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Improved PBL Hybrid with LBL is Beneficial to Fundamental Knowledge Acquisition in a Large Class Prior to Medical Internship

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ABSTRACT

Since pre-internship medical students appeared inefficient in acquiring fundamental knowledge in large classes, a hybrid instructional method of problem-and-lecture-based learning (PLBL) was designed to leverage the complementary strengths of PBL in reasoning under minimal guidance and LBL in immediate knowledge retention. We improved PBL (IPBL) in its instructional process and grading in a way that's feasible in large classes, divided in IPBL almost 50 students into 7-10 squads as a figure simulating student counts in classic PBL class to strive for each squad member to achieve the same level of knowledge, and applied IPBL to about half of the instructional contents while LBL to another half for their complementary strengths. In this case, PLBL led to more number of test questions correctly answered by all students in a class, more students in higher test score buckets, and higher student perception scores on the methodology. PLBL facilitates fundamental knowledge acquisition in large classes within 50 students prior to medical internships.

Keywords: PBL, large class, hybrid, internship, LBL

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INTRODUCTION

Due to the shortage of teachers in public medical colleges, lecture-based learning (LBL) has been the conventional approach to fundamental knowledge transferring for pre-internship students, who attempt to form a comprehensive knowledge framework out of large pieces of information based on systematic explanations from teachers. However, LBL, where peer interactions are rare, often leads to a lack of creative and critical thinking exercises for students with limited enthusiasm and initiative (Chotiyarnwong et al., 2021; Zhao et al., 2020). Problem-based learning (PBL) has been used as a discussion-centered educational system (Bandy, 2021) facilitating students' self-learning and independent thinking (Bains et al., 2022; Demikhova, 2016) because instructors no longer occupy the focal point in classes. Although PBL seems to have become a preferred instructional method in medical education (Amoako-Sakyi & Amonoo-Kuofi, 2015), classic PBL is used in small classes of 7-10 students (Dulloo & Pathare, 2013) rather than large classes (Burgess et al., 2020; Ellaway et al., 2015).

PBL in large classes was recently applied to medical interns instead of pre-internship students. Web-based PBL for clinical cases promoted presentation and self-learning capabilities with 18 squads of 8-10 nursing interns each (Ding & Zhang, 2018). Offline patient-playing PBL received positive feedback on information-gathering and communication with 49 squads of 4 medicine interns each (Norose, 2013). In addition, PBL was an add-on component for LBL applied in a large classroom with 45-85 biochemistry undergraduates in Canada and the U.K., improving problem-solving skills and test scores (Klegeris et al., 2013; Klegeris & Hurren, 2011). However, the improved test scores were on short essays of case analyses (Lian & He, 2013) rather than fundamental knowledge in stomatology course (Qin et al., 2010), and the scores on three out of five cases were not significantly different from those in LBL while the other two were slightly better (More et al., 2020). It showed that large class PBL, whether by itself or as an add-on component for LBL, was used only for interns to study clinical cases and had limited outcomes. However, tutors offered LBL to target medical interns who were stuck at learning key issues of clinical cases after PBL and helped them acquire practical knowledge and deepen their understanding of clinical reasoning (Ishizuka et al., 2023). Such evidence pointed towards the potential of a hybrid between PBL and LBL in large classes which needed a refinement for teaching process to transfer fundamental knowledge to students without internship experiences.

