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Application of Problem-Based Learning in Engineering Education Reform

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Abstract: The curriculum is the basic unit of talent cultivation, and curriculum reform has the most direct effect on improving the quality of talent cultivation. Facing the needs of scientific and technological progress and the industrial revolution, developing innovative and complex skills has become the main goal of higher engineering education reform. The PBL model provides an effective way for engineering education reform in China. Problem-based learning (PBL) starts with a problem. It develops problem-solving, exploring, cooperation, communication, and self-growth in students' abilities, which contain grouping, problem presentation, learning and research, and result output steps. Based on analyzing the drawbacks of existing classroom teaching in higher engineering education, the practical implementation plan of PBL reform was proposed. By applying PBL, students' learning interest, team awareness, and self-thinking ability in learning enhanced, and provided a reference for other similar engineering specialty courses.

1. Higher Engineering Education Reform Requirements

With the development of the Internet and intelligent economy, emerging industries have put forward new requirements for the ability of senior compound talents, including interdisciplinary knowledge, problem-solving, creativity, communication skills, etc... However, there are several problems in higher engineering education, such as the talent training chain, scientific research innovation chain, and industrial market chain are not closely connected, the learning content being outdated, and the teaching method being antiquated. As a result, the ability structure of engineering students cannot effectively respond to the new demand of the new economy [1].

Since 2017, the construction of emerging engineering education has been proposed in China. The curriculum is the basic unit of talent training. Class teaching plays a vital role in improving the quality of talent training. At present engineering education, class teaching still has several problems, such as limited knowledge provided, one-way infusion teaching method, and lack of competency-oriented assessment. Those problems caused less participation in class, and students would show a poor understanding of specialty knowledge. Teachers should actively think about the role changes

in the classroom, exploring ways to effectively motivate students, reforming teaching methods, enhancing classroom interaction, and improving student participation initiatives.

2. The Problem-Based Learning Model

PBL first appeared in medical education as a teaching method for medical professional training. Now, it has been introduced to engineering education reform because of its remarkable effect in inspiring students' motivation and developing their abilities [2]. One of the more well-known applications has been by Don Woods in the Chemical Engineering program at McMaster University [3]. Problem-based learning was introduced into civil engineering courses at Monash University (Australia) [4]. A. Yadav's study has been particularly influential among faculties and researchers who follow PBL in engineering education [5]. Guilherme Tortorella proposed combining traditional teaching methods with Problem-based learning to solve real engineering problems [6]. There are many similarities between PBL and the instructional designs that have been implemented in the field of engineering education for many years, which have been summarized by Williams [7] as follows: both of them begin with an identified problem, achieve the course objective through the students' research, focus on developing students' motivation, and emphasize the impact of students' reflection and encourage students to fully assess the results they have achieved. As summarized above, PBL could provide a useful perspective for in-depth reform that is undergoing in the Chinese engineering education field because of its role in fostering students' higher degree of involvement in study activities and a higher level of complex comprehension.

2.1. Theoretical basis of Problem-based Learning

The theoretical roots of PBL are experiential learning, reflective practitioner constructivism, and social learning [8]. The main principles are as follows:

1) Problem is the starting point of learning, and the learning process is centered on solving problems. The learning begins with the exploration of questions [9]. In this process, teachers are no longer imparting knowledge, but as a fundamental guiding role in helping students submit questions, leading students to deep thinking, collect information, analyze, find the answer, or solve problems [10]. Students are no longer passively receiving knowledge but actively exploring.

2) The assessment of the learning effect is one of the most critical parts. Generally speaking, the course assessment method should have three basic functions: orientation, evaluation, and feedback. The assessment should focus on the learning process, and evaluate the learning status and outcomes in an all-round, multiform, and phased way. The main content of the course assessment is the knowledge acquired by the students through the course and the ability to use it inside.

3) PBL is centered on student activity-based learning. Teachers are more of a bridge and link for organizing students, with a focus on commenting on students' work.

4) Enable interdisciplinary learning. PBL revolves around problem-solving. The traditional learning content structure based on subject boundaries has been broken, and students' learning is not subject-oriented but considers problems in real situations [11].

5) Group learning is the fundamental organizational form of PBL. Personal data collection, group integration, active mutual participation process, and mutual feedback, will provide opportunities for students to develop social skills in a group [12].

