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A comparison between the effectiveness of PBL and LBL on improving problem-solving abilities of medical students using questioning

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ABSTRACT

In daily patient-history taking and diagnosis practice, doctors ask questions to gather information from patients and narrow down diagnostic hypotheses. Training medical students to be efficient problem solvers through the use of questioning is therefore important. In this study, the effectiveness of problem-based learning (PBL) and lecture-based learning in improving the questioning abilities of medical students (N = 104) was assessed by a modified 20-question task. In this task, the participants were asked to identify target pictures by asking questions, the problem-solving process of which resembles that of the diagnosis scenario. Moreover, this task requires no medical knowledge, and therefore allows knowledge-irrelevant questioning abilities to be assessed independently. The results show that PBL students generally ask more efficient questions and use fewer questions to complete the task. This finding suggests that PBL curricula may help improve the questioning strategies of medical students and help them diagnose more efficiently in future diagnosis practice.

KEYWORDS

PBL; problem solving; questioning; 20 questions; Medical Education

Introduction

In everyday clinical practice, doctors ask patients questions about their symptoms and conditions in a standard patient history-taking process. By asking questions, doctors collect patient information firsthand. Along with a physical examination, this allows the physician to decide on the diagnosis, its severity and which further tests and examinations to make. The information-inquiry process usually takes the form of a series of sequential questions from the doctor to the patient. Through these questions, doctors learn about the medical history of the patient, get a full picture of symptoms and conditions, narrow down possible diagnostic hypotheses and select a proper plan for further tests and treatments. Therefore, question design and questioning skills are critical for effective communication between

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doctors and patients (Jenkins et al., 2015; M van Es, Wieringa de Waard, & Visser, 2013). The more efficient and informative the questions raised are, the more efficiently doctors arrive at a correct and timely diagnosis. In short, training medical students to be efficient problem solvers by use of directed questions in the patient history-taking process is an important task (Geddes, 1999; Rendón-Macías & Lazcano-Loya, 1995).

The educational methodology of problem-based learning (PBL) seems relevant in improving the problem-solving ability of medical students (Albanese & Mitchell, 1993; Barrows, 1996; Hmelo-Silver, 2004; Neufeld & Barrows, 1974; Taylor & Miflin, 2008; Jiménez-Mejías et al., 2015). In PBL classes, students are given real-world clinical problems to solve, and they need to collect and learn all relevant knowledge in order to do so. It has been suggested that during the problem-solving process, medical students not only acquire new clinical knowledge, but also develop their problem-solving abilities (Jonassen, 2011; Neville, 2009). This hypothesis has been evidenced by many previous studies (Choi, Lindquist, & Song, 2014; Ding et al., 2014; Karantzas et al., 2013; Klegeris, Bahniwal, & Hurren, 2013; Klegeris & Hurren, 2011; Pedersen & Liu, 2002). For example, Ding et al. (2014) performed a meta-analysis on 15 studies in preventive medicine in which the effectiveness of PBL on problem solving was examined using medical examinations and questionnaires, and concluded that compared to traditional lecture-based learning (LBL), PBL was more effective in improving the problem-solving abilities of medical students. Nonetheless, no significant difference between these two educational methods in the improvement of the problem-solving abilities of medical students was also reported (Colliver, 2000; Colliver & Markwell, 2007). Most of the above-mentioned studies generally use perceptions, self-ratings, clinical problems or medical examinations to evaluate problem-solving abilities. The problem situations of these studies were quite different from those encountered in the doctor-questioning-patient scenario. It is therefore of interest to test whether PBL can improve the problem-solving abilities of medical students through the use of questioning, which is critical for patient history-taking in daily diagnosis practice.

As a pilot study, the effects of PBL and LBL on the problem-solving ability of medical students by the strategic use of questions were examined and compared by a problem-solving task modified from a classic 20-questions (20Q) task. In this task, medical students were presented with pictures of common objects and were required to ask questions to target the one picture selected by the experimenter (Mosher & Hornsby, 1966; Ruggeri & Lombrozo, 2015; Siegler, 1977). To identify the target picture, participants needed to analyse the characteristics of common objects, classify, differentiate and design hierarchical questions to narrow down the possible choices. In this way, the questioning process in a 20Q task is analogous to that in the doctor-questioning-patient scenario. Moreover, since the solving of modified 20Q tasks requires no medical knowledge other than familiarity with the characteristics of common objects, it allows questioning skills to be assessed alone without the interference of prior medical knowledge, an issue seen in other studies (Moore, Block, Style, & Mitchell, 1994; Norman & Schmidt, 1992). Thus, this task allows the comparison of the problem-solving abilities of medical students from different educational backgrounds or with different amounts of knowledge storage.

