Impact of problem-based learning in a large classroom setting: student perception and problem-solving skills

Andis Klegeris¹ and Heather Hurren²

¹Department of Biology and ²Centre for Teaching and Learning, University of British Columbia Okanagan, Kelowna, British Columbia, Canada

Submitted 19 May 2011; accepted in final form 20 July 2011

Klegeris A, Hurren H. Impact of problem-based learning in a large classroom setting: student perception and problem-solving skills. Adv Physiol Educ 35: 408–415, 2011; doi:10.1152/advan.00046.2011.—Problem-based learning (PBL) can be described as a learning environment where the problem drives the learning. This technique usually involves learning in small groups, which are supervised by tutors. It is becoming evident that PBL in a small-group setting has a robust positive effect on student learning and skills, including better problem-solving skills and an increase in overall motivation. However, very little research has been done on the educational benefits of PBL in a large classroom setting. Here, we describe a PBL approach (using tutorless groups) that was introduced as a supplement to standard didactic lectures in University of British Columbia Okanagan undergraduate biochemistry classes consisting of 45–85 students. PBL was chosen as an effective method to assist students in learning biochemical and physiological processes. By monitoring student attendance and using informal and formal surveys, we demonstrated that PBL has a significant positive impact on student motivation to attend and participate in the course work. Student responses indicated that PBL is superior to traditional lecture format with regard to the understanding of course content and retention of information. We also demonstrated that student problem-solving skills are significantly improved, but additional controlled studies are needed to determine how much PBL exercises contribute to this improvement. These preliminary data indicated several positive outcomes of using PBL in a large classroom setting, although further studies aimed at assessing student learning are needed to further justify implementation of this technique in courses delivered to large undergraduate classes.

undergraduate courses; surveys; pharmacology; interactive classroom; tutorless groups

CURRENT AREAS OF EMPHASIS regarding student learning in higher education include student engagement, critical thinking, self-directed learning, authentic learning, team skill development, problem-solving skills, and interdisciplinary studies. Problem-based learning (PBL) addresses all of these, as students acquire problem-solving skills while critically analyzing contextualized (authentic) problems posed to them in a collaborative (group) setting. The problem serves as a stimulus for students to identify what they need to learn to understand or solve the problem (29). The PBL approach has been described as an effective learning strategy that can encourage students to become self-directed learners and to develop transferable skills, such as critical-thinking skills, problem-solving skills, and teamwork skills (7, 18, 23). PBL has been implemented in many universities worldwide since its beginnings at McMaster University in Canada in the 1960s. Originally, medical schools were the practice grounds for this type of teaching and learning, but now the PBL methodology has spread to a variety of different content areas, including teaching physiology, and is practiced in many universities and colleges around the globe.

The methodology and application of PBL are not uniform. Some institutions implement single or multiple interventions of PBL within the traditional curriculum framework [e.g., University of British Columbia (UBC) Okanagan and San Diego State University], whereas others have chosen whole curriculum transformation (e.g., McMaster University and Harvard Medical School). Despite this diversity, there is general agreement that the primary defining feature of PBL is the contextualization of learning in a problem presented to students without any preparatory study in the subject matter (27). The fact that a problem is introduced first (as the stimulus for learning) rather than after the presentation of facts and concepts (as an illustration of practical application of knowledge gained) is a distinctive feature of the method. In all cases, the student is an active initiator and participant in the learning process rather than a passive receiver of information.

Typically, students initially analyze a problem as a group (e.g., a patient case history) and identify and integrate the collective background knowledge the group has pertaining to the problem. The groupbrainstorms possible solutions/hypotheses based on the available knowledge and information and then decides what further information is needed to solve the problem and to test the hypotheses. These ideas and suggestions are subsequently refined into learning issues. Independent study follows, as each group member is motivated to find the desired information. The group reconvenes to share gathered information, discuss the problem further, receive additional information, and test previous hypotheses in light of the new information obtained. This process has been described as the seven classical steps of PBL: 1) understand the situation/clarify terminology, 2) identify the problem, 3) suggest possible causes (hypothesize), 4) connect problems and causes, 5) decide what type of information is needed, 6) obtain information, and 7) apply the information (36). Depending on the complexity of the problem, additional research may be required as the group narrows the possible solutions. Therefore, these PBL steps could be repeated several times, and a single PBL case could be tackled in a series of three or more class sessions.