2.2. Objectives of Problem-based Learning

In the PBL model, the objectives should contain 5 aspects of students' achievement, such as problem-solving skills, problem-exploration skills, corporation ability, communication skills, and self-growth ability, Table 1.

Table 1: Achievements of Problem-based Learning.

1. Problem-solving skills	Understand the connotation of the problem Using dedicated knowledge to design a program Fault tolerance during execution
2. Problem-exploration skills	Use network resources to explore problems Communicate with professionals
3. Cooperation ability	Team task decomposition Internal communication and coordination
4. Communication skills	Self-expression Accept the opinions Persuasion and Written report formation
5. Self-growth ability	Teamwork ability Independent study and thinking

2.3. Steps of Problem-Based Learning

In the PBL model, students solve problems through group cooperative learning, realizing the construction and reconstruction of personal and social knowledge. It consists of the following steps:

1) Grouping: Firstly, students participating in the course will be grouped, and a team leader will be nominated as a facilitator in each group.

2) Problem presentation: A specific problem is presented to the student, and the student's task is to make a judgment and provide a reasonable answer. Due to the limited clues offered by the questions, students build hypotheses based on experience and background knowledge. Until they fully understand and obtain the learning objectives, let the students explore their respective learning goals separately.

3) Follow-up questions: After the previous group discussions and target-setting phases, each person will work on the assigned tasks. The panelists discuss again, communicate the information they have acquired, form a new understanding, and test whether the problem is resolved. If a new learning goal occurs, go back to step 2) and cycle once until the problem is solved. In this process, students must evaluate the value of their own and others' information, the source of information, and the reliability. This is a significant part of the follow-up.

3. Problem-Based Learning Model Practice in Higher Engineering Education

3.1. Instructional Design

The effectiveness of problem-solving and collaborative learning in activities is explored through the PBL model in the teaching of specialized courses of vehicle engineering majors at N university in China. The teaching flow includes the three stages of pre-preparation, teaching practice, and post-summary.

(1) Pre-preparation

Set multiple learning objectives to let students gain theoretical knowledge and practice skills through group cooperation, discussions, exploring, and solving problems. Explain to students how the PBL model work and the assessment method to help them involve in the course quickly.

(2) Teaching practice

The period of specialized courses is divided into two parts, including traditional leadership learning and PBL. During the first part, the basic principles, concepts, and knowledge of the courses were introduced. In the following part, the course focused on one particular theme starting with practical questions and exploring the development process.

(3) Post-summary

At this stage, the main work is to review and reflect on the teaching process based on the analysis of data and student learning satisfaction.

3.2. Implementation of Content

The implementation of the problem-based learning model in the teaching process will be carried out in detail.

Grouping: At the beginning, all students in the class are grouped. For better results, the responsibilities and proportion of all team members are clarified.

Problem-based group learning description: Teachers should explain the difference between traditional teaching and problem-based learning to students, and introduce the course's final evaluation method at the beginning of the course.

Layout the theme: According to the basic content of the previous study, the broad theme content of the learning is promoted, which is aimed to stimulate the students' interest in participation, and does not limit to the group's topic, so that the students will focus on any interest within the scope of the subject.

Group discussion: Students explore selected topics in group cooperation. With prior knowledge, they would be encouraged to discuss the topics to reach tentative results.

Assignment and preliminary study: Decompose the tasks within the group and set learning objectives to achieve the goal of decentralized learning and shared responsibility. In the process, ensure that each member of the study group is clear about their learning tasks.

Judgment of new questions: In the process of individual learning, the latest knowledge and answers related to the questions chosen by the group are generated. There will be some content beyond the student's cognition, which is an essential opportunity for them to grow up and learn. The internal communication and re-learning of the group will also be triggered, and the adjustment or modification of the group's preliminary results will be inevitable [13].

The conclusion and report: After the goals in the group are agreed upon, the individual explores the relative responsibilities to contents within the group, learns to use various resources and other channels to solve the problem, and verifies the judgment from different aspects to form a report of the individual's work. At this stage, students should be encouraged to ask questions and hypotheses, clarify problems in the inquiry task, and keep thinking and trying to confirm or verify the hypotheses, which is an excellent chance to reorganize and refine personal knowledge.

Exchange and defense: Each study group will present the conclusion to the proposed problem, and everyone will share the learning results. Each study group will conduct mutual evaluation among the groups to expand the field of study and increase their opportunities for critical thinking and experience exchange. Teachers also have further observations about the work of all groups.

