Status of Problem-Based Learning Research in Pharmacy Education: A Call for Future Research

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Problem-based learning has been increasingly used in pharmacy education. Problem-based learning serves to enhance such skills as problem-solving, critical thinking, clinical reasoning and self-directed learning. The present review draws on previous research into PBL in medical education, and elucidates the applications and outcomes of PBL as applied to pharmacy education. Thus, this article serves to: review the current status of PBL research in pharmacy education, identify trends and student outcomes from the pharmacy courses that have used PBL; present a brief review of PBL research in medical education; and recommend future directions for PBL research in pharmacy education.

Recently, the American College of Clinical Pharmacy (ACCP) White Paper(1) made several predictions and recommendations regarding pharmacy's future. These predictions place a greater emphasis on the patient and patient care. The ACCP also indicated that there is a discrepancy between pharmacy education and the actual environment in which the pharmacist will eventually practice. The report suggests that pharmacy educators need to place more emphasis on preparing students for problem solving, critical thinking, ethics, communication and self-directed learning(1). Therefore, today's pharmacists must be prepared to be self-directed, motivated learners who are able to work effectively with patients to improve their quality of life through the use of such complex processes as problem solving, critical thinking, life-long learning, and clinical reasoning.

In 1993, the Commission to Implement Change in Pharmacy Education(2) also urged schools and colleges of pharmacy to adopt pharmaceutical care as the mission of pharmacy education. The Commission recommended that schools needed to undergo major curricular reform to include an educational process that encourages more student-centered learning; producing an independent, self-directed, individual.

Schools and colleges of pharmacy have responded to these changes in the field of pharmacy by implementing numerous changes to pharmacy curricula. One curricular innovation that has been adopted by many schools/colleges is problem-based learning (PBL). The purpose of this paper is to review the current status of PBL research in pharmacy education, to identify trends from the pharmacy courses that have used PBL, to briefly report on the PBL research in medical education, to present Barrow's taxonomy of PBL and to recommend new directions for further PBL research in pharmacy education based on a synthesis of this research.

OVERVIEW OF PBL

PBL has been incorporated into pharmacy education in an effort to prepare future pharmacists to meet the challenging demands of the pharmacy profession, in particular, the provision of quality patient care. The roots of PBL can be traced back to John Dewey(3). Dewey, an early educational philosopher, recommended that students should be presented with real

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life problems and then helped to discover the information required to solve them. Further, Dewey encouraged reflection as a process that should be used when problem solving. Dewey recognized that we can "reflect" on a whole host of things in the sense of merely "thinking about" them, however, logical or analytical reflection can take place only when there is a real problem to be solved. Both learning by doing and reflection are hallmarks of the PBL process.

McMaster University recognized that Dewey's axiom held true for medical education, therefore, it created a curriculum that applied the PBL approach to teach medical students. In PBL, students are first presented with the patient's presenting problem. Next, the learners engage in such clinical reasoning processes as hypothesis generation, data gathering, data analysis and decision making, while synthesizing basic science and clinical information in an effort to offer some potential diagnoses and courses of treatment for the patient's problem. PBL also incorporates the use of an expert tutor or facilitator who serves to guide the problem-solving process.

PBL stands in stark contrast to a more traditional approach to learning and instruction. PBL provides learner-centered, small group, interactive learning experiences, instead of large-group, didactic, teacher-centered instruction. Professors facilitate or tutor, rather than lecture. Curricula are packaged in problems that trigger interdisciplinary learning opportunities as opposed to curricula contained in discipline-based texts and presentations. PBL students are free to pursue both collectively decided and individually determined learning issues in contrast to students in more traditional curricula who might focus on identifying what material the professor will include on an examination. Finally, the assessments in PBL typically include performance-based and self-reflective assessments, while traditional approaches to instruction often emphasize multiple choice, objective tests(4,5).