PBL has several clear advantages over the more traditional lecture- and seminar- based course delivery techniques. Increased retention of information, an integrated (rather than discipline bound) knowledge base, the development of lifelong learning skills, an exposure to real-life experience at an earlier stage in the curriculum, increased student-faculty interactions, and an increase in overall motivation are some of the benefits that have been previously identified (7, 11, 15). The self-study
and group discussions develop skills, including self-directed learning, interdisciplinary knowledge creation, and collaborative skills. The entire process is very interactive, achieving the goal of student engagement in learning, which has been shown to improve retention and satisfaction (6). Therefore, it is not surprising that most studies have revealed a high level of student satisfaction with this learning technique (4, 13, 34).

With regard to the effectiveness of PBL as a pedagogical intervention, a review of the literature revealed somewhat mixed results. There is evidence supporting that PBL has positive effects on knowledge application skills (10): PBL students are better able to transfer concepts to new problems and develop enhanced self-directed learning skills (25). Prosser (28), who looked at traditional measures of outcomes in a dentistry curriculum, found that PBL students do as well or slightly better than traditionally taught students and that PBL students report adopting deeper approaches to their learning.

The idea that PBL promotes deeper rather than superficial learning is evident in the works of Norman and Schmidt (25), Newble and Clarke (24), and Engel (12).

Even though there is a significant body of evidence demonstrating the advantages of PBL over traditional didactic delivery methods, a study (20) has also suggested that PBL is not superior to conventional educational approaches in all aspects of learning. Furthermore, most studies on the effectiveness of PBL originate from observations made in a small-group setting, usually involving five to nine students with a tutor supervising each group. Therefore, it cannot be assumed that introduction of PBL as a course content delivery technique will automatically lead to enhanced student learning or satisfaction, especially in a large classroom setting with tutorless groups.

The superiority, or at least the noninferiority, of PBL over standard course delivery techniques must be proven for each individual PBL delivery method.

Since the traditional PBL delivery to small groups of students involves the supervision of group processes by a tutor, this methodology is associated with considerably higher costs compared with traditional lectures given to large groups of students. Here, we describe an approach where PBL cases are delivered to large groups of up to 85 students facilitated by a single course instructor (tutorless groups) within undergraduate biochemistry and biology courses at UBC Okanagan. We have obtained evidence that this approach leads to increased student satisfaction. More importantly, the study that we conducted within a course delivered through a combination of PBL and lecture format showed a significant improvement of student problem-solving skills.

METHODS

Teaching Method

The teaching method described below was designed by applying elements from PBL in small groups (2, 16, 25) as well as by modifying previously implemented large-class PBL and group work delivery techniques described by others (26, 29, 32, 37). We have presented the PBL technique that we use as well as some of the preliminary findings of this study at the annual Learning Conferences at UBC Okanagan. We also presented a poster on the PBL process at the Improving University Teaching 35th International Conference in Washington, DC.

In 2007, PBL was introduced in the Pharmacology 1 (Bioc 308) and Pharmacology 2 (Bioc 309) courses taught to third-year undergraduate biochemistry, biology, and chemistry students at the UBC Okanagan campus in Kelowna, BC, Canada. These are required courses for students registered within the Medical Biochemistry stream (~30% of the students) and elective courses taken by general biochemistry, biology, chemistry, microbiology, and other science students. Traditionally, upper-level courses at UBC Okanagan involve 80-min lectures twice a week. PBL was introduced by substituting some traditional lectures with PBL sessions. This was initially done with the goal of assisting students in learning mechanisms of physiological processes since the majority of students have not taken the human physiology courses that cover concepts essential to understanding drug action. However, due to the popularity of these exercises, the PBL component of the Pharmacology courses has been expanded, and cases are now written to include exploration of mechanisms of drug actions in addition to concepts of physiology.

Each PBL case is presented to students over the course of three class sessions spaced at least 1 wk apart to allow sufficient independent study time. Two such cases are delivered during the fall term (Pharmacology 1), and another two cases are delivered during the winter term (Pharmacology 2). Terms are typically 13 wk long in Canadian universities; therefore, the PBL sessions represent ~25% of the course delivery time. Pharmacology 1 is a prerequisite course for Pharmacology 2, and since some students opt to take just one of the pharmacology courses, enrollment for Pharmacology 1 is typically 30% higher than for Pharmacology 2. Within these courses, PBL cases are used to introduce new material; therefore, lectures delivered in between PBL sessions are not directly related to PBL case content and do not reveal answers to case questions. The class is randomly divided into groups of seven to nine students before the start of each case, and, depending on enrolment, six to nine PBL groups are created. Students are randomly redistributed for each subsequent PBL case; therefore, students have the opportunity to experience different group dynamics if they take both Pharmacology 1 and 2. It is important to note that the PBL methodology described below can also be used for integrated PBL and classical lecture delivery of course material where lectures are used to supplement PBL case materials.

