Design and practice of navigation-based learning (NBL) as a novel method for clinical thinking training

Yi-Zhou Wu[1], Jie Sun[2]

**Corresponding author:** Prof Jie Sun yssjmm@126.com

**Institution:** 1. Department of Cell Biology, School of Basic Medicine, Nanjing Medical University, 2. Safety Assessment and Research Center for Drug, Pesticide and Veterinary Drug of Jiangsu Province, School of Public Health, Nanjing Medical University

**Categories:** Curriculum Planning, Educational Strategies, Technology

Received: 23/07/2019
Published: 09/09/2019

**Abstract**

**Objectives:** In recent years, many medical universities in China have launched Problem-Based Learning (PBL) curriculum. It improves the autonomous learning ability, but also exposes some problems and shortcomings. For example, the low learning efficiency due to excessive freedom of atmosphere and insufficient guidance of tutor, the lack of clinical training due to case compiling and curriculum design, etc. To solve these problems, we conceive a new method Navigation-Based Learning (NBL) in this study.

**Methods:** A standard learning group includes one tutor and ten students. The NBL cases containing two acts are generated by expanding and modifying real clinical records. The learning process comprises a series of steps: Introduction (10 min), Act I (75 min), Act II (75 min), Summary (20 min). The learning quality is further evaluated by an objective examination and a subjective questionnaire, followed by quantitative analyses with various statistical models.

**Results:** The results of examination show that NBL achieves similar learning quality as PBL. Benefiting from enhanced guidance and compressed course time, NBL reaches a higher learning efficiency than PBL. The results of questionnaire show that the approval rating of NBL is 85.11%. Compared with PBL, the high support rate of NBL is attributed to the advantages of four aspects, including learning efficiency of unit time (HR=1.119, \(p=0.029\)), clarified learning orientation (HR=1.093, \(p=0.039\)), authentic simulation of clinical diagnosis and treatment scenarios (HR=1.139, \(p=0.033\)), clinical thinking and logical reasoning (HR=1.089, \(p=0.033\)).

**Conclusions:** NBL has been proved to be an effective learning method in clinical thinking training for medical students. It achieves a balance between promoting efficiency and maintaining interest in medical learning.

**Keywords:** Navigation-based learning; Problem-based learning; Curriculum; Clinical scenario; Medical education
Introduction

Education is not the filling of a pail, but the lighting of a fire. William Butler Yeats stressed the need for teachers to light the student's fire by inspiring them to learn, explore and create. For beginners of clinical medicine, if learning starts with interest, the learners will devote a great deal of enthusiasm and vigor, which will naturally lead to higher learning efficiency and better outcomes. Modern medical knowledge covers a wide range from basic physiology, anatomy, pathology to clinic. It contains a large amount of detailed knowledges and complicated mechanisms, which are relatively abstract and difficult to master. If the interest of students cannot be effectively stimulated in the initial stage of learning, it is likely that there will be a phenomenon of "get half the results with double the effort". In this situation, Problem-Based Learning (PBL) was proposed. The PBL curriculum require students to discover problems independently, learn relevant knowledge, communicate and solve issues, and cultivate self-learning ability (Preeti, Ashish and Shriram, 2013; Ellaway, Poulton and Jivram, 2015; Orsmond and Zvauya, 2015; Torre, van der Vleuten and Dolmans, 2016).

Many universities in China launch PBL in recent years, however, several issues emerged in course implementation. For example, low learning efficiency due to the free and relaxed learning atmosphere and insufficient guidance, the lack of clinical simulation in case conception, and the lack of clinical thinking training, etc. (Fan et al., 2014; Sun, Chen and Wu, 2018). (1) Due to the long-term of "duck-feeding" education in school, our students become heavily dependent on traditional Lecture-Based Learning (LBL), lacking the initiative and ability to discover and solve problems. Students get used to merely asking and answering questions, but lack the ability to solve problems. Some students have poor learning consciousness or even resist to discussion. (2) Clinical tutors always have dual identities. Their clinical work is very onerous and they have to undertake teaching. Sometimes their roles in teaching are not clear. It is even believed that the difference between PBL and LBL is only the exchange of roles between students and teachers, that means, students are the speakers of the class, while teachers are the listeners and evaluators. (3) To train the students to independently bring out issues, analyze and solve problems, tutors are more inclined to simply listen to discussion and evaluate their performance, allowing students to play their part ad lib. This may lead to a deviation from the direction of learning and ultimately a serious loss of learning objectives. In fact, students hope that the tutor can play a more guiding role to in curriculum implementation (AlHaqwi, 2014; Chang, 2016).