In line with the very processes that PBL demands, PBL also serves to develop the processes of the activation and elaboration of prior knowledge, the restructuring of knowledge, learning in context and epistemic curiosity(6). Further, Evensen and Hmelo(7) suggested that in comparison to students enrolled in a more traditional curriculum, PBL students might be more highly motivated, better problem-solvers, more able to integrate basic science into clinical problems and more self-directed learners.

REVIEW OF PBL RESEARCH IN PHARMACY EDUCATION

An online search of *International Pharmaceutical Abstracts* (*IPA*) was used to identify PBL research articles in pharmacy education from 1980 through 2000. It was believed that IPA would yield the most information related to PBL in pharmacy education. The phrase "problem-based learning" was used to identify pertinent articles related to PBL. The authors believed that if other keyword phrases had been utilized, the focus of the review would have been changed.

Abstracts identified in this search were not included in the final selection due to the lack of detailed information. Also, articles not directly related to PBL research in the pharmacy professional curriculum were eliminated. The remaining articles were organized into the following areas: (*i*) examples of PBL implementation in pharmacy courses; (*ii*) the effects of PBL on academic achievement; and (*iii*) the effects of PBL on knowledge, critical thinking, problem-solving and clinical reasoning.

Examples of PBL Implementation

A perusal of the pharmacy education literature revealed that there were a substantial number of articles that discussed the implementation of PBL methods into the curriculum, along with the necessary measures that were taken to implement this complex method. For example, in 1983, Love and Shumway(8) described a Patient-Oriented Problem-Solving Instruction (POPS) module they developed to teach pharmacy students problem solving skills. They used this module in student-led small group discussions that focused on study questions and clinical cases. In small groups, each student was assigned a clinical case with questions and the student was required to teach the material to the other student members of his/her group. The instructor facilitated the group by guiding the students to appropriate references and redirecting their inquiry if they were deviating from the goal.

The authors used the modules with BS and PharmD students during their clerkships. Students reported favorable comments about the module and encouraged the faculty to create more modules. The method appeared to improve problem-solving skills and the module was found to have content and construct validity. Jang and Solad(9) later referred to this instructional method as the first reported application of PBL in pharmacy.

Winslade(10) described the revision of a course from a traditional therapeutics course to one that was based on the principles of pharmaceutical care and PBL. During the first class, students received detailed information about the PBL curriculum and the responsibilities of the students were emphasized. The next several classes focused on the development of the therapeutics. Once the process had been developed, the first case-based problem was assigned. The author alluded to some challenges of the implementation of PBL, which included student evaluation and faculty training.

Woods *et al.*(11) described experiences with both tutored and tutorless student groups. The authors, who represented the fields of Engineering, Geography and Pharmacy, had experience with tutorless student groups using the PBL method. They observed various difficulties in the tutorless group setting that related to the actual group processes and student interaction. Input was sought from experienced tutors in Health Sciences at McMaster University regarding process issues arising within tutored groups. An electronic bulletin board was used to gather this information.

Distinct differences were noted between tutored and tutorless groups in the "within group" issues. For example, while student attendance was identified as an issue for tutorless groups, it was not identified as such with tutored groups. The authors pointed out that while the tutor must possess the skills to deal with issues in the tutored groups, it is the student who must do likewise in the tutorless group. They concluded that proper training is essential for both students and facilitators(11).

Culbertson, Kale and Jarvi(12) implemented a PBL curriculum at Idaho State University. In the first year of their curriculum, the basic science courses were taught using a didactic method. In years two and three of the curriculum, the PBL method was used. The curriculum used a clinical problem-solving model that was based on the nine stages as outlined by Barrows and Tamblyn(13). Tutorial sessions consisting of 5-6 students were presented with the patient's major complaint. Students worked together to interview the patient, exchange knowledge and obtain data. Throughout the process, students identified relevant learning issues, identified appropriate learning resources, self-directed their learning and completed a pharmaceutical care plan. Culbertson *et al.*(12) concluded that there were some challenges encountered in implementing the PBL curriculum. These challenges included the substantial involvement of faculty time, problems related to working in a group, and variability among facilitators.

