Higher Education Research
2017; 2(2): 44-49
http://www.sciencepublishinggroup.com/j/her
doi: 10.11648/j.her.20170202.13

The Application and Assessment of Problem-Based Learning Methods in Biochemistry Classes

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To cite this article:
Yin Zhou, Yi Li. The Application and Assessment of Problem-Based Learning Methods in Biochemistry Classes. *Higher Education Research*. Vol. 2, No. 2, 2017, pp. 44-49. doi: 10.11648/j.her.20170202.13

Received: January 16, 2017; **Accepted**: January 25, 2017; **Published**: February 22, 2017

Abstract: Problem-based learning (PBL) approach which has been widely applied in pedagogy for decades to brings challenges, interest, motivation and enjoyment into the class environment. In this study, PBL was undertaken for the first time in Biochemistry classes in our institute. According to the teaching effectiveness of classes and the statistic results in questionnaire, it is showed that almost all of the PBL students could accept this teaching method and students in the advanced class felt easier to adjust to this method than those in common class. However, some minor problems should be solved in the further popularization.

Keywords: Problem-Based Learning (PBL), Biochemistry, Instructor and Trainees, Educational Reform, Pedagogy

1. Introduction

Problem-based learning (PBL) initially designed for graduates of medical school education in 1960s' by Barrows and Tamblyn [1, 2] has become a popular teaching method widely applied in pedagogy. Compared to the traditional teaching approaches, PBL is apprenticeship for a real-life problem solving [3], which contains three steps: initiating learning with a problem, solving the problem with interdisciplinary knowledge, and working collaboratively with classmates to solve the problem under the guidance of instructors (or tutors) [4]. The most crucial step in PBL is the designing of suitable problems. Typical characteristics of these problems were summarized by Tchudi and Lager [5], which are similar to: what do I know, what do I need to know, how do I learn, how do I measure or describe the results and so on. These problems could neither be too difficult for the trainees, nor too far from the textbooks, and the process of solving these problems should provide enough space for students to motivate their interests and enthusiasm, to expand their vision and problem-solving skills as well as to enhance their critical thinking and creative capabilities. PBL is focusing on cognitive process, in which students could make a strong impression of the knowledge and master the technology beneficial for their career in the future instead of learning some superficial theory or conclusions in textbooks. It is also a challenge in PBL for instructors who should have broad knowledge and ability to integrate undefined information, unsolved problems and basic theory into these questions [6]. When students search related materials or information at the beginning and then present the solutions for the problems in the end of the class, instructors should provide guidance for students, but not to control or limit their thinking.

However, the PBL implementation has some disadvantages. First of all, since there is no standard design approaches for instructors, PBL could not provide an 'off-the-peg' teaching system with uniform approach, but determined by different levels of trainees, different subjects and different educational units. Secondly, it is difficult to quickly assess and analyze PBL through testing form [7]. Large part of PBL was executed outside the classes, and instructors could not strictly follow the process of learning in detail but just speculate or judge from their presentation in the end. Therefore, the success or failure in the final tests of a term could not measure and assess the performance of students in PBL. Third, the PBL lacks obvious effectiveness, at least not the magnitude of effectiveness compared to the standard teaching method [8], which severely frustrated the positivity of educators.

Most extensive applications of PBL were reported in science subjects, especially in medical science, environmental protection, chemistry, dietetics and food production et al [7, 9-11]. Gallagher et al. pointed out that PBL could and should include experimentation as a tool for solving problems [2].

Biochemistry, a basic and theoretical course in Biology Department, is often offered for sophomore students who have learned General Biology, Inorganic Chemistry, Organic Chemistry in Grade one. But unlike other special courses, Biochemistry seems a little 'useless' even boring and soggy to them. For instance, students felt confident that they could master how to get sterilized or regenerated shoots in Plant Tissue Culture classes that strengthened their hands-on ability and that they could learn how to clone a gene and transform it into target cells in Gene Engineering classes. In Biochemistry classes, however, they feel horrible because of the failure in the final exams due to the disorder and abstract knowledge. Some students may make an effort to study this course only by reciting the presented theory and conclusions in the textbook without any enjoyment. In fact, many real problems in our daily life could be solved with biochemistry principles, some of which exist in our subconscious but we may not realize them. In order to encourage students to think critically and creatively, improve their problem-solving skills and establish relationship between theory and practice, problem-based learning method was introduced into Biochemistry classes.

