Original Article

Integrating a flipped classroom and problem-based learning into ophthalmology education

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Background: Ophthalmology is an important medical science subject, but it is given with insufficient attention in undergraduate medical education. Flipped classroom (FC) and problem-based learning (PBL) are well-known education methods that can be integrated into ophthalmology education to improve students' competence level and promote active learning.

Methods: We used a mixed teaching methodology that integrated a FC and PBL into a 1-week ophthalmology clerkship for 72 fourth-year medical students. The course includes two major sessions: FC session and PBL session, relying on clinical and real-patient cases. Written examinations were set up to assess students' academic performance and questionnaires were designed to evaluate their perceptions.

Results: The post-course examination results were higher than the pre-course results, and many students gained ophthalmic knowledge and learning skills to varying levels. Comparison of pre- and post-course questionnaires indicated that interests in ophthalmology increased and more students expressed desires to be eye doctors. Most students were satisfied with the new method, while some suggested the process should be slower and the communication with their teacher needed to strengthen.

Conclusions: FC and PBL are complementary methodologies. Utilizing the mixed teaching meth of FC and PBL was successful in enhancing academic performance, student satisfactions and promoting active learning.

Keywords: Flipped classroom (FC); integrated; ophthalmology education; problem-based learning (FBL); undergraduate

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Introduction

Ophthalmology is an essential part of medical curriculum system. Gaining medical knowledge of the eyes (e.g., ocular anatomy, red eye, common diseases of vision loss, ophthalmic emergencies, relationships between eyes and systemic diseases) and the skills of basic eye examinations are critical for all medical students and physicians (1). Unfortunately, in China, the quality of ophthalmology education in undergraduates is relatively inadequate, thus students do not acquire sufficient understanding of eye diseases. This lack of knowledge may be attributed to limited class time and lack of financial resources. As ophthalmology is not a subject in post-graduate entrance examinations or medical qualification examinations in the China, many medical colleges do not emphasize ophthalmology education, and students put less efforts

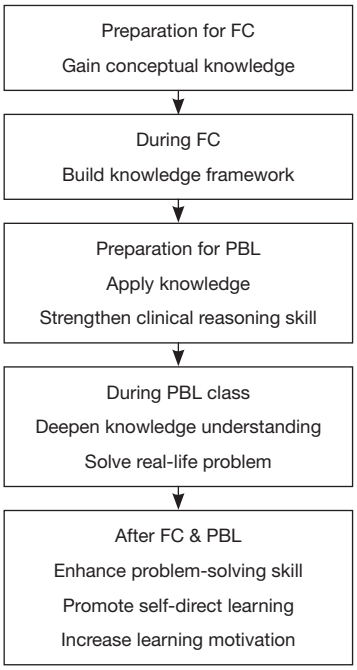

Figure 1 Learning process of and problem-based learning (FC & PBL).

into learning this subject. As a consequence, they are inadequately trained to solve the most basic eye-related problems, and majority of students do not acquire an interest in pursuing a career in ophthalmology. Therefore, a more active, self-directed learning approach needs to be incorporated into the ophthalmology curricula.

Flipped classroom (FC) and problem-based learning (PBL) are well-known active-learning pedagogical strategies. Compared to traditional lecture, FC can promote academic performance, student satisfaction, and active learning (2-5). It is alleged that the FC model can facilitate low-level learning (basic concepts) outside of class and high-level (application of knowledge) learning in-class. Students can develop deeper understanding and higher-order thinking throughout the process. Similarly, PBL is effective in stimulating interests and promoting self-directed learning (6). Implementation of PBL into medical courses can also assist students in developing lifelong habits of independent-learning, clinical reasoning, and collaboration (7-9). The FC contributes to setting up the framework for conceptual knowledge, while PBL is a more interactive methodology that helps to narrow the gap between theory and practice.

We hypothesized that integrating a FC with PBL (FC & PBL), taking advantage of both approaches, would be an effective method to improve undergraduate students' competence in ophthalmology and encourage active learning. The intent of this study was to assess the performance and perception of students by using both approaches in ophthalmology clerkships and evaluating whether their attitudes became more positive towards ophthalmology after the clerkship.

Methods

We used a mixed teaching method of integrating a FC and PBL approaches as the basis for our study.