Participants

A total of 104 participants were approached from Chinese Medical University (CMU), which has used PBL in medical education since 2004 (Du, Emmersen, Toft, & Sun, 2013; Du, Liu, Toft,

& Sun, 2010). Since the participants were admitted into CMU according to the same scholastic standards and the assignment of them to study under either the PBL or LBL was totally raondom, it was reasonable to assume that both groups of students had the same problem-solving abilities at the beginning. When this test was conducted, these students had been trained under the PBL or LBL curricula for six years.

All PBL and LBL students were majoring in clinical medicine. For the PBL group, a fourth of the total curriculum, including most of the medical curriculum, was delivered through PBL mode, such as pharmacology, pathophysiology, pathology and etc. The chosen clinical problems are quite typical of those encountered in practice and involve common knowledge found in the curriculum (Du et al., 2010; Qiao, Sun, & Yu, 2009). The PBL methodology is implemented as follows: the clinical case is first issued to students, and several clinical problems are posted. Then the students discuss the case and further define the problems. After class, the students collect relevant knowledge and try to analyse and answer the question by themselves. During the last session, students present their own solutions, discuss all possible answers and draw a final conclusion. The whole curriculum lasts for about eight weeks, and two sessions are delivered each week. During the whole process, teachers serve only as guides.

Before participation, all medical students signed informed consent forms. The study was approved by the Ethics Committee of the Institute of Psychology, Chinese Academy of Sciences.

Figure 1. The picture board used in the modified version of the 20Q task.

Table 1. Summarised information of medical students trained in PBL and conventional LBL curricula.

	LBL group	PBL group	*sig*
Total number	52	52	
Age (years)			
Mean	23.7	23.9	$t = -1.78, p > .05$
SD	.6	.6	
Gender	M 21 (40.5%) F 31 (59.5%)	M 19 (52.2%) F 33 (47.8%)	$\chi^2 = .69, p > .05$

Materials and procedure

The problem-solving task was designed based on the classic 20Q Test (Mosher & Hornsby, 1966), which was originally developed to investigate the questioning abilities of children, and recently has been modified to test the problem-solving abilities of various groups of people (Marschark & Everhart, 1999; Marshall, Karow, Morelli, Iden, & Dixon, 2003; Marshall, McGurk, Karow, & Kairy, 2007) In this work, the complexity and difficulty of the task is increased by including 64 coloured pictures of common objects on the picture board in order to match the problem-solving ability of adults, as shown in Figure 1.

In the task, the experimenter first randomly selected one picture from the 64-picture board and then asked the participants to target the selected picture by asking questions. Every student participated in one test; no time limit was set in order to ensure that every participant was able to reach the target picture. The target pictures were chosen randomly by the experimenter, and in total, there was no noticeable difference in terms of the frequency of the chosen pictures for the PBL and LBL groups ($\chi^2 = .46$, $p > .05$).

The participants were tested one by one to avoid any possible interference with each other. Also, to avoid any possible influences created by the experimenter's presence and behaviour, the experimenter and the participant were in neighbouring rooms and communicated exclusively through non-verbal online texting.

Scoring

Three measures were used to examine the questions asked by participants, as in previous studies (Marschark & Everhart, 1999; Marshall et al., 2003, 2007; Siegler, 1977): mean number of questions, type of questions and efficiency of individual questions. The evaluation of questions was blind in regard to the student type.

Mean number of questions for the PBL and LBL groups were obtained by summing and averaging all questions asked by participants from the PBL and LBL groups, respectively.

Type of questions provides the quantitative measure on the different types of questions used by participants to identify the target picture. There were three types of questions: constraint-seeking (CS), pseudo-constraint (PS) and hypothesis-scanning (HS) questions (Siegler, 1977). CS questions are more efficient than HS and PS questions in eliminating pictures and in solving modified 20Q tasks.