This is the first time to apply PBL method in our institute. According to the teaching effectiveness of classes and the statistic results in questionnaire, this method could be accepted by almost all of the PBL students, especially in advanced classes. With intensive modification and adjustment, this method could be executed further in Biochemistry classes.

2. Method

One hundred and thirty-three students in PBL classes are selected randomly from sophomores, who have learned Biology, Inorganic and Analytic Chemistry, Organic Chemistry in Grade One. 72 traditional biochemistry credit hours are designed in one term. Almost all of the problems were designed to be coordinated with the traditional teaching schedule. It took about 10 minutes to solve the problem before each two classes and the next new problem was assigned to two or three students at the end of each two classes. These students were responsible for searching related materials or information in extracurricular time, answering and discussing the questions with other students in the next class. The flowchart in detail was shown in Figure 1. A total of 35 designed problems were listed in Appendix 1. Before the term ended, all the PBL students participated in the questionnaire to collect their suggestions about PBL. The questionnaire was mainly designed to survey self-assessment of PBL students, as well as their impression and suggestions of other participants and instructor, based on Macdonald's handbook [12]. They could also share their experience in PBL methods, especially based on Questionnaire 2, 12 and 20. The questionnaire was added in Appendix 2 including 21 questions.

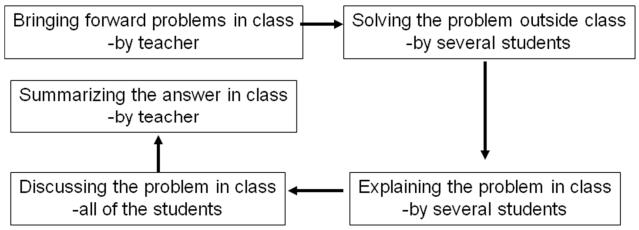

Figure 1. *The flowchart of PBL in Biochemistry classes.*

3. Results

Among 133 sophomores, 49 were from advanced classes whose students were selected by entrance examination in Grade One. The rest were from common classes. The primary result was shown in Table 1. According to the result in Questionnaire 2, 4, 12 and 20, almost all of the PBL students approved this method applied in Biochemistry classes, based on the advantages of PBL method in Questionnaire 5, 6 and 16. Considering mentioned characteristics of PBL method above, most PBL students maintained positive attitude towards this experience as shown in Questionnaire 3, 8 and 15. However, statistical result suggested that considerable number of students were lacking self-awareness as shown in Questionnaire 7, 9, 10 and 11. They could not evaluate their problem-solving ability correctly, neither before nor after this term, since they could not judge whether they have changed their way of thinking or improved their thinking ability. As the saying goes, "lookers-on see most of the game". These PBL students were harsh to others' performance as shown in Questionnaire 17, 18, 19 and 31. When presenters stood on the podium, others sitting down in the class were always counted on them too much. For the sake of their not so good foundation, most PBL students were lacking active thinking ability as shown in Questionnaire 13 and 14, because the main way to solve the problem for them was searching on the Internet or referring to materials. Fortunately, they stayed motivated all the time.