In this study, to solve the above mentioned issues, we design and develop a novel learning method, Navigation-Based Learning (NBL), for medical students in clinical thinking training. In NBL curriculum, the tutors actively guide students to participate in the whole learning process, create and maintain the atmosphere of discussion, simulate the clinical diagnosis and treatment scenarios, help students to establish clinical logical reasoning and strengthen clinical thinking, finally complete the learning objectives efficiently.

Methods

1. Case design and hardware construction

We design and establish a NBL case library through compiling the authentic clinical records. Each case comprises two acts. The content of Act I include the chief complaint, history of present illness, past medical history and abnormal physiological indicators and signs. The content of Act II include the actual clinical diagnosis, therapeutic schedule and prognosis. According to the standard PBL curriculum, we also revise several cases for PBL control group. All cases are approved by ethical review and rationality verification. We also establish an exclusive classroom for NBL, which is equipped with computer, projector, blackboard, wireless network, electronic literature database, etc. The classroom is separated into two compartments, students and tutor room and observers room. The single-blind observers can synchronously evaluate the performance of students and tutor (Figure 1).
Figure 1. A standard NBL classroom. (A) students and tutor room, (B) observers room.

2. Methodological framework
A standard learning group includes one tutor and ten students. The tutor’s role includes organization of the learning process and control of the pace. The NBL case is randomly selected from the library and the whole study of single case is tightly completed in three hours. The learning process of NBL is designed as follows. (1) Step 1: Introduction (10 min). The tutor generally explains the learning procedure and the students introduce themselves. Throughout the learning process, students should take notes by themselves and prepare their own multimedia equipment for real-time web access. (2) Step 2: Act I (75 min). The students read materials of Act 1, take preliminary analysis and judgment of physiological abnormalities, and brainstorm a list of issues. Subsequently, the students freely form teams according to the issues they are interested in. Each team enters the stage of deep-learning by self-organize. Students get the initial diagnosis of the disease and enumerate the basis of diagnosis by quickly inquiring the web resource and so on. Finally, the tutor guides the students to participate in a collective discussion and summarize a consensus, then confirms the rationality of the pre-diagnosis. (3) Step 3: Act II (75 min). The students read materials of Act II. The tutor helps the students to self-examine, answers the questions, improves the pre-diagnosis and summarizes the learning results of Act I. Then tutor guides the students to study the treatment and prevention parts. After collaborative learning in teams, the students take in a collective discussion, supplement and answer the remnant questions. (4) Step 4: Summary (20 min). Finally, the tutor summarizes the case. The students further review their notes after class and complete their reports.

3. Population
A total of 300 students majoring in clinical medicine are recruited to participate in NBL course (Table 1). These students all have complete experience of three PBL cases, including 165 males and 135 females. For educational system, these students include 249 of eight-year clinical medicine (8Ymed) in combined bachelor's and master's degree, 51 of five-year clinical medicine (5Ymed) in bachelor's degree. For control study, another 300 students participate in standard PBL course, using the relevant revised cases. All students are informed the purpose of the course and volunteer for the research study.

Table 1. Baseline characteristics of students in NBL curriculum

| Characteristics     | Constituent Ratio |
|---------------------|-------------------|
| Gender              | Male (55%) Female (45%) |
| Educational system  | 8Ymed (83%) 5Ymed (17%) |
4. Quality evaluation and data quantization
The learning quality of NBL or PBL is evaluated when course finished. It consists of two parts: the objective in-class test of professional knowledges, and the subjective questionnaire about the comparison between NBL and PBL. All students complete the tests and questionnaires anonymously.