Mean proportion of CS questions was obtained by dividing the total number of CS questions by the total number of questions asked by participants.

Efficiency of individual question provides the measure of informativeness for individual questions and how the informativeness changes over the questioning process. The efficiency of a question was calculated by dividing the number of targeted or eliminated pictures (the smaller number) by the number of pictures under consideration. Mean efficiencies of

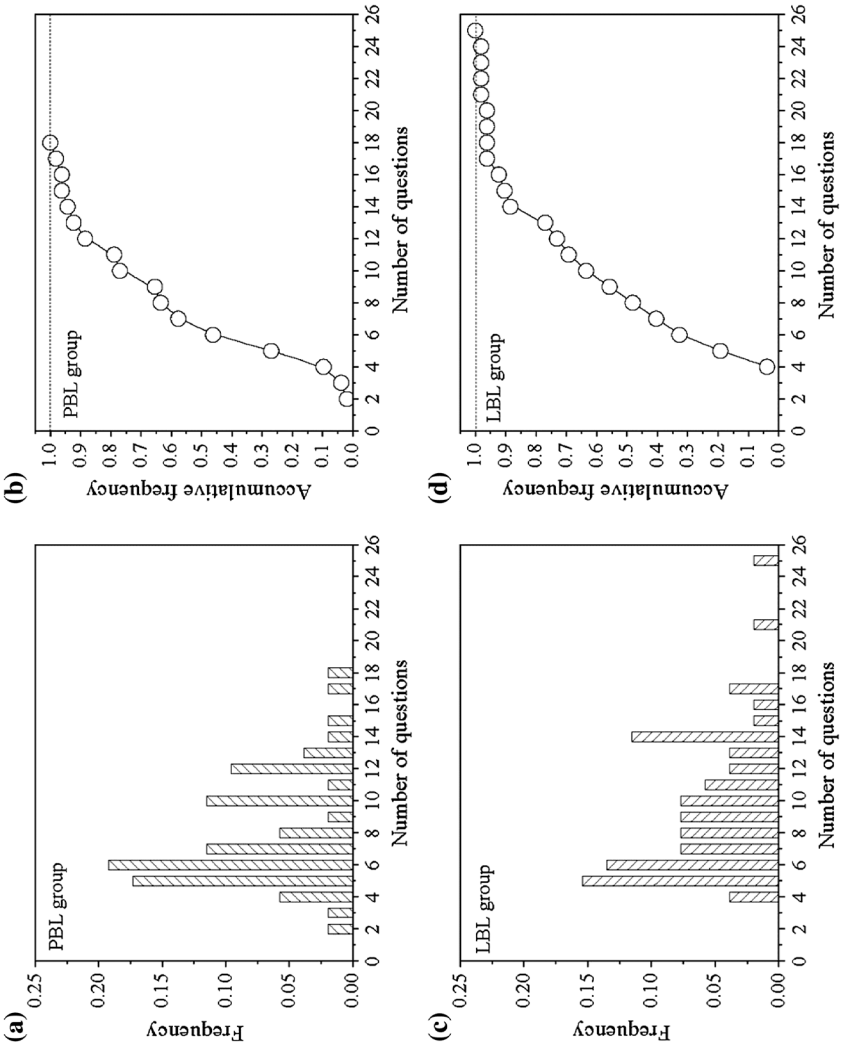

Figure 2. The distribution of frequency (a) and accumulative frequency (b) of the total number of questions asked by PBL students; the distribution of frequency (c) and accumulative frequency (d) of the number of questions asked by LBL students.

Table 2. Mean number of questions, mean proportion of CS questions, mean proportion of HS and PS questions asked by medical students from the PBL and LBL groups.

	LBL group	PBL group	*sig*
Mean number of questions			
Mean	9.69	8.04	$t = -.25, p < .05$
SD	4.57	3.61	
Proportion of CS questions			
Mean	.72	.72	$t = .22, p > .05$
SD	.13	.13	
Proportion of HS and PS questions			
Mean	.28	.28	$t = .31, p > .05$
SD	.03	.04	