Recently, some pharmacy courses have added a computer and/or electronic communication component to PBL. The following studies by LeBlanc and Aiache(14), Catney and Currie(15), and Rhodes(16) illustrate these uses. Leblanc and Aiache(14) employed a student-centered PBL approach to pharmacokinetics through the use of workshops and computer-assisted simulation software. They divided 100 students into groups of 25 and a tutor was assigned to each group. The students participated in 12 workshops in which they had to solve problems and discuss pharmacokinetic concepts for two hours. Tutors served as facilitators and provided more information to stimulate the group discussion. The majority of the students (72 percent) expressed satisfaction with this approach and preferred it to the traditional lecture method. The authors also concluded that student motivation was higher and student participation was good. However, they believed that many of the students were not computer literate and this caused some limitations.

Catney and Currie(15) reorganized a large, introductory pharmaceutical care course to incorporate elements of PBL. In addition, they used WebCT to facilitate communication between the students and the instructor. WebCT features that were utilized included a bulletin board, email, course pages, student management, a self-test tool and online chat. Since WebCT was new to the students at this school, it was included only as an option for students in this class. Even with this limitation, the authors reported that the WebCT site was accessed by 107 of the 110 students in the class approximately 3,500 times during the semester. The authors felt that WebCT was a tool that enhanced and provided significant support for the PBL process.

Rhodes(16) utilized electronic communications in a PBL setting. The use of email played a significant role in a chemistry course for pharmacy students. The class was divided into two groups, one group used a PBL approach in which communication with the instructor occurred via electronic mail and the other group utilized a PBL approach where the students met with an instructor or teaching assistant. The authors completed this evaluation for three PBL exercises over two class years. The use of email was found to be advantageous and produced no significant disadvantages.

Effects of PBL on Academic Achievement

In addition to research articles that have primarily described the implementation and challenges of PBL, other research articles have begun to assess the effects of PBL on pharmacy students' academic performance and achievement. For example, Raisch, Holdsworth, Mann, and Kabat(17) highlighted the need for problem-based, student-centered learning in pharmacy externship rotations. Thus, a problem-based, student-centered learning program was developed which emphasized the use of preceptors who served as the primary facilitators. Two hospital pharmacy cases and two community pharmacy cases were used in the study. The control group performed the externship with no modifications. The experimental group participated in eight student-centered PBL sessions as part of their externship rotations. The experimental group achieved significantly higher scores on all three parts of the final exam. The authors, however, noted several study limitations including such factors as the small number of students, the relatively short duration of the study, the lack of random selection of the preceptors, and the low reliability of the final exam. The authors concluded that since the study was conducted over a short period of time, a longitudinal assessment would be helpful to identify long-term differences.

Nii and Chin(18) compared the effects of PBL to traditional lectures on clerkship performance. The students all had similar coursework and didactic lectures for the first two years of the curriculum. The students were then randomly assigned to either a PBL or a traditional didactic lecture condition. While the mean grade point average (GPA) of students for the first two years of pharmacy school was not statistically different between the two groups, there was a significant difference in GPA for the PBL group and the didactic lecture group in their clerkships. Thus, students who received PBL in their third year had a significantly higher GPA in the fourth-year clerkship rotations(18). The authors concluded that there is a need to conduct high-quality evaluative research on PBL. They further asserted that this is difficult due to the multifaceted nature of PBL.

Sibbald(19) used a PBL approach in pharmaceutical care courses. Each PBL group was required to collaboratively prepare and teach one case to the rest of the class. Results of a pretest that was given at the beginning of the course demonstrated that first-year students scored an average of 28 percent, second-year students scored an average of 26 percent, and third-year students scored an average of 26 percent on the pretest. Results of a posttest that was administered after students participated in the PBL curriculum demonstrated that first-year students scored an average of 70 percent, second-year students scored an average of 91 percent, and third-year students scored an average of 76 percent on the posttest.