PEDAGOGICAL FRAMEWORK

Problem-and-lecture-based learning (PLBL) was designed as a novel instructional method in large classes (Figure 1), combining complementary strengths of PBL in reasoning under minimal guidance (Jiménez-Saiz & Rosace, 2019) and LBL in immediate retention of fundamental knowledge (Solomon, 2021) for students. Student discussion is essential in PBL, and classic PBL requires a small number of 7-10 students to be efficient (Jiménez-Saiz & Rosace, 2019). We thus improved classic PBL (IPBL) in its instructional and grading processes to be more suitable for a large class with almost 50 students. Before class started, students were divided into 7-10 squads to imitate a similar student count of 7-10 in a classic PBL setting, and the squads were assigned to find and figure out key issues on instructional content of two class hours through in-depth squad-discussion without tutors' guidance. During class, to strive for every squad member to obtain the same level of knowledge, a squad and then a member of the squad were randomly chosen to present one issue, followed by other members' supplemental views, based on which a squad-score was determined. Additionally, the teacher-centered lecture is the essential element of LBL, beneficial to fundamental knowledge learning. LBL was thus used in half of the curricular content while IPBL in another half for their complementary strengths. In short, PLBL's strategies focused on squads of size 7-10 to imitate the number of students in classical PBL, the squad-score on random presentation, and the respective application of IPBL and LBL in different halves of the curricular content.

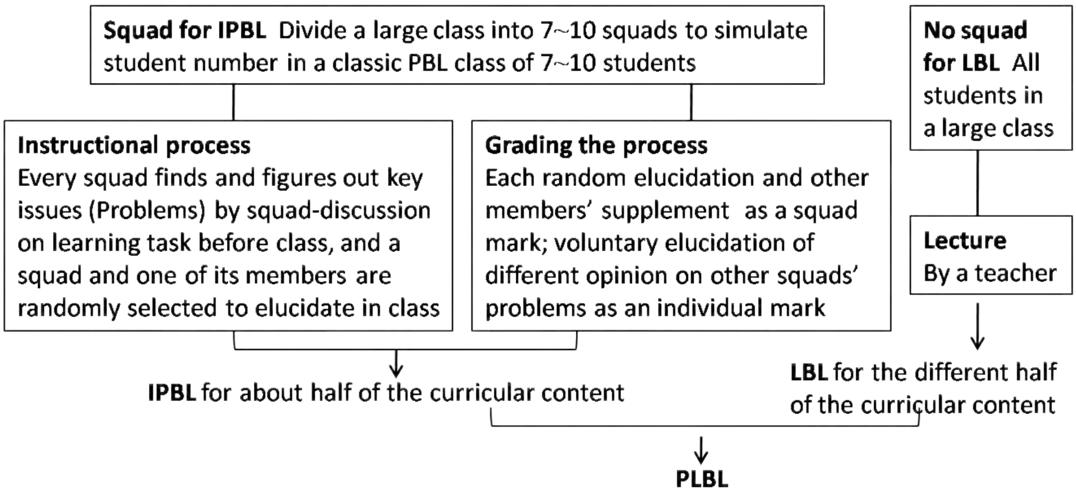

Figure 1. The instructional design of problem-and-lecture-based learning (PLBL).

IMPLEMENTATION

Participants

A total of 189 junior students were enrolled in a mandatory pathophysiology course during the spring semester in 2018 (n=92) and 2019 (n=97) majoring in clinical medicine at the Medical School of Lanzhou University in China, where students do not yet have clinical internships. The students participating in the case were randomly divided into

PLBL (n=46 in 2018, 48 in 2019) and LBL groups (n=46 in 2018, 49 in 2019) in every year. PLBL group was randomly divided into 7 squads (sub-groups) for IPBL teaching to imitate student number of 7-10 in classic PBL.

For ethical considerations, the students were briefed on the case purpose and process without any adverse effect on this course grade because test questions were composed of objective questions. The participants filled in the informed consent form, and the procedure was approved by the Curriculum Development and Ethics Committee School of Basic Medical Sciences at Lanzhou University in China.

Instructional design in PLBL

Pathophysiology, a theory course, was applied to PLBL as a sample for fundamental knowledge learning in the large class in the case.

Distribution of curricular content

The curricular content consisted of ten chapters based on the syllabus of pathophysiology. PLBL groups received IPBL on random four chapters (Fever, Hypoxia, Edema and Hepatic failure) and LBL on the other six chapters (Acid-base imbalance, Shock, Disseminated intravascular coagulation, Respiratory insufficiency, Cardiac insufficiency and Renal insufficiency), while LBL groups received LBL on all ten chapters. Both groups had the same instructor.