Table 1. *The statistical result of questionnaire.*

Questionnaire	Positive			Negative			Marks
	Advanced	Common	Total	Advanced	Common	Total	
1	46.9%	44.0%	45.1%	36.7%	26.2%	30.1%	24.8%
2	100%	95.2%	97.0%	0	4.8%	3.0%	0
3	85.7%	73.8%	78.2%	12.2%	26.2%	21.1%	0.8%
4	100%	95.2%	97.0%	0	4.8%	3.0%	0
5	91.8%	84.5%	87.2%	8.2%	14.3%	12.0%	0.8%
6	93.9%	86.9%	89.5%	6.1%	13.1%	10.5%	0
7	73.5%	61.9%	66.2%	20.4%	26.2%	24.0%	9.8%
8	85.7%	79.8%	82.1%	14.3%	16.7%	15.7%	2.2%
9	61.2%	45.2%	51.1%	38.8%	51.2%	46.6%	2.2%

Questionnaire	Positive			Negative			Marks
	Advanced	Common	Total	Advanced	Common	Total	
10	65.3%	56.0%	59.4%	32.7%	40.5%	37.6%	3.0%
11	81.6%	72.6%	76.0%	18.4%	23.8%	21.8%	2.2%
12	98.0%	96.4%	97.0%	2.0%	2.4%	2.2%	0.8%
13	77.6%	73.8%	75.2%	22.4%	22.6%	22.6%	2.2%
14	14.3%	7.1%	9.8%	85.7%	90.5%	88.7%	1.5%
15	83.7%	66.7%	72.9%	12.2%	28.6%	22.6%	4.5%
16	85.7%	88.1%	87.2%	10.2%	10.7%	10.5%	2.2%
17	85.7%	69.0%	75.2%	12.2%	25%	20.3%	4.5%
18	69.4%	73.8%	72.2%	22.4%	17.9%	19.5%	8.3%
19	87.8%	82.1%	84.2%	12.2%	15.5%	14.3%	1.5%
20	100%	96.4%	97.8%	0	3.6%	2.2%	0
21	91.8%	89.3%	90.2%	8.2%	10.7%	9.8%	0

Marks: Unsure or Not filling

All the questionnaire answers were divided into two categories: 'Positive' and 'Negative'. Positive includes 'Yes', 'Appropriate', 'I do', 'Satisfied', 'Rational' and 'Improved', while Negative stands for 'No', 'Improper', 'I do not', 'Dissatisfied', 'Irrational' and 'Cancelled'. The positive ratio was marked with white and negative ratio with black in Figure 2, indicating that most students maintained positive attitude to the PBL approach applied in Biochemistry classes. Considering the PBL students from different learning levels, students coming from advanced and those from common classes were separately selected to be compared in Figure 3 and Figure 4, advanced students represented with black histograms and common with grey. Obviously, advanced students were more positive to the PBL than common students, suggesting that they were easier to adjust to this approach.