Subjects and setting

A total of 72 fourth-year undergraduates in the clinical medicine specialty at Sun Yat-sen University were enrolled in our study. Before starting this course, the students completed the traditional ophthalmology theoretical course and passed the final examination. The mixed-teaching-method course was administered in 1-week rotations delivered to approximately 24 students per round. In every rotation, students were divided into two cooperative teams that consisted of several small groups with 4 to 5 students and a teacher. Informed oral consent was obtained from each student, teacher, and patient in this study. The quality of every rotation was equivalent and the teachers were experienced ophthalmologists from Zhongshan Ophthalmic Center. Additionally, approval was received from the Institutional Review Board of the Zhongshan Ophthalmic Center (2017KYPJ025).

Study design

The course relied on clinical and real-patient cases that varied from ocular anatomy to ocular trauma as well as other common diseases of ophthalmology. Course design was guided by a desire to make students better able to meet the following learning objectives: (I) develop interests in ophthalmology and better understand ophthalmology; (II) improve ability to assess common eye diseases and manage ophthalmic emergencies; and (III) cultivate students' learning ability to better prepare for their future roles in clinical work.

There are two major sessions in the course (*Figure 1*):

(I) FC session: students were provided with information, instruction, and websites related to FC and PBL

before the class. Online resources, including recorded lectures, theoretical slides, operational videos and chapter exercises, were provided to assist students' learning. Students could utilize other websites, professional books or the related literature to fill gaps in the provided educational resources. During class, students were asked to be the teacher and they gave lectures on what they had learned. Each group summed up what they had learned and then posed questions. The next group was required to find the answers and solve problems using what they had learned. Group teachers gave feedback on these problems, helped to answer questions, and corrected mistakes. The preparation and implementation of the FC provided students with a theoretical ophthalmology base for the subsequent PBL;

(II) PBL session: students acquired the medical histories of patients with ocular blunt trauma in face-to-face interactions. Related information such as visual acuity, intraocular pressure, and ocular findings were given to students in electronic form before the PBL. Teachers assigned homework consisting of "what auxiliary examinations should be taken", "what is the probable diagnosis" and "select an appropriate treatment" for the provided case. The PBL process consisted of many steps (10). Pre-class, students worked in teams to clarify the patient's situation, explain the possible causes of the signs and symptoms, list the necessary examinations and develop a preliminary diagnosis. In class, representatives of each team presented a slideshow of the group's thoughts and diagnosis. Students from the other teams could raise concerns and put forward their own views. After that, teachers gave information of further examinations. Then students researched and integrated the new information into their diagnosis and treatment plans by synthesizing a comprehensive explanation and discussing the different opinions. Lastly, the teacher would systematically explain the patient's diagnosis and treatment, summarizing the presentations and answering questions.

Students were encouraged to ask questions and make comments throughout the course. The teachers acted as guides facilitating the process. Students were also introduced to the basic skills of ocular examination including vision testing, slit-lamp examination and direct ophthalmoscopy to make them better understand the clinical features of eyes.

Measures of effect

A written examination paper was set up to evaluate students' academic performance. The theoretical examination is the pre-course exam and the written examination after the clerkship is the post-course exam. Both the pre-course and the post-course exams were consistent in format and knowledge range of ophthalmic diseases. The knowledge range contained ocular trauma, keratonosus, glaucoma, cataract and uveitis. The post-course exam contained case-based problems, which further assessed the students' clinical analysis and knowledge application abilities. Post-course scores were compared with pre-course scores to objectively evaluate the teaching effect.

Measures of affect

The pre-course questionnaire contained nine statements and post-course questionnaire contained 30 statements that evaluated students' perception of the course. Each statement of the questionnaire used a 4-point Likert scale, ranging from 1 (strongly disagree) to 4 (strongly agree) (*Figure 2*). The post-course questionnaire repeated the nine statements of pre-course questionnaire and added 21 extra questions to understand the students' experiences in the ophthalmology clerkship. Additionally, students could write down their feelings and suggestions at the end of the survey, and the responses were categorized into groups. Pre-course questionnaires and post-course questionnaires were completed by students at the beginning of the course and at the end of the course, respectively. The difficulties of pre- and post-course questionnaires are similar.

Data analysis

Paired *t*-test was used to analyse pre-course and post-course examination results. After collapsing the responses of the nine identical statements into two categories: agree (indicates "strongly agree" and "agree") and disagree (represents "disagree" and "strongly disagree"), the comparison of pre- and post-course results were analysed using exact McNemar's test. All analyses were output by SPSS for windows version 22.0 (IBM, Armonk, NY, USA). A P value less than 0.05 was considered significant.