According to the medical knowledges involved, ten questions with varied difficulty levels are designed for each case. Each question has 10 scores and 100 scores in total. These questions could also be typed into four different fields. (1) Symptoms and Signs. Symptoms mainly refer to the personal statement, such as headache, abdominal pain and so on. Signs refer to the abnormal changes found by the doctor when examining the patient. (2) Diagnosis, it mainly includes the basis of diagnosis of diseases and differential diagnosis of other diseases. (3) Treatment and Prevention, it mainly includes drug treatment, surgical treatment, post-operative nursing, preventive measures and so on. (4) Etiology and Pathogenesis, it mainly refers to the pathological changes within the body and the factors of increasing the disease occurrence probability.

The questionnaire based on comparison between NBL and PBL is designed, which include the following factors: (1) general approval rating, (2) learning efficiency of unit time, (3) clarified learning orientation, (4) collaborative skills, (5) clinical simulation, (6) clinical thinking, (7) tutor’s navigation role and so on. The score of each question ranges from 0 to 100, increasing every 10 scores. The score greater than or equal to 60 is defined as a positive attitude, while less than 60 is defined as a negative attitude. The NBL confidence index is defined as positive attitude of 1 and negative attitude of 0, according to the scores of general approval rating.

5. Statistical analysis
All data are analyzed using SAS 9.1 software. Chi-square test is used for counting data, and mean ± standard deviation (or standard error) is used for measuring data. T test and F test are used for comparison between groups, \( p < 0.05 \) is significant difference.

Results/Analysis

1. Objective evaluation of NBL learning quality: Examination
The average score of NBL group is 69.67 ± 12.54 (mean ± S.D.), slightly lower than 73.20 ± 13.14 in PBL group. The results of statistical analysis are \( p=0.388 \) in F-Test (two-sample for variances) and \( p=0.311 \) in t-Test (two-sample assuming equal variances), showing no significant difference between two learning methods. Firstly, we analyze the scoring of NBL and PBL in different fields (Figure 2a). The average score of NBL is slightly higher than that of PBL in symptoms and signs, diagnosis parts, and slightly lower than PBL in treatment and prevention parts. But the statistical results show no significant difference between NBL and PBL. However, in etiology and pathogenesis parts, the average score of NBL (66.67 ± 4.71) is lower (\( p=0.020 \)) than that of PBL (71.30 ± 3.46). This may be due to the fact that NBL has compressed the whole course time than PBL, the study of etiology and pathogenesis is not as deep and solid as that of PBL, especially knowledges related to the field of basic medicine. These knowledges could be further supplemented by an after-class review.

Figure 2. Quantitative analyses of detailed scoring in NBL and PBL.
Table 2. Statistical analysis of scoring based on the difficulties of questions

| Degree of Difficulty | NBL Scoring | PBL Scoring | F-test p value | T-test p value |
|----------------------|-------------|-------------|----------------|----------------|
|                      | Mean        | Standard Deviation | Mean            | Standard Deviation |                |                |
| 1                    | 100%        | 0            | 100%           | 0               | -              | -              |
| 2                    | 90%         | 10%          | 91.11%         | 8.39%           | 0.316          | 0.802          |
| 3                    | 76.67%      | 5.77%        | 91.11%         | 8.39%           | 0.015          | 0.117          |
| 4                    | 83.33%      | 5.77%        | 84.07%         | 4.49%           | 0.479          | 0.948          |
| 5                    | 73.33%      | 11.55%       | 78.52%         | 11.18%          | 0.316          | 0.571          |
| 6                    | 66.67%      | 5.77%        | 65.56%         | 15.03%          | 0.446          | 0.723          |
| 7                    | 56.67%      | 5.77%        | 52.96%         | 18.47%          | 0.485          | 0.961          |
| 8                    | 33.33%      | 11.55%       | 39.26%         | 5.59%           | 0.411          | 0.617          |
| 9                    | 13.33%      | 5.77%        | 23.70%         | 18.27%          | 0.117          | 0.316          |