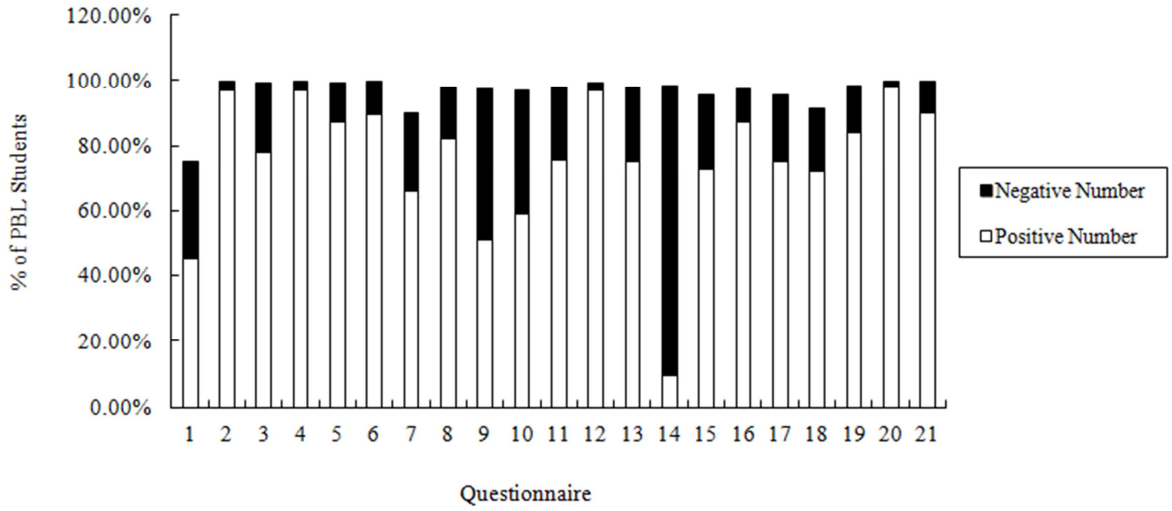

Figure 2. *Positive and negative ratio of PBL students in questionnaire.*

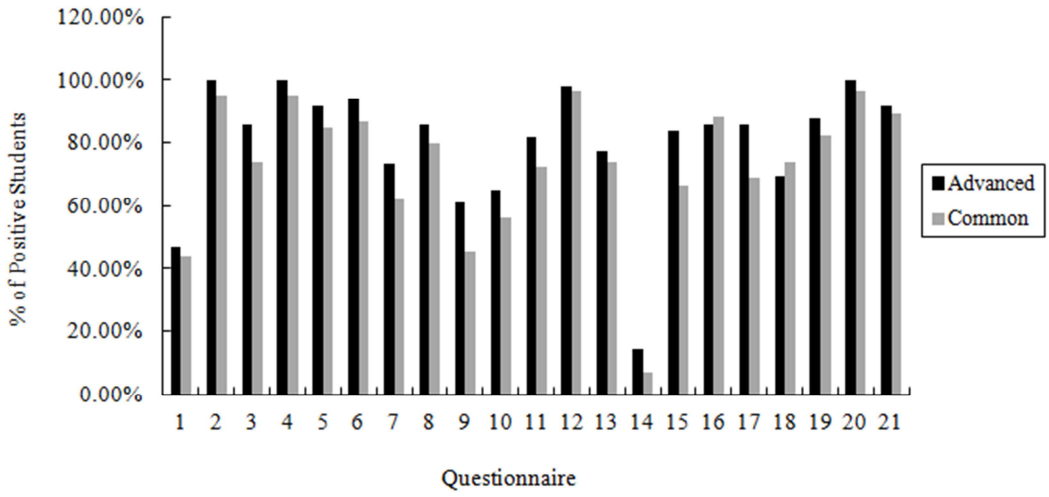

Figure 3. *Comparison of positive ratio between advanced and common PBL students.*

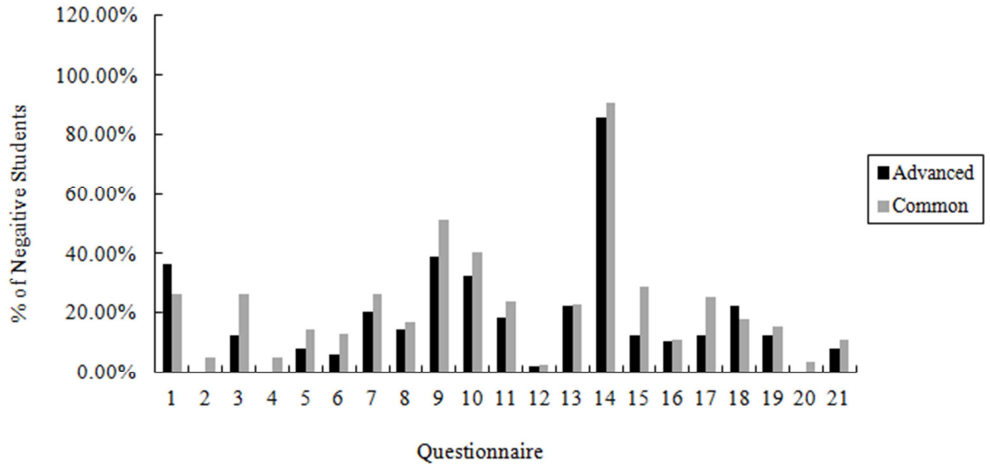

Figure 4. *Comparison of negative ratio between advanced and common PBL students.*