Case materials are displayed using slides projected in a large lecture auditorium with students sitting in assigned groups. Usually two to three slides are shown per case per session. At the beginning of the class, the first case slide is presented, and students are asked to work within their assigned groups to assess the presented information list various concerns/problems, hypothesize as to what might be happening, and identify issues that cannot be addressed without further study. Usually 10–15 min are allotted for this initial discussion. Individual group discussions are not supervised since only one instructor is present in the classroom. These discussions are followed by an open classroom discussion with all groups participating and the instructor moderating the discussion. This may involve establishing, for example, a list of hypotheses where groups take turns contributing explanations that need to be added to the list in order of priority or individual groups presenting brief reports indicating their hypotheses and reasoning. Groups are encouraged to be brief and to the point so that all reports may be heard. The initial reporting group is picked in a random manner so that all groups are attentive and ready to report, but other groups also get a chance to participate in a predetermined order. After all groups have reported, additional opinions may be solicited. At this stage, the instructor may ask guiding questions if clarifications are needed or if the discussion needs to be redirected or refined. If no immediate answers are offered, additional 1- to 5-min group discussion periods could be held before returning to classroom discussion.

After all groups have reported and the initial slide has been exhausted, additional case information is presented followed by 5–15 min of individual group discussion. The new information may change or confirm hypotheses as well as prompt identification of additional learning issues for independent research. During the open class discussion, detailed notes are taken on white boards by a teaching assistant, although it is our experience that groups can also be assigned to take notes, eliminating the need for a teaching assistant. Students are encouraged to formulate any outstanding questions as

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learning issues, which are recorded in a list. Students are expected to independently research these learning issues as well as other unknowns of the case. The instructor uses guiding questions to ensure that students identify learning issues that are appropriate to the case and consistent with the learning objectives of the course. The role of the instructor is limited to conducting the order of discussion, helping to identify problems and making sure that the case objectives are discussed. The instructor does not supply students with any information or answer case-related questions.

When the PBL session reconvenes in 1 wk, the individual groups are initially given time (10–15 min) to share their independent research on the learning issues that they identified in the previous session and propose a hypothesis based on all the information they have gathered. Open class discussion follows. More information is then presented to students, and the process described above is repeated until all case materials are exhausted. Information sufficient to solve the case is not revealed until the last slide of the final PBL session. The case is concluded by discussing the final hypotheses in the random reporting format described above. If outstanding questions remain after the final case session, they become the responsibility of the students.

The problem shown in Table 3 is an example of the type of initial information given to students. The objectives of this slide would include introducing students to the normal physiological ranges and regulation of blood pressure, body temperature, respiration, and heart rate as well as the initial discussion of the mechanisms of action of the antiviral drug Tamiflu. It is likely that students would already have some knowledge surrounding the normal ranges for the physiological parameters as well as the effects of Tamiflu; however, it is expected that they will create learning issues related to these topics to obtain accurate information, learn the basic concepts of physiology, and ultimately solve the case once all the additional information is revealed on subsequent slides. Another objective of PBL is to introduce students to reliable sources of information; therefore, a list of such sources for general information is made available. Students are also directed to case-specific required reading materials, which usually include two to four primary research articles per case. A list of recommended reading material is also created.

Usually all 80 min of the lecture period are used for the case study. After each PBL session, all materials/slides and learning issues as well as discussion notes organized in rubrics such as “problems,” “hypotheses,” etc. are made available through an online course management system (WebCT Vista). Students are asked to research the learning issues independently; therefore, there is no expectation that groups meet outside of class time.

Student performance during PBL exercises is assessed by J) having the students evaluate other group members through an anonymous online evaluation tool according to three criteria: preparation, participation, and professionalism (the value of this assessment is 5–7% of the course mark per PBL case) and 2) examining the students on all case materials including discussions and the required reading materials during the midterm and final examinations. Student attendance for most PBL sessions is also marked by assigning 1% of the course mark per attended session.