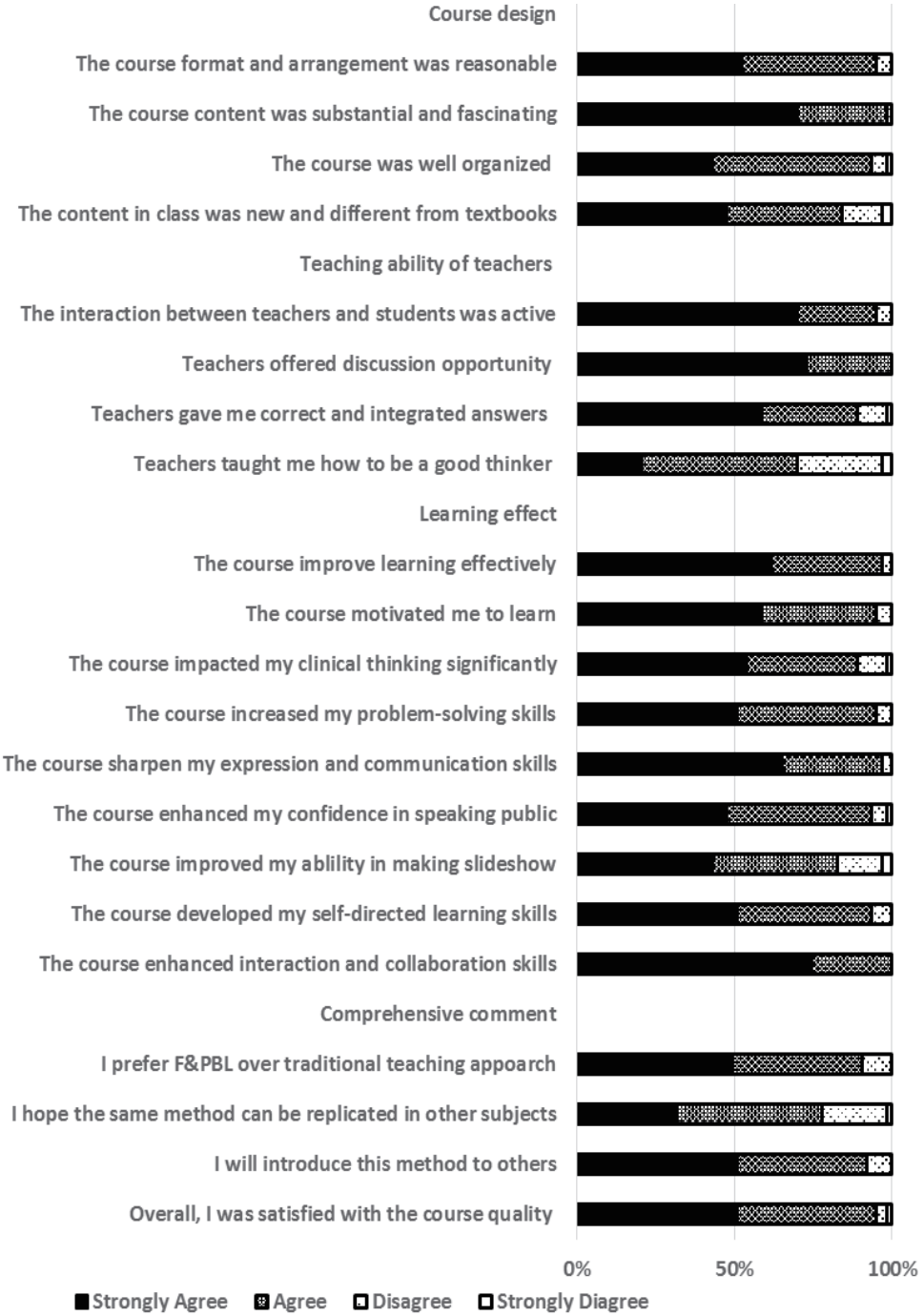

Figure 2 The additional 21 questions of post-course questionnaire.

Results

There were 72 fourth-year medical undergraduates that participated in this study. Sixty-three students (87.5% response rate) completed all the examinations and questionnaires. The reason of loss to follow-up might be that some students failed to hand in the examination papers or questionnaires and some students were absent of the class. The result analysis excluded the loss to follow-up participants.

