Fuzzy Comprehensive Evaluation for PBL Education Quality of Undergraduate Engineering Practice

Xiang-yang XU*, Yuan-wen CAO and Shao-jiang DONG

School of Mechatronics and Automotive Engineering, Chongqing Jiaotong University, Chongqing, China

*Corresponding author

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Abstract. The comprehensive PBL education quality evaluation of university engineering practice is a practical requirement to change the view of engineering education quality, establish the operational evaluation system and promote the reform of engineering innovative talents cultivation. Taking the problem as the guidance, from evaluation factors of PBL education quality of engineering practice, and based on the fuzzy mathematics theory, constructing the fuzzy evaluation models of practice object, practice content, practice input, practice process, practice effects, accessibility improvement and portability, forming a PBL education quality dynamical evaluation system of practice background, input, process, and results of engineering practice. In addition, a specific PBL education quality evaluation case is discussed by using this fuzzy evaluation method.

Introduction

China Manufacturing 2025 Planning and Ministry of Education “Excellent Engineer Education and Training Program” put forward higher requirements for the quality assessment and supervision and security system of education to improve the innovation ability and practical ability of engineering students [1]. In response to the national strategy of the country, domestic colleges and universities currently carry out a large number of reforms to cope with external and internal challenges on the theory and practice of educational evaluation both inside and outside school [2,3]. However, the current practice of engineering education reform mainly focuses on the teaching and teaching method itself, the research on the evaluation system of educational quality is less, and lacks relevant effective evaluation model for PBL (Problem-Based Learning) education quality of engineering practice can be transplanted [4]. Under this background, the exploration on the education quality evaluation of engineering practice has become one of the important propositions for the reform of engineering innovation education in colleges and universities.

Comprehensive Evaluation Connotation of PBL Education Quality

PBL is an innovative educational model based on the concept of constructivist education [5]. In the practice of PBL education model, students need to start from the actual problem situation and on the basis of the analysis of the problem situation, take the initiative to explore, find the problem, analyze the problem and creatively solve the problem. For students, it is a self-exploration and mutual cooperation problem-solving activity. Comprehensive evaluation for PBL education quality of engineering practice is formed after the summary, review and judgment, based on the cognition and practice from the past to the current.

For the evaluation for education quality of university engineering practice, evaluation for PBL education quality of engineering practice observe, describe, collect, record, score, explain and improve the student’s learning process on behalf of the colleges and universities. The implementation of PBL education of engineering practice in colleges and universities includes the various aspects of team organization, problem selection, analysis and determination, task setting, proposal and certification, research and implementation, project report and assessment. Colleges and universities
need to analyze and diagnose problems in all aspects, analyze the corresponding normative system and control and optimize potential changes within a clear context. So this is an urgent need to evaluate the environment, content, process and results of engineering practice.

The Fuzzy Comprehensive Evaluation Model of PBL Education Quality

Construction of Evaluation Content and Evaluation Indexes

Based on the comprehensive evaluation connotation of PBL education quality, the specific evaluation contents of PBL education quality in engineering practice can be divided into four parts of project implementation including the environment, input, process, results, and two parts of project post-processing including improve-ability and portability. These six parts constitute the six basic elements of the evaluation model. According to the evaluation content, the quality of PBL education project in engineering practice is classified as only the first-level evaluation index, and the first-level index can be emphasized according to the different objects of interest. PBL education evaluation of engineering practice can be divided into six second-level indexes: background environment, input content, process, output, improve-ability and portability. As shown in Table 1, in each of the second-level evaluation indicators, it contains the interview survey, the PBL practice outline, the literature review report, the students’ practice diary and report, the evaluation of enterprise mentor, the practice process record data, the students’ live question and answer record, the PBL group speech, picture or video records, the summary report or test results, the result of practical output and other the third-level evaluation indicators, of course, these third-level indicators can also be based on the specific use of the environment to increase or decrease.

Because the evaluation scale of each level evaluation index in the evaluation model is very different, and the indexes are mathematically fuzzy, the fuzzy evaluation method in fuzzy mathematics can be used to evaluate the evaluation indexes.

Table 1. The second-level evaluation indexes and evaluation factors (or third-level indexes).