IPBL's process and the process grading

As figure 2 shows, before IPBL class for PLBL group, each squad was assigned to look for and figure out 5-6 problems (key knowledge points) by squad-discussion on two class hours of teaching content. 3-4 of the problems were on the studying (upcoming content), 1-2 on the studied (previous content not limited to pathophysiology), and another 1-2 on the unstudied relevant to the studying. Such arrangement aimed to build students' continuous thinking from health to disease and even diagnosis and treatment for disease. Then the squads submitted their problems and answers online to the instructor one day before class to facilitate guidance in class.

In class, the instructor, using playing cards for randomization, selected a squad and one of its members to elaborate on one of the squad's problems followed by other members' supplemental views, and every squad member got the same mark regarding the elaboration and supplement, a system that aimed to facilitate comprehensive discussions among squad members on every problem before class. Afterwards, other squad members elaborated individual opinions of their own accord on this problem to obtain an individual mark, leading to more open discussions. Such procedures repeated until all squads presented their problems or class ended. The squads that were not able to present, if any, would receive a mark by averaging all other squads'. The instructor summed up the key knowledge points by analyzing students' presentations and provided a relevant clinical case for squad-discussion post-class. All squads were assigned to submit a new relevant case with analysis one day before next class.

Similarly in next class, a squad and a member of the squad were randomly chosen to present the cases, followed by the instructor's summary.

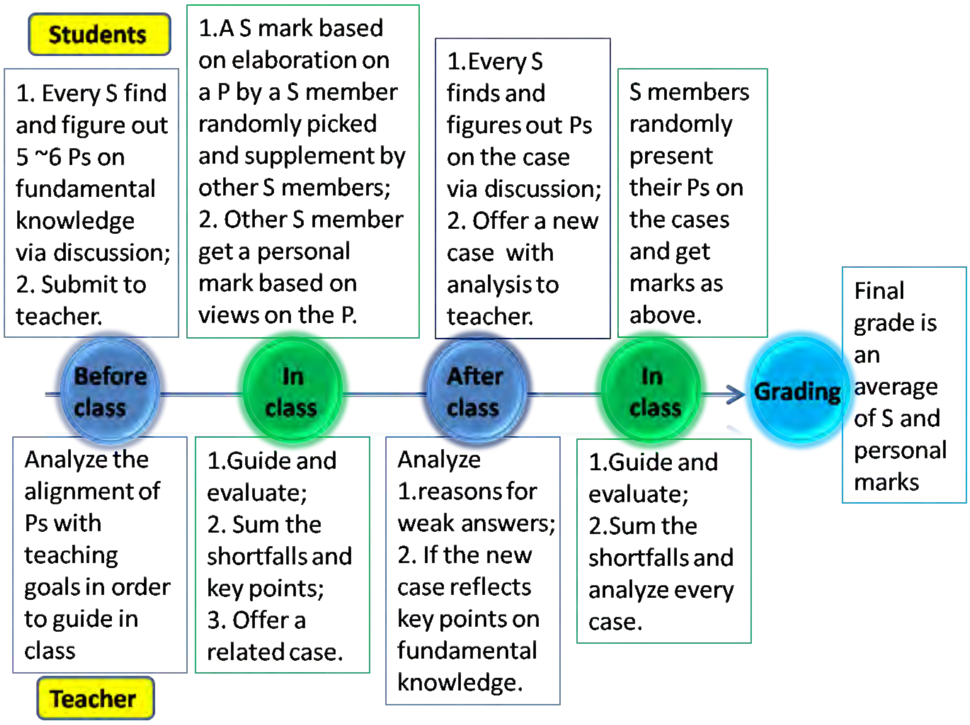

Figure 2. The instructional process and grading of improved problem-based learning (IPBL).
Note. P, problem; S, squad