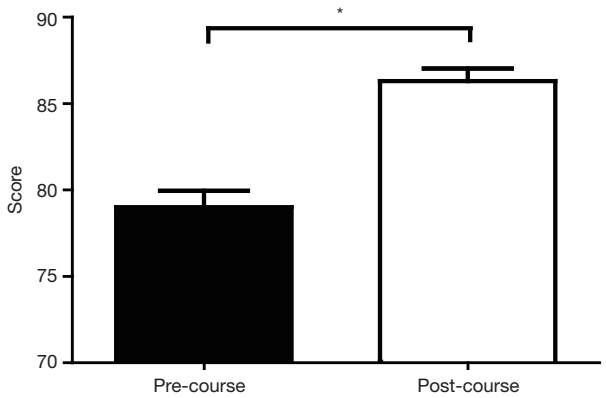

Figure 3 Comparison of pre- and post-course written examination results. *, statistical significance.

Academic performance of pre- and post-course examinations

Examination results of all the students from the theoretical course and the clerkship were collected and analysed. Post-course results (range from 60 to 93.5; mean score 86.3000; standard deviation 5.8146) were significantly higher than pre-course results (range from 72 to 100; mean score 79.0079; standard deviation 7.5169) (mean increase of 7.29; 95% confidence interval, 5.18-9.41; P<0.0001) (*Figure 3*). The gap between high scores and low scores was narrow. Forty-nine students (77.78%) gained ophthalmic knowledge and learned skills to different degrees (10.59±6.20).

Student perception

The statements on the pre-course questionnaire were designed to establish a baseline of the students' attitudes and preferences before class (*Table 1*). The majority of students were willing to participate in FC & PBL and quite optimistic about learning ophthalmology before class. Thirty-nine (61.90%) students agreed and strongly agreed that they had motivation to study ophthalmology throughout their life, but only 5 (7.94%) students wanted to be ophthalmologists. Responses to questions 7 through 9 indicated that a certain number of students felt stressful and reluctant to do the presentations and were afraid that the implementation of FC & PBL would disturb their daily life.

Comparison of pre- and post-course questionnaires indicated remarkable changes in four questions. After class, the interest and motivation to study ophthalmology increased, and 24 (38.10%) students expressed desires to be eye doctors, which is significantly higher than pre-course responses. Additionally, the number of students that felt stressful about the class reduced.

The 21 additional post-course questions were set up to have a deeper insight into the influence of FC & PBL on the learning experience, including course design, the teaching ability of the teachers, the learning effect and comprehensive comments (*Figure 2*). All of the statements received more than 50% positive responses. Most of the students were satisfied with the course design and teachers' teaching abilities.

For the learning effect perception, students strongly agreed or agreed that the course improved learning knowledge effectively (n=61, 96.83%), motivated students to learn (n=60, 95.24%), impacted clinical thinking significantly (n=56, 88.89%) and increased problem-solving skills (n=60, 95.24%). Of the 63 respondents, 57 (90.48%) participants preferred the FC & PBL model over the traditional course format, and 95.24% were satisfied with the quality of the course. All students strongly agreed or agreed that teachers offered opportunities for discussion and the course enhanced interaction and collaboration skills immensely. However, perceptions on "teachers taught me how to be a good thinker" and "I hope the same method can be replicated in other subjects" had relatively less positive responses, but the number of strongly agree and agree still accounted for more than half of respondents.

In the open-ended section for suggestions and feelings, majority of students considered the new method in ophthalmology clerkship fresh and attractive. Students spent a lot more time preparing than in the traditional class, but the rewards were greater. Whereas some students argued that they were incapable of finding satisfying answers. A part of students suggested that the process could be slower so that they could grasp the core concepts more clearly. Another suggestion was that more communication with teachers was needed outside of the classroom.

Discussion

The results of current study show that utilizing FC and PBL increased students' knowledge and produce more positive attitudes towards ophthalmology. We were delighted to see that the number of students that now aspire to be eye doctors markedly increased after the clerkship.

The advantages of FC and PBL have been revealed in this study. The post-course examination contained case-based problems, and the improved results demonstrated the students' comprehension of clinical analysis and knowledge

Table 1 Comparison of pre-course and post-course perception on FC & PBL (n=63)

Statements	Pre-course		Post-course		P value[a]
	Agree	Disagree	Agree	Disagree	
Willing to attend FC & PBL on ophthalmology	58	5	59	4	1.000
Learning ophthalmology can deepen understanding of general medicine	60	3	62	1	0.500
Ablitiy of using direct ophthalmoscope and slit lamp is essential for doctors	56	7	58	5	0.625
Consider ophthalmology interesting and have enthusiasm for learning this subject	40	23	53	10	0.011*
Have motivation to study ophthalmology lifelong	39	24	50	13	0.019*
Want to be an ophthalmologist in the future	5	58	24	39	<0.001*
Feel stressful about the class	53	10	28	35	<0.001*
Unwilling to prepare or give presentations	15	48	11	52	0.388
Implementation of FC & PBL will affect/affected my rest and entertainment	26	37	21	43	0.327