3.3. Diversified Curriculum Assessment

The curriculum evaluation also corresponds to 2 parts, including traditional leadership learning and PBL. In the first part, the classroom behavior and test papers are selected to measure the learning effect of knowledge learning [14]. In the PBL part, the individual report of the group members, the mutual evaluation of the group defense, and the teacher assessment are selected as the consideration indicators for the group study. The overall distribution ratio and relationship are shown in Figure 1 below.

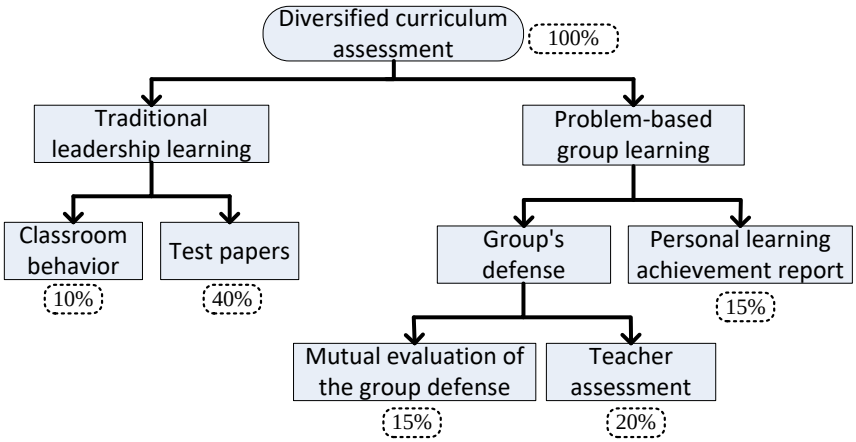

Figure 1: Diversified curriculum assessment and distribution ratio.

In the section on the group defense, the mutual evaluation and teacher evaluation focus on the quantitative evaluation of the defense and communication from 10 questions in 4 aspects, while leaving open questions to expand the content of the assessment further. As shown in Figure 2.

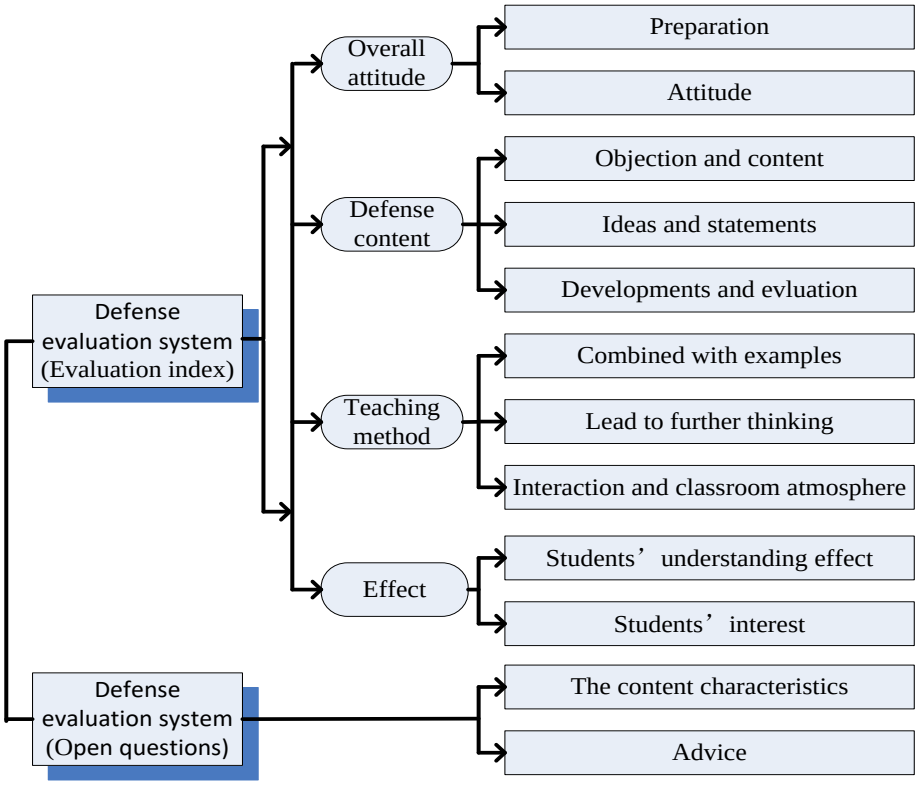

Figure 2: Defense evaluation systems.

