem-solving, the students shall take the attitude and approach of self-directed learning in PBL. The guidance of the teachers plays an important role in PBL as well. Although most of the engineering teachers in China are experts in their respective fields, they have very limited experience in real projects of the industrial circles. Hence, PBL is also a huge challenge to the teachers.

The site of engineering practice shall be a place which encourages the students to exchange ideas and inspire them to innovate. Not limited to certain space, the site of engineering practice shall be student-focused, conducive to teacher-student interaction, and more importantly, providing the students with resources necessary to transform the product designs into results.

For the project itself, to what extent should the project be real has become an important topic for discussion. Whether all conventional verifying experiment projects shall be disused or not and whether virtual projects and real projects have a significant impact on learning results are questions to be considered. What is indisputable is that PBL is a teaching activity instead of a place of staff training for the enterprises

4. The Process of PBL: Integrated PBL Process Model based on CDIO (C-DREAM Model)

C-DREAM Model covers C-conceive, D-design, R-resources, and EA-evaluation and assessment, and M-modification. This model is to guide students to learn self-management in PBL, to provide clear and integrated learning paths for students by guidance in different learning phases and to assess the learning results in stages.

Phase one, C-conceive. There are four tasks in this phase: firstly, divide the students into groups based on project complexity; secondly, select a project topic based on the level of the students and the principle of more real and complex projects as the school year progresses, and subsequently determine project cycle; thirdly, identify tutor, site of engineering practice and other relevant information, and ensure a weekly teacher-student meeting to give project progress report and have discussion; lastly, jointly prepare Project Declaration, divide the project into several sub-projects, assign one sub-project to each student, and hold group discussions at least once a week.

Phase two, D-design. This phase mainly covers technical design of the project. Responsible for their own sub-project, each student shall take demand positioning, systematic analysis and other factors into consideration in solving engineering problems, and design more than one solution. With coordination among team members being the most important factor in this phase, the interrelation of sub-projects holds the key to the success of the whole project. Therefore, group meetings and teacher-student discussions shall be held frequently and meeting minutes well-kept.

Phase three, R-resources. The focus of this phase has shifted from technical design to non-technical fields like market, product and service. This phase covers two tasks: on the one hand, finalize the best implementation plan through adequate group discussions from the perspectives of market, product commercial value, cost, free resources and energy conservation; on the other hand, manufacture the products with the focus on whether the best products are manufactured with the least resources and balancing resource utilization rate and product quality of the project.

Phase four, EA-evaluation and assessment. The main tasks for the students in this phase are product presentation and evaluation. Generally speaking, the students tend to consider product manufacturing as the last step of the project. However, C-DREAM Model requires the students to understand the whole project life cycle by attaching the same importance to product presentation and evaluation, which will develop the students' ability of using technical terms, peer communication and quality awareness.

Phase five, M-modification. Modification for the students includes three aspects: primarily, product modification; secondly, learning reflection which is more important by taking into account the whole process and all factors of learning like learning methods, learning motivation, group discussion and product design, and marking what they draw from the project on the student learning progress report; thirdly, assessment on learning results by a judging panel consisting of both teachers and students, teaching and learning improvement with the assessment results, attention to information flow and management of assessment results.

It can be concluded that there are four differences between PBL based on comprehensive engineering training and conventional PBL. The first difference is dynamic, which can be seen in the fact that PBL based on comprehensive engineering training integrates knowledge, ability and career awareness based on different phases and types. The second difference lies in openness, which can be shown in the student-focused PBL based on comprehensive engineering training oriented towards the disciplinary forefront, social demand and future development in project selection and implementation. Another difference is level, which refers to the mutual relationship of knowledge learning and ability training in PBL based on comprehensive engineering training, with less complex elementary projects focusing on in-depth knowledge learning and more complex intermediate and advanced projects emphasizing integrated ability training. The last but not the least difference is process, in which the students take the initiative to be involved in the whole process of PBL and experience the gradually changing problems in the process.

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