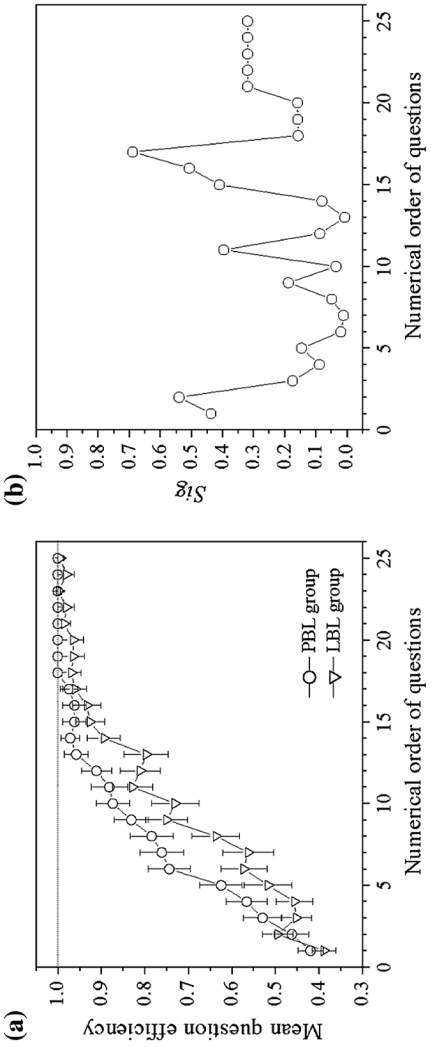

Figure 3. (a) Mean efficiency of individual questions in increasing numerical order asked by PBL and LBL students. (b) *t*-test analysis of mean efficiency of individual questions shown in (a).
Notes: With *sig* value below .05, the difference between mean question efficiencies of PBL and LBL groups becomes statistically significant. Note that PBL and LBL groups only show significantly different mean question efficiencies in the middle part of the questioning process.

individual questions were obtained by summing and averaging the efficiency of individual questions asked by all participants with the same numerical order. For solving the task, the most efficient questions are those that could reduce the remaining pictures in 50% increments, i.e. from 64 to 32, 16, 8, 4 and 2.

Results

Demographic information of participants

There were 104 participants: 52 educated in PBL curricula for six years and 52 in LBL curricula for six years (Table 1). The LBL group (age: 23.7 ± .6 years old; 21 males) and PBL group (age:

23.9 ± .6 years old; 19 males) showed no significant difference in terms of age ($t = -1.78$, $p > .05$) and gender ($\chi^2 = .69$, $p > .05$).

Frequency distribution of number of questions asked by participants

For the PBL group, the participants asked a total number of 418 questions (Figure 2). They all finished their tasks within 18 questions, with the quickest using only 2 questions (Figure 2(a)). Of the PBL group, 63% of the students finished the task within 8 questions (Figure 2(b)). In comparison, participants from the LBL group asked a total of 504 questions and generally used more questions to finish the task, spanning from 4 to 25 questions in total. Only 48% of the LBL students finished their 20Q task within 8 questions – much smaller than the percentage of PBL students finishing the task within 8 questions. On average, PBL students used 8.0 (SD = 3.6) questions to finish the task, as opposed to 9.7 (SD = 4.6) used by their LBL peers ($t = -.25$, $p < .05$) (Table 2).

Type of CS questions

Table 2 shows that out of all the questions asked, 72% were CS questions and 28% were HS and PS questions for both the PBL and LBL group. There was no difference in terms of types of questions for the PBL and LBL groups ($t = .22$, $p > .05$).

Mean efficiencies of individual questions

For both the PBL and LBL groups, mean efficiencies of individual questions generally increased as the question numbers increased, moving from around .4 for the first question to nearly 1 for the last few questions (Figure 3(a)). However, mean efficiencies of individual questions increased more quickly for the PBL group than for the LBL group, leading to generally higher mean efficiencies of almost all individual questions by the PBL group. A *t*-test analysis (Figure 3(b)) shows that the group difference in mean efficiencies of individual questions becomes significant from question 6 ($p = .019$) and remained significant for questions 7, 8, 10 and 13 ($p = .011$, .048, .035, and .006), mostly during the middle period of the question-asking process.