Mehvar(20) reported on the development and evaluation of a teaching strategy that combined some aspects of traditional instruction with PBL in the context of basic and clinical pharmacokinetics courses. Computer-assisted instruction was also used. At the end of the semester an evaluation containing both quantitative and qualitative items was administered to the students. The evaluation indicated that the majority of students strongly agreed that the PBL approach was appropriate for learning basic and clinical pharmacokinetics. While there were no significant differences among the performance of students before the implementation of the new strategy, students' grades after the implementation of the combined traditional and PBL strategy were significantly higher than those of previous years in which a traditional lecture format had been used.

Effects of PBL on Knowledge, Critical Thinking, Problem-Solving, and Clinical Reasoning

The previous research studies sought to investigate the effects of PBL on academic achievement, as measured by posttest scores, final examination scores, grades and GPA. Other research has been conducted into the effects of PBL on such cognitive outcomes as knowledge acquisition, critical thinking, problem solving, and clinical reasoning. Some of these studies are outlined below.

Haworth *et al.* utilized a PBL approach in a pharmaceutics course at the University of Southern California School of

Pharmacy(21). Student comments suggested that from their perspective, the pharmaceutics course left the student with a broad knowledge base that s/he was able to access long after the course was over. They also state that the course simulated the collaborative nature of the "real world," team-oriented, work environment and encouraged critical thinking. While information regarding the students' perspective of participating in a PBL approach to pharmaceutics was obtained, Haworth *et al*.(21) posit that they were unable to provide quantitative information to support that the PBL approach does meet it's long-term objectives due to the relatively short-term nature of the study.

Abate, Meyer-Stout, Stamatakis, Gannett, Dunsworth and Nardi(22) developed and evaluated computerized PBL cases. Previously, at this school non-computerized PBL had been used but it was believed that this required an excessive time commitment by the faculty. Therefore the authors had several goals for this project including: (*i*) develop computerized PBL cases; (*ii*) evaluate the effectiveness of the computerized PBL cases; and (*iii*) "develop, refine, incorporate and evaluate concept maps as tools to enhance problem-solving and learning when used in conjunction with computerized PBL exercises." Two versions of the cases were developed, one version that incorporated concept maps, and one version without concept maps. The experimental group completed the computerized PBL cases and participated in facilitator-led sessions in small groups. The control group received only facilitator-led sessions in small groups. The students in the experimental group indicated that the most important skills they acquired from the PBL were problem-solving skills, resource skills, and communication skills.

In 1995, the College of Pharmacy at The University of Arizona began to implement a major curriculum change(23). Student-centered, problem-based case discussion courses were added during the first three semesters to enhance learning in pharmacology and medicinal chemistry. A test was given both before and after each course to evaluate students' knowledge, problem identification skills, and problem solving abilities. Results demonstrated that post-test scores showed significant improvement over pretest scores. There was also a significant improvement in students' scores on a pharmacology examination. Finally, results of a student attitude survey demonstrated that 75 percent of the students expressed confidence in their self-learning skills, 75 percent expressed that the cases helped them to improve their problem-solving skills and 66 percent felt that the cases helped them to improve their clinical reasoning skills. The authors asserted that since there was no control group, there is always the chance that the class of 1999 could have just been better students compared to previous classes.

The University of North Carolina School of Pharmacy developed a student-centered, case-based, integrated sequence of courses(24). The goals of these courses were to develop critical analysis, problem solving, decision-making, communication skills, ability and motivation to be an active learner, and a commitment to life-long learning. Surveys from preceptors indicate overall improvements in student's abilities to solve problems and to interact with patients. However, while the grade distributions over the last four years were reported, the authors stated that since "no baseline data was collected from prior courses, no direct comparisons of achievement of specific learning objectives or retention of learning has been possible." Thus, the authors concluded that there is a need for additional research into the effectiveness of PBL in improving student learning and knowledge retention, and motivating students to become more self-regulated learners(24).