EVALUATION

Final exam

A written exam was administered in classroom at end of the course simultaneously for the students of PLBL and LBL groups in each academic year. The exam questions consisted of 100 multiple choice questions that were categorized into three difficulty levels according to Bloom's taxonomy of "recall", "understanding", and "application" (More et al., 2020; Singh et al., 2016). There were 40, 36, and 24 questions of respective difficulty level to compare PLBL with LBL. 42 of the 100 questions were from the 4 chapters where IPBL was applied, of which 16, 16, and 10 questions respectively correspond to the three difficulty levels to compare IPBL with LBL.

Questionnaire

A set of questionnaire was designed as 20 statements for the students' feedback on three elements: method of PLBL, engagement in teamwork, and learning skills (Table 4). There were 6 statements on methodology of PLBL that was not carried out in LBL group. As a result, 20 statements were anonymously conducted among PLBL group while 14 statements among LBL group. A perception score on a five-point scale from 1 (strongly disagree) to 5 (strongly agree) was calculated to assess the extent in favor of PLBL over LBL.

Data Analysis

The final exam was assessed by Pearson's χ^2-test for the three difficulty levels. The independent T-test was used for average marks on the final exam and perception scores on the students' feedback. SPSS 19.0 for Windows software (SPSS, Inc., Chicago, IL, USA) was used to conduct statistical analysis of data and the level of significance was set at *p* value less than 0.05 for all the tests.

RESULTS

There were no statistical significance between IPBL and LBL on the final test score

42 questions from the 4 chapters applied IPBL in PLBL group while LBL in LBL group in the final exam. Students' average marks were not significantly different between the two instructional methods of IPBL and LBL (p>0.05, data not provided). Furthermore, the number of questions correctly answered by all students in a class was put into contrast, which also showed that IPBL alone did not perform better than LBL (p>0.05, Table 1). Overall, the data suggested that IPBL's application in a large class was not more efficient in fundamental knowledge learning than LBL for the students prior to medical internships.

Module	Number of students	Recall (16 questions)	Understanding (16 questions)	Application (10 questions)	Overall (42 questions)
2018 IPBL	46	14	9	2	25
LBL	46	12	8	1	21
2019 IPBL	48	13	10	3	24
LBL	49	13	9	2	24
$p(\chi^2)$ 2018	92	0.365(0.821)	0.723(0.126)	0.531(0.392)	0.381(0.769)
2019	97	1.000(0.000)	0.719(0.130)	0.606(0.267)	1.000(0.000)

Table 1. IPBL-LBL comparison of the number of questions correctly answered by all students in a class in final exam.

Note. Data from the 4 chapters undergoing IPBL teaching in group PLBL while LBL teaching in group LBL.

PLBL performed better than LBL on the final test score

However, PLBL, a hybrid of IPBL and LBL, exhibited different outcomes from LBL in the final exam (Table 2 and 3). In spite of indifference on average marks (p>0.05, data not provided), PLBL group fared better in "understanding" components (p=0.033) in the year of 2019, and better in overall performance than LBL group in the two years of 2018 and 2019 (p=0.026, 0.047), because of more questions correctly answered by a maximum number of students (Table 2). Furthermore, more students in PLBL group (p=0.002) obtained A score (high, 80~100 marks) and fewer students (p=0.001) in B (low, 60~79 marks) than LBL group, while comparable (p=0.298) in C (no pass, 0~59 marks) (Table 3). Such evidence suggested that PLBL, by combining IPBL and LBL, worked better than LBL in a large class to transfer fundamental knowledge to students prior to medical internships.