Discussion

The present study shows that PBL students performed better in problem-solving by use of questions compared to their LBL peers, as evaluated by a modified 20Q task. Students from the PBL group generally asked more efficient CS questions and finished the modified 20Q task using fewer questions. The results indicate that PBL was more effective than LBL in improving the problem-solving abilities of medical students, which is consistent with the results of previous studies (Choi et al.,2014; Ding et al., 2014; Karantzas et al., 2013; Klegeris et al., 2013; Klegeris & Hurren, 2011; Pedersen & Liu, 2002), although different problem-based situations were involved in these studies. For example, by using a real-world clinical problem, Klegeris et al. (2013) assessed the impact of PBL on the problem-solving abilities of biomedical students and found that their problem-solving abilities were significantly improved by PBL.

In order to solve the modified 20Q task effectively, it is essential to identify the common characteristics shared by pictures and use them to ask sequential questions to eliminate pictures. The best questions are those that refer to the characteristics in the pictures that could divide the remaining pictures into subsets with approximately equal numbers of pictures. The differences in mean efficiency of individual questions for the PBL and LBL groups (Figure 3) thus reflect the abilities of participants to find the optimal characteristics. At the start of the questioning process, the optimal characteristics of the pictures, such as food, animals and tools, were easily found by all participants, which led to no group difference in efficiencies of individual questions (Figure 3). At the end of the questioning process, the number of pictures had been greatly reduced and only a few pictures remained, which also made it easy for participants to identify the optimal characteristics. However, during the middle of the picture-targeting process, two factors could come into play simultaneously. Compared to the beginning of the questioning process, the number of pictures under consideration had been reduced, making it easier for the participants to identify category-classifying characteristics, as evidenced by increasing efficiencies of individual questions for both PBL and LBL groups (Figure 3(a)). However, the participants were required to expend more effort to identify the more subtle category-classifying characteristics since the obvious, easily found characteristics had already been found at the beginning. At this stage, the ability to analyse the remaining pictures, compare different characteristics, think systematically and design hierarchical questions began to come into play (Legare, Mills, Souza, Plummer, & Yasskin, 2013; Marschark & Everhart, 1999). The significant difference in efficiencies of individual questions for PBL and LBL groups at this stage (Figure 3(b)) suggests that the skills needed to solve problems may be improved by PBL education.

In PBL classes at CMU, medical students are presented with real-world clinical problems. To solve these problems, students generally undertake a self-directed learning cycle (Hmelo-Silver, 2004; Othman, Salleh, & Sulaiman, 2014; Chua, Tan, & Liu, 2016). They need to analyse and define the problem, propose hypotheses about possible solutions, identify the knowledge deficiencies related to the clinical problem, acquire new knowledge, understand the newly gained knowledge and then apply it in order to solve the problem. In this process of PBL learning, several questions were repeatedly asked and answered by the participants themselves: what knowledge was needed; in light of the knowledge already gained, could the hypothesis or clinical problem be solved; and what other knowledge was still needed for the solution? During this problem-solving process, the skills of collecting information, analysing, classifying and reasoning were used, which may have resulted in the improvement of these abilities, enabling PBL students to perform better in the middle stage of the modified 20Q task relative to LBL students.

In the above results, we show that PBL students performed better on the modified 20Q task and possessed more efficient questioning strategies than their LBL peers. However, this does not necessarily mean that PBL students would perform better and diagnose more efficiently in daily diagnosis practice. Correct and timely diagnosis requires not only efficient questioning strategies, but also demands that doctors possess extensive medical knowledge and experience. In the modified 20Q task, the medical knowledge and experience of the students did not contribute to their performance. Strictly speaking, only knowledge-irrelevant problem-solving abilities concerning the use of questions to solve problems were evaluated in this study. Therefore, it would be useful for future studies to examine whether the process of diagnosis by the use of questions in the patient history-taking situation is improved

by PBL, as well as how much the improved questioning strategy reported in this study contributes to the diagnosis process.

Conclusion

In this study, using a modified 20Q task, we evaluated the effectiveness of PBL in improving the problem-solving abilities of medical students by the strategic use of questions. The results show that students trained in PBL generally asked more efficient questions and used fewer questions to finish the tasks relative to their peers trained in LBL curricula for six years. This finding suggests that PBL curricula might help refine the questioning strategies of medical students. It should be noted that the modified 20Q task only evaluates knowledge-irrelevant questioning abilities. It would be useful for future studies to address to what extent PBL's improvement of questioning ability contributes to the doctor-questioning-patient and diagnosis practices, in which previous medical knowledge and experiences are involved.

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