In an effort to redesign a second year endocrine pharmacology course, Lubawy and Brandt(25) developed a method utilizing "microsituations" as course problems. Microsituations are essentially mini cases in which the student applies basic science in the context of clinical practice. As each topic was addressed in class, the students were presented with a related microsituation. Students were first expected to work on the microsituation individually, then before class, they met as a group to finalize their plans. In class, one group was randomly selected to present the case to the class. After implementing microsituation teaching, the authors noted an increase in students' preparation, active learning, problem-solving skills, motivation and performance on a cumulative final examination.

Since the body of literature about PBL in pharmacy is a small subset of the larger body of literature about PBL, the next section of the paper presents a summary of reviews about PBL research in medical education. Both of these sections were then used to make recommendations for further research in pharmacy.

REVIEW OF RESEARCH IN MEDICAL EDUCATION

In 1993, two different comprehensive literature reviews on PBL in medical education were completed by Albanese and Mitchell(26) and Vernon and Blake(27). The findings from these reviews are summarized in the next paragraphs. Readers are referred to the reviews for a more complete description of this research.

Albanese and Mitchell(26) completed a meta-analysis of literature from 1972 to 1992 on problem-based learning in medical education. The purpose of this review was to address questions "pertinent to any institution considering PBL as part of curricular [revision]". Since Albanese and Mitchell(26) were concerned about curricular change they surveyed faculty to determine their concerns regarding PBL in their programs. The interviews led to five research questions, which served as the context for the meta-analytical literature review. These research questions were:

1. "What does PBL cost compared with conventional lecture-based instruction?
2. Do PBL students develop the cognitive scaffolding necessary to assimilate new basic sciences information?
3. To what extent are PBL students exposed to an adequate range of content?
4. Do PBL students become overly dependent on a small-group environment?
5. Do faculty dislike PBL because of the concentrated time commitment required?"

The results of the meta-analysis by Albanese and Mitchell(26) revealed that "compared with [traditional] instruction, PBL is more nurturing and enjoyable; PBL graduates perform well, and sometimes better on clinical examinations and faculty evaluations; and they are more likely to enter family medicine." They further learned that "PBL students in a few instances scored lower on basic sciences examinations and viewed themselves as less well prepared in the basic sciences than were their conventionally trained counterparts. PBL graduates tended to engage in backward reasoning rather than the forward reasoning experts engage in, and there appeared to be gaps in their cognitive knowledge base that could affect practice outcomes. The costs of PBL may slow its implementation in schools with class sizes larger than 100." Finally, the authors recommend that "caution be exercised in making comprehensive, curriculum-wide conversions to PBL until more is learned about: (*i*) extent to which faculty should direct students throughout medical training; (*ii*) PBL methods that are less costly; (*iii*) cognitive-processing weaknesses shown by PBL students; and (*iv*) the apparent high resource utilization by PBL graduates".

In another meta-analytical review by Vernon and Blake(27), the evaluative PBL research literature in medical education was examined from 1970 through 1992. The purpose of this analysis was to answer the question: Does problem-based learning work? They examined studies that compared PBL with more traditional methods of medical education. Their results revealed that "PBL was found to be significantly superior with respect to students' program evaluations (*i.e.*, students' attitudes and opinion about their program)." The results were also significantly superior with respect to "measures of students' clinical performance. PBL and traditional methods did not differ on miscellaneous tests of factual knowledge and tests of clinical knowledge." However, students from traditional programs performed significantly better on the National Board of Medical Examination Part 1 that those from PBL programs.