Secondly, we analyze the scoring of NBL and PBL according to the difficulty levels. The results show no significant difference (Table 2). We conduct the linear regression analysis (Kotter and Niebuhr, 2016; Liang et al., 2018). The
regression equations are \( Y_{\text{NBL}} = -0.088X + 1.178 \) \( (R^2 = 0.892) \) and \( Y_{\text{PBL}} = -0.083X + 1.177 \) \( (R^2 = 0.918) \). Here, \( X \) represents the difficulty and \( Y \) represents the accuracy (Figure 2b). To determine whether two slopes of NBL and PBL equal, we apply statistical analysis and the results are \( F = 0.562 \) and \( p = 0.457 \), which indicate that if the overall slopes are identical, there is a 46% chance of randomly choosing data points with slopes this different. So we can conclude that the differences between the slopes of NBL and PBL are not significant. Next, to determine whether the elevations or intercepts equal, we apply statistical analysis and the results are \( F = 1.944 \) and \( p = 0.169 \), which indicate that if the overall elevations are identical, there is a 17% chance of randomly choosing data points with elevations this different. Taken together, we can conclude that the difference between the correctness curves of NBL and PBL are not significant. Furthermore, since the slopes and intercepts are not significantly different, it is possible to calculate single slope for all the data. The pooled slope equals -0.085. It is also possible to calculate single \( Y \) intercept for both NBL and PBL. The pooled intercept equals 1.177. Therefore, in the practices of NBL or PBL, the functional relationship between accuracy and the difficulty levels can be expressed as a single regression equation: \( Y_{\text{NBL/PBL}} = -0.085X + 1.177 \).

Thirdly, we analyze the scoring proportions of NBL and PBL through various statistical models (Bland and Altman, 2004; Omata et al., 2018). The results are \( \chi^2 = 1.364 \), \( p = 0.243 \) in Mantel-Cox test and \( \chi^2 = 1.203 \), \( p = 0.273 \) in Gehan-Breslow-Wilcoxon test, which indicate no significant difference between the two scoring curves (Figure 2c). However, compared with PBL, the hazard ratio (HR) of NBL is 1.085 (0.872-2.327, 95% C.I.) in Log-rank analysis, indicating that the risk (equals to error probability) of NBL is 1.085 times that of PBL. On the contrary, compared with NBL, the HR of PBL is 0.967 (0.361-1.125, 95% C.I.), indicating that the error probability of PBL is 0.967 times that of NBL. These results demonstrate that along with the increasing difficulties, the risk of loss scoring in NBL is approximately 8.5% higher than that in PBL. But in general, the above analyses show that NBL can achieve similar learning quality as PBL. Considering that NBL strengthens tutor guidance and greatly reduces the overall time than PBL, it can conclude that NBL has a higher learning efficiency.

2. Subjective evaluation of NBL learning quality: Questionnaire

Generally, the approval rating of NBL curriculum is 85.11%, with an average score of 81.50 ± 14.42 (mean ± S.D.) and the mode score of 100 (25.53%). For learning efficiency of unit time, NBL reaches an 80.85% approval rating with an average score of 80.53 ± 13.55 and the mode score of 80 (27.27%). For clarified learning orientation, NBL reaches an 82.97% approval rating with an average score of 79.49 ± 13.37 and the mode score of 80 (21.28%). The NBL course is more compact in time than PBL. Students focus around solving clinical problems under the guidance of tutor, so greatly improve the learning efficiency. For collaborative skills, NBL reaches an 80.85% approval rating with an average score of 80.00 ± 14.14 and the mode score of 70 (21.28%). Since each team focuses on its objectives and excavates enough in-depth information, they can collaboratively construct a complete interpretation of the case. For simulation of clinical diagnosis and treatment scenarios, NBL reaches an 85.11% approval rating with an average score of 81.75 ± 14.48 and the mode score of 80 (29.79%). For clinical thinking and logical reasoning, NBL reaches an 85.11% approval rating with an average score of 83.50 ± 14.06 and the mode score of 100 (27.66%). NBL uses limited time to simplify the course content and learning process, so naturally improves the acceptance of the course. The clinical consultation and situation in NBL course are simulated more truthfully than PBL, so as to cultivate the clinical thinking and logical reasoning. For tutor's navigation role, NBL reaches an 76.60% approval rating with an average score of 81.94 ± 14.51 and the mode score of 80 (25.53%). Because the expertise and teaching behavior of tutors have a great impact on students' learning effect (Dolmans and Wolfhagen, 2005; Chng, Yew and Schmidt, 2011; Lee, Lin and Lin, 2013). NBL emphasizes the guidance of tutor, so that students can target the diagnostic clues and find the optimal therapeutic regimen more efficiently.