Group	Number of students	Recall (40 questions)	Understanding (36 questions)	Application (24 questions)	Overall (100 questions)
2018 PLBL	46	27	18	6	51
LBL	46	22	11	3	37
2019 PLBL	48	28	20	5	54
LBL	49	26	11	3	40
$p(\chi^2)$2018	92	0.251(1.317)	0.093(2.829)	0.267(1.231)	**0.026**(4.944)
2019	97	0.166(1.920)	**0.033**(4.589)	0.439(0.600)	**0.047**(3.934)

Table 2. PLBL-LBL comparison of the number of questions correctly answered by all students in a class in final exam.
Note. Data from the 10 chapters undergoing hybrid teaching of IPBL and LBL in group PLBL while only LBL teaching in group LBL. Bold type: there are statistical differences.

Exam score bucket	PLBL(n=94)	LBL (n=95)	p (χ^2)
A. High (≥80)	21(22%)	6(6%)	**0.002**(9.909)
B. Low (60~79)	56(60%)	77(81%)	**0.001**(10.450)
C. No pass (≤ 59)	17(18%)	12(13%)	0.298(1.082)

Table 3. PLBL-LBL comparison of the number of students getting score buckets in final exam.
Note. Full mark was 100. Data from the 10 chapters undergoing hybrid teaching of IPBL and LBL in group PLBL while only LBL teaching in group LBL. Bold type: there are statistical differences.

There was a considerable acceptance from students of PLBL on methodology as well as ability training

From analyzing feedback from 94 students of PLBL group and 95 students of LBL group in the two years (Table 4), the sum of perception scores was higher in PLBL than LBL (p=0.031) according to the 14 statements that both groups went through. Furthermore, there were significant differences in the survey between PLBL and LBL on fundamental knowledge learning (p=0.035), engagement in teamwork (p=0.032), problem-finding (p=0.041), problem-solving (p=0.039), learning motivation (p=0.037), presentation (p=0.049), and information management (p=0.036). Especially, PLBL's method obtained top perception scores in "IPBL in large classes" (4.44±0.83), "IPBL hybrid with LBL" (4.51±0.74), and "fundamental knowledge learning" (4.47±0.77) with 3, 3 and, 2 statements respectively, coming only after problem-finding (4.82±1.05). It suggested a definite and considerable acceptance by the students prior to internship for PLBL's methodology on fundamental knowledge learning in large classes under the instructional strategies as well as ability training on learning and teamwork skills.

Classification of statements		Statements	Perception score (*Mean*±*SD*)		
			PLBL(*n*=94)	LBL(*n*=95)	*p*(t)
Method of PLBL	IPBL in large classes	1.IPBL's squad numbers were efficient. 2.IPBL's instructional process and grading were efficient. 3.IPBL was appropriate for large classes.	4.44±0.83	-	-
	IPBL hybrid with LBL	1.Necessary to blend LBL and IPBL. 2.PLBL preserved advantages of LBL and PBL. 3.Efficient to assign different half of contents to IPBL and LBL.	4.51±0.74	-	-
	Fundamental knowledge acquisition	1.Help the knowledge understood. 2.Help the knowledge vivid.	4.47±0.77	3.80±0.84	**0.035** (2.095)
Engagement in teamwork		1.Improved peer interaction 2.Increase engagement in teamwork	4.03±0.86	2.37±0.66	**0.032** (2.107)
Learning skills	Problem-finding	1.Easier to focus on the key problems. 2.Helpful to identify problems.	4.82±1.05	3.44±0.70	**0.041** (2.084)
	Problem-solving	1.Improve skill to solve problems. 2.Easier to find a way to problems.	4.38±1.01	2.41±0.82	**0.039** (2.088)
	Learning motivation	1.Improved learning motivation. 2.Promoted interest in learning.	4.03±0.72	3.39±0.94	**0.037** (2.092)
	Presentation	1.Allowed me to present better. 2.More willing to express.	3.01±0.66	2.28±0.43	**0.049** (2.043)
	Information management	1.Improved the ability to collect and sort learning materials. 2.The materials I searched were more relevant.	3.80±0.87	2.41±0.49	**0.036** (2.096)
Sum for 14 statements (5×7=35)			29.13±4.27	20.33±3.91	**0.031** (2.110)

Table 4. Classification of statements and comparison of perception scores on PLBL and LBL.
Note. Bold type: there are statistical differences.