The next comprehensive review since 1993, was completed by Colliver in 2000(28). In this review he examined the literature on the effectiveness of problem-based learning since these last two reviews. Colliver(28) has argued that PBL has yet to live up to the claims of its supporters. Two major problems he found dealt with: (*i*) the magnitude of differences (effect sizes) between PBL and traditional student groups reported in major PBL meta-analyses(27,28); and (*ii*) educational theory and related research supporting PBL.

Effect sizes are generally categorized as: small (0.2), medium (0.5) and large (0.8). Colliver(28) believed that the effect sizes reported in the meta-analyses should have been large (0.8 to 1.00 or higher), based on previous research done by Bloom(29) on the effects of individualized tutoring. The effect sizes reported in the meta-analyses however were usually small-to-medium and many were negative, indicative of PBL being outperformed by traditional methods. He felt that this finding revealed the lack of clear proof of the superiority of PBL over traditional methods. Further, Colliver(28) believed that the theory supporting PBL effectiveness, and its associated research, were connected by ties, which were "loose at best." He also felt that much of the research that has been done does not provide evidence that would warrant such a major change as converting a curriculum to PBL.

Albanese(30) and Norman and Schmidt(31) responded to Colliver's critique. Albanese(30) argued that large effect sizes would probably not be seen and indeed may be unrealistic to expect, given the magnitude of change that would be required. He felt that a ceiling effect might also be a limiting factor and that even small effect sizes would be equivalent to "moving a mountain." He also posed the question as to whether it would be reasonable to expect a traditional student group, trained for many years in a traditional curriculum, to suddenly perform poorly when traditional methods are used and compared to PBL methods? Albanese(30) also presented a review of several education theories that he felt did support the proposed benefits of PBL, including: information processing theories research into self-determination theory, control theory and cooperative learning.

Norman and Schmidt(31) focused on Colliver's(28) criticism of PBL research and theory. They agreed that the ties between research and theory are loose, but not because of the inappropriateness of theory. They argued that "the problem lies with the programme evaluators, not the theoreticians." Further, they suggested that more theory-based research in PBL is needed. These authors argued that curriculum-level interventions have little chance of having success shown by usual research methods focusing on typical outcomes. The absence of true-blinded interventions, pure outcomes, and uniform interventions will minimize any differences. Norman and Schmidt(31) believe that PBL is composed of multiple components that interact. Hence, any evaluation method that does not capture all of these synergistic components along with their interactions may minimize differences.

Norman and Schmidt(31) recommended that research be conducted that includes theory-based research, highly controlled, experimental conditions, as well as evaluations done in the real world setting with efforts being made to capture all variables possible, rather than "randomize them away."

TAXONOMY OF PBL

As noted in these reviews from the pharmacy and medical education literatures, there are many variations of PBL. Various taxonomies(32,33) have been developed to classify the different dimensions of PBL based on the taxonomy originally proposed by Barrows(34).

In his taxonomy, Barrows included the following forms: lecture-based cases, case-based lectures, the case-method, the modified case-method, PBL, and closed loop or reiterative PBL(34). Barrows argued, "The term problem-based learning must be considered a genus for which there are many species and subspecies." The aforementioned PBL methods are listed in the order of the degree to which they accomplish the following four educational objectives:

1. the structuring of knowledge for use in clinical contexts (SCC),
2. the development of an effective clinical reasoning process (CRP),
3. the development of effective self-directed learning skills (SDL), and increased motivation for learning (MOT).

The two PBL methods listed above that accomplish these four educational objectives to the greatest degree are PBL, and closed loop or reiterative PBL(34). Table I gives more details about this taxonomy and provides Barrow's explanation about how the method does or does not achieve these educational objectives.

Finally, Barrow's(34) noted that the "wide variety of educational methods that are referred to as problem-based learning methods can address quite different educational objectives." He asserted that "all descriptions and evaluations of any PBL method must be analyzed in terms of the type of problem used, the teaching-learning sequences, the responsibility given to students for learning and the student assessment methods used. Any teacher who wishes to employ PBL should decide on the desired educational objectives [as noted above] and then select the method that fits best."