[a], exact McNemar's test; *, statistical significance; FC & PBL, flipped classroom and problem-based learning.

application. Although most students were satisfied with this study, some students were not. Some students did not understand the class well and had low efficiency in their searches for satisfactory answers, which might due to their unfamiliarity with active learning modules. Some of them wished to have communication with teachers. Hence, it is necessary to promote active learning methods in medical education and teachers have to put more effort into interactions with students.

Ophthalmology is a relatively underrepresented medical specialty. As such, little effort has been put into the curriculum by educational institutions and students. Combined with traditional didactic teaching models, students' passion for learning ophthalmology is relatively nonexistent. Both FC and PBL are feasible ways to reverse the declining trend of ophthalmology education (5,8,11,12). In FC, students study independently to gain conceptual knowledge. In-class teaching is based on teacher-student interactions instead of one-way lecturing, which leads to greater student engagement, enhanced motivation to learn, more positive attitudes, and better relationships between teachers and students (13). PBL is another active learning approach. Preparation for PBL is a process of applying knowledge and strengthening clinical reasoning skills. In this manner, students learn about a subject by exploring an unstructured topic. Moreover, it emphasizes the application of theoretical knowledge to solve problems in the real world. Students are allowed to stage a debate during the class, where they have to articulate their thoughts and develop arguments to support their views. Communication, problem-solving, and critical-thinking skills are fostered in the process.

Nevertheless, some educators argue that PBL is not better than traditional teaching methodologies in improving learning outcomes. This may be due to student unfamiliarity with the new module or inadequate understanding of basic concepts (14,15). Adopting a FC to facilitate conceptual framework formation is an optimal solution for this problem. Until now, educators understood that integrating a FC and PBL was a possibility, but few studies document the combination. These two methodologies share an emphasis on higher order thinking skills, and are used in conjunction with one another. That is, they are complementary. Using FC&PBL maximizes class time and allows students to learn individually or through group activities. Without PBL, students put less effort into understanding concepts, and they do not learn how to handle real life problems. Likewise, implementing PBL without FC module will require too much class time for teaching and learning to be able to apply the knowledge. The FC provides a promising framework of knowledge for PBL instruction, which promotes information retention.

Meanwhile, because ophthalmology is a visual science and ophthalmologists make judgements on visual characteristics, we applied clinical cases, real patients, and slit-lamp multimedia systems as subsidiary strategies to improve class quality (16). Besides, we used ocular trauma as the major content of case discussions. Ocular trauma is

an ophthalmic emergency that needs considerable attention. It is a preferable discussion topic due to its complexity and various clinical features. Clinical images of ocular traumas are available to show different signs, so students can see exactly what the clinical features look like. Multimedia systems can assist teachers in demonstrating the dynamic changes from real patients, such as iridodonesis.

There were several limitations in our study. First, the PBL team size was large, thus few students had frequent chances to make statements or communicate with others. Second, because the teaching faculty had to pay attention to everyone's performance, not receiving enough individual attention may have negatively affected some students' attitudes. Third, as the participants were voluntarily taking part in our study, the willingness of active learning might influence the teaching outcome and we cannot evaluate the effect among the less initiative students. Fourth, there was not a control group to compare the effectiveness of the format, due to ethical problems and time constraints. Further studies and investigations are required that include a control group to obtain a better understanding of this methodology. Additionally, it might take a lot of time for students to prepare the class, and further and more extensive studies would find out the practicality of these approaches. Another limitation was that some sections like diabetic retinopathy and age-related macular degeneration were not included in our study, and we will add these sections in the future study.

Conclusions

The study is a preliminary attempt to integrate the FC and PBL approaches in ophthalmology education. This relatively cost-effective methodology provides an engaging and active learning environment where students can gain ophthalmic knowledge, clinical skills, problem-solving abilities, self-directed learning abilities, and motivations. All of these elements contribute to the lifelong professional growth of medical students and can assist in their future careers.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: Approval was received from the Institutional Review Board of the Zhongshan Ophthalmic Center (2017KYPJ025) and written informed consent was obtained from all patients.

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