REFLECTIONS

PBL has predominantly been focusing on patient cases, a strategy to enhance skills and competencies necessary to bring science into professional contexts (Stentoft, 2019).

Although the benefits of PBL are well-known, there are aspects open to improvement such as “How does PBL work in different specific contexts?” (Hung et al., 2019).

To achieve a small-class outcome of classic PBL in large classes, two strategies were used to realize the same gain of knowledge for every squad member in IPBL class besides squad count imitating student count of classic PBL. One was to randomly pick a squad and its member to elucidate one of the squad’s problems found and contemplated by squad-discussion before class. The other was to have all members of a squad get the same mark (squad-score) for a problem according to the elucidation and subsequent supplemental views of other squad members. These measures encouraged every squad member to actively engage in and study on every problem during squad discussions, making IPBL feasible in the context of large classes. Such feasibility and effectiveness were demonstrated by students’ feedback on “IPBL in large classes” with a high perception score (Table 4).

Whether a stand-alone or add-on to LBL, PBL predominantly occupied the center stage in clinical cases for medical interns who could more easily understand theoretical implications of fundamental knowledge due to their internship experiences (Stentoft, 2019; Yan et al., 2017). In our case, IPBL was implemented for students without internship experiences to learn fundamental knowledge, which was not demonstrated to be more favorable in terms of test scores in final exam than LBL (Table 1). However, IPBL combined with LBL, namely PLBL, displayed better learning outcomes for fundamental knowledge on “understanding” in year 2019 and “overall performance” in years 2019 and 2020 (Table 2), and more students got scores at the high bucket (Table 3) than LBL. The outcomes of PLBL were also identified by the feedback on “fundamental knowledge learning” with a higher perception score than LBL (Table 4), indicating that PLBL was efficient in transferring fundamental knowledge to students without internship experiences.

Also, the advantages of PLBL over IPBL or LBL suggested the complementarity of IPBL and LBL. Likewise, a recent study reported that students unfamiliar with clinical practice had preferred LBL because of its remarkable effect on immediate knowledge retention over PBL (Solomon, 2021). A systematic review supported an eclectic system in which the pedagogical tools from LBL and PBL were used cooperatively in the best interest of education and satisfaction of students (Jiménez-Saiz& Rosace, 2019). However, PBL was an add-on component to LBL applied together to all instructional contents in the eclectic system (Ishizuka et al., 2023; Klegeris et al., 2013; Klegeris & Hurren, 2011; Lian & He, 2013; More et al., 2020; Qin et al., 2010). In the case, PLBL leveraged the complementary strengths of IPBL in independent reasoning and LBL in immediate knowledge retention by applying each of them to half a curriculum, resulting in superior outcomes on fundamental knowledge learning as well as students’ acceptance with a high perception score on "IPBL hybrid with LBL" (Table 4). Additionally, PLBL was unsurprisingly more helpful in ability training of "learning skills" and "engagement in teamwork" than LBL according to the feedback (Table 4).

In summary, IPBL effectively simulated classic PBL's outcomes because of its strategies on squad count, random presentation, and grading system. PLBL's hybrid strategy achieved a synergy of IPBL and LBL each applied to distinct instructional contents. Hereby, PLBL was suitable and effective for students without internship experiences to learn fundamental knowledge in a large class within 50 students.

The precondition in classic PBL to have a low student count of 7-10 for instructional effectiveness inspired the strategy in PLBL to form 7-10 squads among students in a large class. Assigning squad-scores according to random presentations facilitated comprehensive discussions among squad members to realize learning outcome for one whole squad in a way similar to one sole person. Analogizing one squad as one "student", a large classroom can have at most 10 "students". Theoretically, the appropriate sample size is up to 100 students in a large classroom, though further research is needed for settings with more than 50 students.

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