4. Discussion

In China, especially in the nine-year compulsory education system, knowledge was directly introduced to students by teachers. The learning process is almost thoroughly deprived of interest and pleasure [13]. Problem-based learning (PBL) approach has been executed for more than five decades with different forms in different schools [14, 15]. This method brings active and divergent thinking as well as vitality into the class, which facilitates to cultivate independent, creative and cognitive students [16]. In this study, we used PBL approach to guide students to learn Biochemistry course, which seems to work well, although further modifications and improvements are needed in the future.

Biochemistry is a special and basic course which combines two subjects of Biology and Chemistry. Many students experience difficulty to learn this course for the reason that knowledge is too scattered and boring, and the main learning method is mechanical recitation. In order to improve teaching efficiency in classes, PBL method was first introduced in Biochemistry classes in our institute. Some unexpected results would occur at any time, but the most crucial step is problem designing. Different problems would result in different teaching effects in classes. Taken account of the problem-solving ability of our students, problems in PBL are not too difficult. Another reason is that each problem should be solved and discussed no more than 10 minutes before traditional classes begin.

Many designed problems in Appendix 1 properly linked theory with practice. For example, Question 3 has been a hot topic in China for a long time. Nitrogen content in milk powder could be rapidly detected with Kjeldahl Determination method and the average nitrogen content in protein is less than 16%, so whether the milk power is mixed with trimeric cyanine amine-can not be determined according to this standard. Question 5, 7, 9, 14, 15, 26, 29 and 31 were common sense close to our daily life, which we know well but we may never think about why they should be like this, yet basic principle in Biochemistry textbook could give us answers. However, some questions like 8, 16 and 27 are extended from textbook and thought to be too hard for PBL students to answer, for they could not search any direct answers on the Internet or other references. In fact, a few students with intensive reading could find some clues in textbook and solve the problem by adding a little divergent thinking, but according to the presented answers and discussion in classes, PBL students in this experiment were lacking active and intensive thinking and were too much dependent on the references and Internet search engineers, which was coincidence with the result in Questionnaire 13 and 14.

The questionnaire statistical results showed that most students accepted this method and admitted it feasible in our institute. Overall, PBL students from advanced classes seems more acceptable than those from common classes, suggesting that PBL method carried out in top universities may have better effect. In order to look further insight into PBL students' thinking, Questionnaire 2, 12 and 20 were discussed more thoroughly. We could not judge or evaluate whether PBL students had any cognitive change from these answers, and this was also reluctant or difficult for themselves to answer in Questionnaire 10 and 11 [17]. Some students considered that several problems, such as Question 8, 25 and 27, were difficult for them to solve. Some students acclaimed almost all of the problems were assigned accompanied with the traditional teaching schedule, but the solutions did not conform to the requirement of difficulty and importance in syllabus, so they thought we wasted time in doing something irrelevant with final exam. Additionally, some students thought that the time for answering questions was too long and took too much from the traditional teaching time, and they hoped the teacher could control it. This phenomenon reflects the contradiction of teaching method between traditional education and advanced education, the former emphasizing textbook knowledge and demanding students to pass the final exam, while the later helping students to broaden their knowledge by teaching them to gain the ability of learning.

5. Conclusion

Problem-based learning method has been successfully

introduced in Biochemistry classes in our college, which provides interest, enthusiasm and challenge into the classes as well. We will continue implementing and improving this learning method in the following educational reform.

Acknowledgement

The financial support from the educational commission of Hubei province (No. 2012391) and Wuhan Institute of Bioengineering (No. 2012J04) are gratefully acknowledged. Thanks Robin Popa for proofreading the manuscript.