The popularity of a new learning method is influenced by many factors. Simply comparing a single score hardly
reflect deeper information, such as the key factors involved in the questionnaire and their different weights. In order to reveal which factors mentioned above are essential to influence the popularity of NBL, we apply the epidemiological analysis model and the univariate logistic regression analysis (Armstrong et al., 2012; Direkvand-Moghadam et al., 2016). The statistical relationship between these factors and NBL confidence index are quantitatively analyzed. The results show that four factors have significant statistical correlation with NBL confidence index (Table 3). For learning efficiency of unit time ($p=0.029$), the HR of students with positive attitude is $1.119 (1.011-1.239, 95\% \text{ C.I.})$, indicating that the probability of positive attitude is 11.9% higher than that of negative attitude. For Clarified learning orientation ($p=0.039$), the HR of students with positive attitude is $1.093 (1.005-1.189, 95\% \text{ C.I.})$, indicating that the probability of positive attitude is 9.3% higher than that of negative attitude. For simulation of clinical diagnosis and treatment scenarios ($p=0.033$), the HR of students with positive attitude is $1.139 (1.011-1.284, 95\% \text{ C.I.})$, indicating that the probability of positive attitude is 13.9% higher than that of negative attitude. For clinical thinking and logical reasoning ($p=0.033$), the HR of students with positive attitude is $1.089 (1.007-1.178, 95\% \text{ C.I.})$, indicating that the probability of positive attitude is 8.9% higher than that of negative attitude. However, there are two factors, tutor’s navigation role ($p=0.117$) and collaborative skills ($p=0.088$), showing no significant statistical correlation with the approval of NBL. This demonstrates that although the guidance role of tutor is obviously enhanced in NBL, it does not affect the support attitude towards NBL.

Table 3. Univariate logistic regression analysis of risk factors in NBL confidence index

| Risk Factors          | B   | Standard Error | Wald | df | $p$ value | Hazard Ratio | 95% C.I. HR | HR | Lower | Upper |
|-----------------------|-----|----------------|------|----|-----------|--------------|-----------|-----|-------|-------|
| Learning efficiency   | 0.113 | 0.052           | 4.756 | 1  | 0.029     | 1.119        | 1.011     | 1.239 |
| Clarified orientation | 0.089 | 0.043           | 4.270 | 1  | 0.039     | 1.093        | 1.005     | 1.189 |
| Clinical simulation   | 0.130 | 0.061           | 4.570 | 1  | 0.033     | 1.139        | 1.011     | 1.284 |
| Clinical thinking     | 0.086 | 0.040           | 4.564 | 1  | 0.033     | 1.089        | 1.007     | 1.178 |
| Collaborative skills  | 0.059 | 0.034           | 2.918 | 1  | 0.088     | 1.060        | 0.991     | 1.134 |
| Navigation role       | 0.052 | 0.033           | 2.463 | 1  | 0.117     | 1.053        | 0.987     | 1.124 |

We also analyze the suggestions on NBL curriculum in the questionnaire. In terms of NBL course time, 59.57% of students agrees with the current time, believing that the three-hour course could maintain a better balance between learning efficiency and content. Only 12.77% of students demands an additional half-one hour to complete the in-depth study. Many students hope to add some performance evaluation in the autonomous learning stage, which requires further improvement of the process evaluation system, such as joining an independent third-party observer. In addition, students suggest the tutors to bring their own experience into class, not only organize the course. Students need more learning guidance from first-line clinicians, rather than the rigid pattern of finding keywords and raising issues under the student-chaired course in PBL. In addition, some students also suggest to classify the case library on the basis of clinical departments, organs, diseases and so on, so that students can choose the case they are interested in more conveniently.
Discussion

According to previous report, 70% of the students are more inclined to clinical-oriented case study after completing the basic course of PBL (Aljarallah and Hassan, 2015). But PBL or Case-Based Learning (CBL) are too standardized and procedural in issues description, and students are prone to lose interest after several studies (Sun, Chen and Wu, 2018). To stimulate the learning interest and enhance the motivation for autonomous learning, it should create an authentic clinical situation. In this study, the design of ill-structured NBL curriculum has very high requirements for clinical scenario simulation. It is devoted to creating an atmosphere of clinical multidisciplinary consultation and simulating an authentic clinical situation.