<table>
<thead>
<tr>
<th>Evaluation index</th>
<th>Background environment</th>
<th>Input content</th>
<th>Process</th>
<th>Output</th>
<th>Improve-ability</th>
<th>Portability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interview survey</td>
<td>√</td>
<td>O</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>PBL practice outline</td>
<td>O</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Literature review report</td>
<td>√</td>
<td>√</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Practice diary and Report</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Evaluation of enterprise mentor</td>
<td>O</td>
<td>O</td>
<td>√</td>
<td>√</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Practice process record data</td>
<td>O</td>
<td>O</td>
<td>√</td>
<td>√</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Students’ Q &amp; A records</td>
<td>√</td>
<td>O</td>
<td>√</td>
<td>√</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>PBL group speech</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Picture or video records</td>
<td>√</td>
<td>O</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Summary report or test results</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
<tr>
<td>Results of practical output</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>√</td>
</tr>
</tbody>
</table>

Note: "√" means content related, "O" stands for no content

The Design for Multi-level Fuzzy Comprehensive Evaluation

The educational quality of PBL education in engineering practice is the main content of the evaluation model, but the various indexes in the evaluation model are not completely equivalent in practical application, so it is necessary to give weight to these indexes according to the application object and environment. Based on the characteristics of the study object, the current general analytic hierarchy process (AHP) can be used to weighing the indicators. According to the results of expert scoring, the results are averaged, the criterion layer is compared with the judgment matrix, and finally the consistency of the judgment matrix is tested to obtain the weight of each index.

At the same time, because the evaluation indexes of the evaluation model are using a multi-factor comprehensive evaluation method, so it is necessary to use a certain mathematical method to transform the evaluation factors into a unified comprehensive evaluation value. In order to establish
the multi-factor fuzzy evaluation model of each index, the evaluation factors are classified as fuzzy factors, and the evaluation indexes are classified according to the evaluation factors, then the evaluation factors are divided into five or more factors. The ambiguity of each evaluation factor is characterized by membership function.

In order to determine the selective set of the fuzzy evaluation of the evaluation index, each cut-off \( \lambda \) of the object of evaluation should be designed. According to the different design conditions and requirements of the evaluation object, they need to be divided reasonably into \( p \) values according to the equivalent / unequal step size, then the selective set \( \lambda =\{\lambda(1),\lambda(2),\ldots,\lambda(n)\} \) is formed.

In determining the weight of the evaluation factors, the factor level weight set should be established according to the evaluation factors. In order to accurately reflect the influence of each factor on the evaluation object \( \lambda \), the corresponding weight \( A \) of each factor should be given, and determine the factor weight set. Then the membership degree of the \( n \)-th second-level evaluation index \( Un \) is assembled to \( Un=\{Un1,Un2,Un3,Un4,Un5\} \). Then the first level fuzzy evaluation matrix \( B1=\{B1(1),B1(2),\ldots,B1(n)\} \) can be established according to the fuzzy membership degree score of the factor level under each three-level evaluation index and the product of the weight of all the three indexes under the second-level index, and realize the evaluation of the second-level index; then the second level fuzzy evaluation matrix \( B2=\{B2(1),B2(2),\ldots,B2(n)\} \) is established according to the product of the second-level index weight and the first level fuzzy evaluation matrix under the primary index, and the evaluation of the first grade evaluation index is realized.

Based on the optimal level cut-off set method based on the maximum proximity principle, the optimal level value is determined by the first or second fuzzy comprehensive evaluation method, can be got as equation (1).

\[
\lambda^* = \frac{\sum_{i=1}^{n} B(i)\lambda(i)}{\sum_{i=1}^{n} B(i)}
\]

(1)

Then the fuzzy optimization model is transformed into the conventional optimization evaluation on the optimal level cut-off set. It is necessary to establish the sets of factors, the selective sets, the weight sets of factors, the weight sets of the factors level and determine the mathematical model. Therefore, the optimal confidence level \( \lambda^* \) is calculated and compared with the elements in the selective set \( \lambda \). According to the principle of maximum proximity, we can know what level the evaluation results are at and select the evaluation results of different second-level evaluation indexes according to needs. So the project selection and improvement plan under each index is obtained.

**Application and Discussion of PBL Education Quality Fuzzy Comprehensive Evaluation**

**Fuzzy Comprehensive Evaluation for PBL Education Quality of Engineering Practice**

This case comes from a small engine assembly practice project in the practice base of TYO, which was completed by the mechanical engineering students of Chongqing Jiaotong University. The core goal of this PBL education is to accomplish a specific engine dismounting task, so as to achieve the purpose of practicing innovative quality education.