Appendix 1. Designed Problems in PBL

1. What do you think of using monosodium glutamate for cooking?
2. How to explain the methods of fingerprint extraction in the movie?
3. Why did milk producers take a risk to add trimeric cyanine amine into milk powder?
4. What is the principle of Protein Sequencer?
5. Why it can be said that permanent wave is a biochemical project?
6. How many kinds of anemia have been found and what are their molecular mechanisms?
7. How to make soybean milk into Tofo curd and please explain its principle?
8. Please design a simple experiment to measure the pI (isoelectric point) of an unknown protein.
9. How to wash clothes with enzymatic laundry powder and why?
10. How to preserve enzyme?
11. What is the principle of suicide by swallowing gold, heavy metal poisoning, carbon monoxide (CO) poisoning and cyanide poisoning?
12. In the process of PCR, what else should be added into the cocktail except template DNA, DNA polymerase, reaction buffer, primers, dNTP and ddH_2O? Sometimes it is added into reaction buffer together. And what's the function of it?
13. What is the reason of diabetes? How to cure it? Which organ is insulin synthesized and why it could be used to treat diabetes?
14. It is said that when you eat meat without garlic, the nutrients in meat would be decreased in half. Why?
15. When you are eating seafood, you'd better not drink orange juice together. Why?
16. How to use glucose to synthesize glucono-δ-lactone? And what does it used for?
17. What are the products of starch catalyzed with salivary amylase for different lengths of time? What colors of these products stained with iodine?
18. Could nucleic acids be developed into a kind of dietary supplement? Why?
19. What are the initial materials for DNA synthesis? dNMP, dNDP or dNTP? And what are the structural units to form DNA double-strand with 3', 5'-phosphodiester bond? dNMP, dNDP or dNTP?
20. Why is there a thymine base in tRNA (TΨC loop) which should not have been appeared in RNA?
21. How to detect the deteriorated oil?
22. What diseases occur related with fat?
23. All organisms have mitochondria, don't they?
24. Does cellulose include any nutrients for human? Why we should add cellulose in our daily dietary?
25. What is the principle of pentachlorophenol (PCP) and Tubatoxin as insecticide?
26. Why do you feel muscular aches after strenuous exercise?
27. How to genetically modify and design an engineering bacterium which could transfer glucose into ethanol?
28. What's the function of gluconeogenesis? Why the patient with hypoglycemia was prone to faint?
29. Is there any relationship between sugar dietary and obesity?
30. How do dormant animals live in winter?
31. Why could drinking green tea decrease the accumulation of fat?
32. What is the formation mechanism of the fatty liver and how to treat it?
33. Please explain Big Head Baby event with corresponding biochemistry knowledge.
34. What's the relationship between the activity of transaminase and liver function?
35. How to asses if the meat is fresh or not, and why?

Appendix 2. The Questionnaire in PBL

1. Is this the first time you got in touch with PBL?
2. Do you think this method fits for learning Biochemistry?
3. Would you like to participate in this tentative teaching method?
4. Do you think these problems in PBL are helpful for your learning Biochemistry?
5. Compared to traditional teaching method, does PBL give you a strong impression of related theory knowledge or not?
6. Compared to traditional teaching method, does PBL improve your interest in Biochemistry learning or not?
7. Are these problems designed in the range of your problem-solving ability?
8. Will you spend extra curriculum time in solving these problems?
9. Are you satisfied with your performance in solving the problem?
10. Is there any change in your way of thinking during the solving process?
11. Is your thinking ability improved more or less in the solving process?
12. Do you think these problems are designed properly?
13. Do you feel resources are limited when you searched related materials to solve the problem?
14. When solving the problem, do you refer more to related

materials or do you think actively more?
15. Do you participate in the discussion process?
16. Do you get any new findings in the discussion process?
17. Are you content with the performances of other students when they explain the problem?
18. Do you think the question is scientific brought forward by other students in the discussion process?
19. Do you think the explaining and discussion time of PBL in the class is suitable or not?
20. Should Problem-based Learning method be cancelled right now or executed continually with further modification?
21. Are you satisfied with the performance of the teacher during the whole process?

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