4. Results and Summary

This paper will summarize the reform's effect from two aspects: achievement of students' abilities and student satisfaction.

(1) Achievement of students' abilities

The realization of students' competencies will be analyzed from five aspects that the PBL model contains as described above, such as problem-solving, problem-exploration, collaboration, communication, and self-growth.

Solving skills: Students could successfully develop a report of a solution based on an extensive review of materials, analysis, design, and verification by following certain procedures. Through the presentation of learning outcomes and defense, it could find students have engaged in active thinking and discursive activities. But some students may have difficulty applying the knowledge to problem-solving.

Problem exploration skills: As a whole, the problems that students exploited have been beyond the previous course content. But some groups' problem exploitation was more dependent on the teacher's inspiration.

Cooperation ability: Those with better ability in the group could have a clear direction for self-goal and can achieve better, and vice versa. In teamwork, some members are active, and several of them are confused.

Communication skills: During group cooperation, students learn to handle the process in all its stages, the understanding and expression skills have been exercised. It cannot be ignored that some students still have communication limitations.

Self-growth ability: The overall academic level of the student failure rate is reduced, with increasing the number of high scores, and the overall performance shifts upward. Collaborative and independent learning ability that satisfies students' interests through group learning and self-learning interspersed during the period.

The student's ability to achieve as expected. Most of them gain academic level and ability development through the PBL model. But, under the influence of long-term traditional teaching, students are accustomed to passively accepted knowledge and lack exercise in independent thinking, discernment, and analysis. It is necessary to learn how to make the connection between knowledge content and knowledge application. Individual differences in communication skills and knowledge reserves lead to differences in the performance of cooperative learning. Diversified assessment methods provide more opportunities for diverse students to demonstrate their abilities and exercise themselves while meeting the learning objectives.

(2) Student satisfaction

The evaluation of student satisfaction includes three aspects: adaptation of the learning method, recognition of PBL, and trust degree of evaluation method. Students were surveyed for satisfaction before final grades were released. The survey results are summarized below.

Understanding of PBL: Most students could understand how the PBL model works and are willing to follow the directives.

Acceptance of PBL: For both traditional and group learning, about 85% of students favored this approach, were interested in group learning, and agreed with the need for traditional learning. At the same time, about 10% of the students have opinions about group learning, and they thought they had undertaken most of the work or were unsuitable for collaboration.

Assessment: Most students are supportive of diversified assessments. They have strong confidence in traditional examinations and self-learning but are skeptical about group and teacher assessments.

Overall, the students show high satisfaction with the PBL model. They could understand the PBL methods, be more motivated and work harder in PBL. But some of the students may not coordinate the relationship within the group, and some of them are more uncertain factors. These are also necessary means to promote teamwork and learning.

5. Conclusion

To cultivate engineering talents to support the needs of future technological and industrial development, the emerging engineering education systemically remolds the existing engineering education with new concepts, new models, new cultivation systems, new curriculum contents, new learning methods, new quality standards, and new requirements, explores a new paradigm of engineering education. The curriculum is the most fundamental teaching unit; curriculum teaching reform is the most direct factor affecting the quality of talent training, and it is the practice reform forefront of exploring the emerging engineering training paradigm. The PBL model leads students to deep learning, improves students' initiative, motivation, and participation, drives the curriculum to increase the degree of advanced, innovative, and challenging, enhances students' autonomy and choice in learning meets the needs of individualized development, and helps each student achieve better academic success[15].

The reform experiment at N university vehicle engineering major shows significant changes in students' learning content, effect, and motivation between PBL and traditional teaching methods. The knowledge that students gain through problem-solving has dramatically exceeded the scope of the book. Some groups even designed the experimental steps or learned to use professional software to enhance the depth of research further. The goal of students' ability training is effectively achieved, and students can get more independent learning, explore problems, and have communication opportunities. The satisfaction survey of students shows a high degree. Students are more motivated and show higher participation with the PBL model. The PBL practice overcomes many shortcomings in the teaching process of colleges and universities in China and deepens the understanding of college teachers on diversified teaching methods and assessments. It could be used as a reference and guiding significance for other similar engineering courses in China.

Acknowledgments

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