In the practice of engine assembly PBL education, the proposition and solution of problems on the principle and construction of mechanical device are through the whole process. Specifically, in the engineering practice PBL education evaluation, each of the six students were organized in a group and a enterprise mentor was provided for them. The theoretical knowledge and expertise of the engine need to be prepared by each group in advance, and they need to put forward the relevant problems in the process of disassembly and solve these problems by themselves in the specific implementation process; the instructor only gives the reference, not directly give the results. The design and result evaluation of each disassembly step should be completed by the students themselves. Using the cut-off set method of fuzzy comprehensive evaluation, we determine each cut-off level \( \lambda \) of excellent grade A+ and A-, excellent grade B+ and B-, good grade C+ and C-, general grade D+ and D-, worse grade E+ and E-, belonging to the selective set of engine assembly PBL education quality, into 0.95, 0.90, 0.85, 0.80, 0.75, 0.70, 0.65, 0.60, 0.55, 0.50.
The level of the evaluation factors of all the second-level indexes in the evaluation system are divided into five grades and the corresponding fuzzy evaluation criteria are: a is great for 90-100 points, b is good for 80-90 points, c is general for 70-80 points, d is worse for 60-70 points, and e is severe less than 60. Take the factor “Interview survey” of the second-level indexes as an example, the evaluation criteria are as follows: The evaluation factor grade of well understanding the PBL practice teaching ideas and doing a perfect job on the preparation of PBL knowledge points in the interview survey is a; the evaluation factors’ grade of general well and also good for preparation is b; the evaluation factors’ grade of understanding most of the PBL practice teaching ideas and preparing for the PBL knowledge points is c; familiar with the PBL practice teaching ideas and doing a part of preparation for the PBL knowledge points is d; the evaluation factors’ grade of being not familiar with the PBL practice teaching ideas and preparing badly for the PBL knowledge points is e. Then all of the evaluation factors grades of the second-level indexes in the table 1 can be got from this method.

According to the implementation plan of training syllabus and teaching excellence engineers, the implementation of the project is focused on completion of the syllabus and teaching plan, and the improve-ability and portability under limited funding. According to the scoring results of 15 experts of the college professors committee, the results are averaged, the criterion layer is compared with the judgment matrix, and finally the consistency of the judgment matrix is tested to obtain the weight of each index: \{0.06,0.33,0.09,0.18,0.21,0.13\}. According to the actual data records and document materials and other evaluation materials, using the same 15 expert scoring way, the environmental background, input content, practice process, output, improve-ability and portability of the engine assembly practice are calculated respectively, and the corresponding value at the confidence level are given 0.942, 0.885, 0.837, 0.917, 0.735, 0.924, respectively. Based on the maximum membership degree method (or weighted average method), taking the closest element in the selective corresponding to the maximum evaluation index, it is determined that the evaluation results of practical content, input content, practice process, output, improve-ability and portability belong to A+, A-, B+, A-, C+ and A+ respectively.

Discussion of the Evaluation Results

The following discussion discusses interview surveys, student practice diaries, corporate evaluations, practice reports, group discussions, and conference documents, which are organized according to the six second-level indexes of the evaluation model.

Discussion about the Background and Goal of the PBL Education. The evaluation result of environment, a second-level evaluation index, is A+. The results show that PBL educational environment and goals can significantly influence students' motivations and goals, especially when they are dealing with real objects. The results show that students are not quite clear about the reasons for adopting the PBL practice model. But they all showed a good understanding of the practical significance of PBL education, and felt comfortable with the new practice projects and their relationship with the enterprise mentor. The students spontaneously mentioned PBL, and their training goals were clearer.

Discussion about the Input of the PBL Education. This evaluation index grade is A-. The analysis of the evaluation results showed that in the stage of development in PBL education programs, enterprises given appropriate infrastructure and equipment resources cooperatively, but they ignored the students’ comprehensive application of component knowledge on the arrangement of practice content, making students unfamiliar with part of the practice content.

Discussion about the Process and Output of the PBL Education. According to the discussion of the second-level indexes about the process of grade B+ and the output of grade A-, the weakest part is the students' cognitive process of components. Students lack the application of component knowledge and the discovery of problems. In addition, for nearly 23% students believe that difficulties need to be completed under the guidance of the teacher and they do not need to use their own brains and hands. For the 50% of the interviewed mentors, the main difficulty is the students’
participation in the practical project and the evaluation of the results of the practice, not just the content of the practice.

**Discussion about the Improve-ability and Portability of the PBL Education.** The evaluation result of improve-ability, a second-level evaluation index, is C+. The analysis of index find that the main difficulties are the size of the practice group, the size of each project, and the project funding, which need to be adjusted when planning new projects. The evaluation result of portability is A+. The analysis of the results show that the relevance of each topic, combined with the knowledge, skills and capacity service project developed in books and courses, and appropriate evaluation tools are the key elements of project migration. In addition, the document and image records of the practice process, is the basis for the PBL project migration.

**Conclusion**

To construct the fuzzy comprehensive evaluation model of PBL education quality in colleges and universities, it is necessary to grasp the purpose of PBL teaching, and based on the connotation and evaluation principle of PBL education quality evaluation in engineering practice, to establish the multi-level evaluation index of six aspects of practice environment, content input, practice process, practical effect, improve-ability and portability, as well as the multi-category evaluation factor sets and membership degree fuzzy evaluation mathematical model. Through the combination of qualitative analysis and quantitative analysis, linking theory with practice, it can realize the measurable work of engineering practice education and prevent the deviation of training goal, and can provide reference for the transplantation and improvement of colleges’ engineering education.

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