The new learning strategy NBL has three characteristics. (1) NBL requires students to have basic medical knowledges and is not suitable for all students. The first act of NBL course is mainly about clinical signs, physiological and pathological indicators, the junior students lacking systematical studies of clinical courses will be difficult to combine physical signs with clinical indications. So students, especially those entering medicine directly from school, are unable to form a preliminary understanding of the disease and finally result in low efficient learning. (2) NBL strengthens the active guidance and control of tutor over the course. It requires tutor to guide students according to clinical scenario, so as to avoid excessive divergent and aimless learning that often occurs in self-driven spontaneous discussion. Generally, NBL greatly reduces the course time, enhances the direction of learning and improves the learning efficiency. (3) NBL curriculum is designed from the actual cases. It helps students to understand the actual clinical diagnosis and master the therapeutic regimen following certain diagnostic guidelines, and building a good foundation for future clinical work.

Conclusion

In this study, the NBL learning strategy is firstly proposed. Our results indicate that NBL is an effective learning method in clinical thinking training for medical students. NBL is featured by enhancing tutor’s guidance and simulating the clinical scenarios. It achieves a balance between promoting efficiency and maintaining interest in medical learning.

Take Home Messages

1. NBL achieves comparable learning quality as PBL and reaches a higher efficiency than PBL.
2. NBL emphasizes the guidance role of tutor and greatly compresses the overall course time.
3. NBL strengthens the authentic simulation of clinical diagnosis and treatment scenarios.

Notes On Contributors

Yi-Zhou Wu is an assistant professor of cell biology at School of Basic Medicine Nanjing Medical University, P.R.China. Dr. Wu’s research mainly focuses on developing novel methodology in higher medical education, including artificial intelligence and deep-learning algorithms.
ORCID: https://orcid.org/0000-0001-9768-8144

Jie Sun is an assistant professor of pharmacy at School of Public Health Nanjing Medical University, P.R.China. Dr. Sun’s research mainly focuses on the application of problem-based learning and e-learning, designing the medical curriculum.
ORCID: https://orcid.org/0000-0001-7823-2897
Acknowledgements

The authors would like to thank all students and teachers who volunteered to participate in this research.

Yi-Zhou Wu is the creator/owner of Figure 1.
Jie Sun is the creator/owner of Figure 2.

Bibliography/References

AlHaqwi, A. I. (2014) 'Learning outcomes and tutoring in problem based-learning: how do undergraduate medical students perceive them?', *Int J Health Sci (Qassim)*, 8(2), pp. 125-32. https://doi.org/10.12816/0006078

Aljarallah, B. and Hassan, M. S. (2015) 'Problem based learning (PBL) vs. Case based curriculum in clinical clerkship, Internal Medicine innovated Curriculum, Student prospective', *Int J Health Sci (Qassim)*, 9(2), pp. 147-52. https://doi.org/10.12816/0024111

Armstrong, M. J., Naglie, G., Duff-Canning, S., Meaney, C., et al. (2012) 'Roles of Education and IQ in Cognitive Reserve in Parkinson's Disease-Mild Cognitive Impairment', *Dement Geriatr Cogn Dis Extra*, 2(1), pp. 343-52. https://doi.org/10.1159/000341782

Bland, J. M. and Altman, D. G. (2004) 'The logrank test', *BMJ (Clinical research ed.)*, 328(7447), pp. 1073-1073. https://doi.org/10.1136/bmj.328.7447.1073

Chang, B. J. (2016) 'Problem-based learning in medical school: A student's perspective', *Ann Med Surg (Lond)*, 12, pp. 88-89. https://doi.org/10.1016/j.amsu.2016.11.011

Chng, E., Yew, E. H. and Schmidt, H. G. (2011) 'Effects of tutor-related behaviours on the process of problem-based learning', *Adv Health Sci Educ Theory Pract*, 16(4), pp. 491-503. https://doi.org/10.1007/s10459-011-9282-7