A CALL FOR FURTHER EMPIRICAL RESEARCH

Noted PBL researchers Norman and Schmidt(31) have

Table I. Taxonomy of problem-based learning[a]

Educational method	Description of method	Barrow's comments	Barrow's rating of meeting the educational objectives[b]			
			SCC	CRP	SDL	MOT
Lecture-based cases	Information is presented as lectures first and then cases are used to emphasize significant points.	"Some hypothesis generation, data analysis and limited decision-making May be required. No inquiry or case-building skills needed."	1	1	0	1
Case-based lectures	Cases are presented first for study prior to class lecture, then the lecture covers relevant material.	"This effort should cause some clinically oriented structuring of the subsequent information provided in lecture, as opposed to possible restructuring of information already provided, as may occur in the lecture-demonstration method above. There is no self-directed learning, unless through curiosity the student looks up some resources to understand the cases better."	2	2	0	2
Case Method	A complete case is given to the student for study prior to class discussion, which is facilitated by a tutor. This method combines both student-directed and teacher-directed learning.	"This is a stronger challenge to hypothesis generation, data analysis and decision-making with more active structuring of information in a clinical context. It is a more motivating method. However, the case material is already organized and synthesized for students, thus limiting the amount of reasoning which will occur."	3	3	3	4
Modified case based	This format features sequential management problems. Students receive some of the information and are asked to decide on the forms of action and decision they may make. Following their conclusion, they are given more information about the case.	Some self-directed learning is addressed. However, the "clinical reasoning process and self-directed learning are not fully addressed because the students are not required actively to apply the results of learning as, for instance, reasoning through the problem again."	4	3	3	5
Problem-based	Students are presented with the patient problem and allowed free inquiry in tutor-led groups.	Activation of prior knowledge, self-directed learning and clinical reasoning processes utilized. "Nevertheless, structuring of knowledge for use in clinical contexts (SCC), clinical reasoning processes (CRP) and self-directed learning (SDL) should not be given full credit as the new information learned is usually not actively applied to a revaluation of the problem."	4	4	4	5
Closed loop or reiterative	An extension of the problem based method above. However, after initial problem solving, the students are asked to reflect on the information and processes they used and return to the original problem for re-evaluation of their problem solving activities.	"These steps further address CRP, SCC and SDL as students have to go beyond the acquisition and discussion of new knowledge in a way that allows them to see its value and to evaluate actively their knowledge and problem solving skills."	5	5	5	5

[a] Barrows, H.S., "A Taxonomy of PBL Methods," *Med. Educ.,* **20,** 481-486, Nov. 1986.
[b] Barrows' score 1 to 5 represents the likelihood (1=least and 5=most) that this educational method will likely meet the educational objectives. SCC= structured clinical context; CRP = clinical reasoning process; SLD = self-directed learning; MOT = motivation for learning.

described the need for more theory-based research and issued an important caveat. The authors pointed out that PBL is not a single intervention but rather is itself composed of numerous variables, with the possibility of important interactions taking place among these variables. Regarding future PBL research, Norman and Schmidt(31) believe that "the field will advance only by a systematic research program which encompasses all aspects from theory building and testing conducted with rigorous experimental designs in highly controlled and artificial settings to program evaluations in realistic settings with a deliberate attempt to capture all possible variables and interactions rather than randomize them away."

Much of the pharmacy research into PBL is descriptive in nature. In other words, the focus is on the description of the steps in the implementation of PBL methods into pharmacy education. This research has also outlined the positive effects of PBL on such student outcomes as: posttest performance, final examination performance, grades, and GPA. These are important contributions. Many researchers, however, have highlighted the need for additional research into the effects of PBL. For example, Fischer(35) pointed out the need for quality research in this area and noted that PBL evaluation in pharmacy education was lacking. Raisch, Holdsworth, Mann and Kabat(17) suggested that since their study was conducted over a short period of time, as is often the case with research into PBL, that a longitudinal assessment would be helpful to identify the long-term effects of PBL. Similarly, Haworth *et al.*,(21) agreed that more long-term evaluation of PBL is needed to substantiate its effectiveness. Hence, there is a need for more longitudinal or at least longer-term investigations into the effects of PBL on student outcomes.