Direkvand-Moghadam, A., Suhrabi, Z., Akbari, M. and Direkvand-Moghadam, A. (2016) 'Prevalence and Predictive Factors of Sexual Dysfunction in Iranian Women: Univariate and Multivariate Logistic Regression Analyses', *Korean J Fam Med*, 37(5), pp. 293-8. https://doi.org/10.4082/kjfm.2016.37.5.293

Dolmans, D. H. and Wolfhagen, I. H. (2005) 'Complex interactions between tutor performance, tutorial group productivity and the effectiveness of PBL units as perceived by students', *Adv Health Sci Educ Theory Pract*, 10(3), pp. 253-61. https://doi.org/10.1007/s10459-005-0665-5

Ellaway, R. H., Poulton, T. and Jivram, T. (2015) 'Decision PBL: A 4-year retrospective case study of the use of virtual patients in problem-based learning', *Med Teach*, 37(10), pp. 926-34. https://doi.org/10.3109/0142159X.2014.970627

Fan, A. P., Kosik, R. O., Tsai, T. C., Cai, Q., et al. (2014) 'A snapshot of the status of problem-based learning (PBL) in Chinese medical schools', *Med Teach*, 36(7), pp. 615-20. https://doi.org/10.3109/0142159X.2014.902045

Kotter, T. and Niebuhr, F. (2016) 'Resource-oriented coaching for reduction of examination-related stress in medical students: an exploratory randomized controlled trial', *Adv Med Educ Pract*, 7, pp. 497-504. https://doi.org/10.2147/AMEP.S110424
Lee, G. H., Lin, C. S. and Lin, Y. H. (2013) 'How experienced tutors facilitate tutorial dynamics in PBL groups', *Med Teach*, 35(2), pp. e935-42. https://doi.org/10.3109/0142159X.2012.714883

Liang, J. C., Chen, Y. Y., Hsu, H. Y., Chu, T. S., *et al.* (2018) 'The relationships between the medical learners’ motivations and strategies to learning medicine and learning outcomes', *Med Educ Online*, 23(1), p. 1497373. https://doi.org/10.1080/10872981.2018.1497373

Omata, F., McNamara, K. M., Suzuki, K., Abe, E., *et al.* (2018) 'Effect of the normal mammary differentiation regulator ELF5 upon clinical outcomes of triple negative breast cancers patients', *Breast Cancer*, 25(4), pp. 489-496. https://doi.org/10.1007/s12282-018-0842-z

Orsmond, P. and Zvauya, R. (2015) 'Community of learners: charting learning in first year graduate entry medical students during problem-based learning (PBL) study', *Adv Health Sci Educ Theory Pract*, 20(2), pp. 479-97. https://doi.org/10.1007/s10459-014-9542-4

Preeti, B., Ashish, A. and Shriram, G. (2013) 'Problem Based Learning (PBL) - An Effective Approach to Improve Learning Outcomes in Medical Teaching', *J Clin Diagn Res*, 7(12), pp. 2896-7. https://doi.org/10.7860/JCDR/2013/7339.3787

Sun, J., Chen, Y.-J. and Wu, Y.-Z. (2018) 'Application and evaluation of problem-based learning in undergraduate clinical education in 2014-2018', *MedEdPublish*, 7(4), p. 7. https://doi.org/10.15694/mep.2018.0000228.1

Torre, D. M., van der Vleuten, C. and Dolmans, D. (2016) 'Theoretical perspectives and applications of group learning in PBL', *Med Teach*, 38(2), pp. 189-95. https://doi.org/10.3109/0142159X.2015.1009429

**Appendices**

None.

**Declarations**

The author has declared that there are no conflicts of interest.

This has been published under Creative Commons "CC BY 4.0" (https://creativecommons.org/licenses/by-sa/4.0/)

**Ethics Statement**

This study was approved by institutional review board of Nanjing Medical University (No.12063).

**External Funding**

This study was supported by Natural Science Foundation of Jiangsu Province (BK20171050, BK20180676), Natural Science Foundation of the Jiangsu Higher Education Institutions of China (17KJB310006), Innovative Training Program of Jiangsu Undergraduates (201810312053X, 201810312063X).