Nii and Chin(18) have asserted the need for high-quality evaluative research into PBL. They further pointed out the difficulty of this research due to the complex, multidimensional nature of PBL. Herrier, Jackson, and Consroe(23) reported that since there was no control group used in their study, there was always the possibility that their student sample could have just been better students, thus questioning the validity of their findings of superior test performance. It is suggested here that there is a need for additional empirical research into the effects of PBL using a control group. Until this approach is used, it will be difficult to ascertain the true effects of PBL on student outcomes.

Ives, Deloach, and Ishaq(24) suggested that there is a need for future research into the effectiveness of PBL in improving student learning and retention and motivating students to become self-regulated learners. This need was echoed by Duncan-Hewitt(36) who asserted that future research must be designed to determine the degree to which process-based education improves students' ability to use problem solving and self-assessment processes, and whether such a process focus improves educational outcomes in the long term.

We agree with these researchers and initiate a call for further qualitative, quantitative, and mixed-methodological research into the effects of PBL on such student outcomes as academic achievement, performance on state board examinations, problem-solving, critical thinking, clinical reasoning, motivation, and self-regulated learning. A combination of methodologies and multiple assessment tools may provide the important "multiple lenses" called for by Henderson and Hawthorne(37) in curriculum assessment.

Further, we highlight the need for additional research into PBL in pharmacy education. Some suggested avenues for this research include: an emphasis on more rigorous research methodologies; research into different pharmacy schools, programs, and approaches to PBL; research conducted over a longer duration, and even into the effects of PBL on future pharmaceutical practice; more emphasis on group and facilitator effects, and research into the development, implementation and validation of PBL assessments.

Specifically, we recommend that additional research be conducted into the effects of PBL in pharmacy education using combination of both quantitative and qualitative research methodologies to more fully understand the complex processes involved in PBL as well as the effects of PBL on its students. Further, rigorous research designs should be used which adhere to Campbell and Stanley's recommendations(38).

Research should be conducted into different PBL programs at different pharmacy schools and universities in an effort to more fully understand the processes involved in planning and implementing a PBL program, as well as the variables that contribute to its successes and challenges. Along these lines, there is a need for further research into the effects of different types of PBL programs on different types of learners. In other words, what types of students might be best served by a traditional, a PBL, or a hybrid model of pharmacy education?

Third, much research is needed into the effects of the group dynamics in a PBL setting on learning and achievement. More insight is needed into the factors that may be used in assigning/forming groups as well as into techniques that can be used to help the group to function effectively. More information is needed into the characteristics of effective facilitators as well as effective methods to train these facilitators. An understanding is also needed of the characteristics of both effective and ineffective tutorial groups so that appropriate measures may be taken to enhance the process.

Fourth, there is a need for more long term and even longitudinal assessments of the effects of participating in PBL in pharmacy education. Often, research is conducted into PBL for a length of time that is determined by the experimenter's time and resources, not necessarily the amount of time necessary to provide a thorough investigation into the effects of PBL on student learning. Thus, we propose a call for more long-term assessments into the effects of PBL on student learning. There is a need for research that follows the PBL student into the profession to fully understand the effects of PBL on actual practice.

Finally, we believe that there is a lack of valid and reliable measures that assess the effects of PBL, particularly in pharmacy education. There is a need for measures that effectively assess group process variables, and that assess students' perceptions of the learning process. There is also a need for more effective, authentic assessments to evaluate student academic performance in the PBL setting. It is suggested that one place to start might be a meta-analysis of the existing research into the effects of PBL in pharmacy education on student outcomes.

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