### Research Methodology

**Assessing student perception.** The study presented below was possible through the voluntary participation of students enrolled in the Pharmacology 1 and Pharmacology 2 courses. More than 95% of students entering Pharmacology 2 completed Pharmacology 1 in the same year. The study protocols were approved by the UBC Human Research Ethics Board. All students willing to participate in this study were asked to sign an appropriate consent form. Third-party support was used to ensure that individual student’s consent and responses were hidden from the course instructor (A. Klegeris), who had access only to data summaries or anonymized sets of data.

In the Pharmacology 1 course, student perception was assessed in the following three ways:

1. After exposure to two different PBL cases, students were asked to indicate how many PBL cases they would like to participate in during the winter term (Pharmacology 2). They could write down any number, including zero, which would indicate the elimination of PBL from the curriculum of Pharmacology 2. Student answers are shown in Table 1.

2. An informal questionnaire asking for reasons why they did or did not want to continue with PBL. Student answers are shown in Table 1.

3. Student attendance (see Fig. 1).

In the Pharmacology 2 course, student perception was assessed in the following two ways:

1. Student attendance (see Fig. 1);

2. A formal survey asking students to answer specific questions about their perception of PBL compared with standard lectures. Student answers are shown in Table 2.

Four PBL cases (3 classroom sessions/case) were conducted during the two terms. During the first case in both terms, student attendance and participation were not marked, but marks were assigned to students attending the second case of both terms. After these cases

### Table 1. Informal survey assessing student perceptions of PBL

<table>
<thead>
<tr>
<th>How Many PBL Cases Would You Like to Study Next Term?</th>
<th>Why Would You Like to Continue (or Not) With PBL?</th>
</tr>
</thead>
<tbody>
<tr>
<td>No PBL</td>
<td>Positive comments</td>
</tr>
<tr>
<td></td>
<td>Description</td>
</tr>
<tr>
<td></td>
<td>Process fun/enjoyable/interesting</td>
</tr>
<tr>
<td>One case</td>
<td>Discomfort with the unknown (student hypotheses and research instead of the professor providing with the answers)</td>
</tr>
<tr>
<td>Two cases</td>
<td>Process makes you think</td>
</tr>
<tr>
<td></td>
<td>Retain/learn the information better</td>
</tr>
<tr>
<td>Three cases</td>
<td>Enjoy group interactions</td>
</tr>
<tr>
<td></td>
<td>Learn practical information</td>
</tr>
<tr>
<td></td>
<td>Enjoy researching</td>
</tr>
<tr>
<td></td>
<td>Prefer this method of learning over others</td>
</tr>
</tbody>
</table>

There were 38 total respondents. PBL, problem-based learning.
Attendance data were analyzed before their transformation to percent values. Students could earn marks by attending the second PBL cases in each term. Both terms, student attendance and participation were not marked; however, lecture periods counted are shown in parentheses. During the first cases in lecture periods before, in between, and after the PBL sessions (numbers of lecture periods counted are shown in parentheses). During the first cases in both terms, student attendance and participation were noted, however, students could earn marks by attending the second PBL cases in each term. Attendance data were analyzed before their transformation to percent values. **P < 0.01 by a Bonferroni post hoc test for multiple comparisons.

were concluded, students were also evaluated by their peers, which counted toward their overall course mark.

The total number of students present during all PBL sessions was recorded by a teaching assistant. Attendance at didactic lectures in Pharmacology 1 and 2 is not mandatory and was not usually monitored. All lecture slides were posted online at least 24 h before the lecture, and students were advised to purchase a textbook, which the lectures were based on. For the purpose of this study, the total numbers of students attending several lectures before the first PBL session, in between the PBL sessions, and after the last PBL session were recorded by a graduate student auditing the course. Students were not aware that their attendance was being monitored.

The formal survey questions are shown in Table 2. This survey was administered at the end of Pharmacology 2; therefore, students answering these questions had been exposed to four different PBL cases as well as standard didactic lectures conducted by the same instructor during two terms. The survey was made available online through a course management system (WebCT Vista). Students were given 2 wk to complete this survey. Student participation and individual results were not made available to the instructor, who had access to a blind set of data only.

Assessing problem-solving skills. To assess the dynamics of students’ general problem-solving skills and the effects of coursework involving PBL in a large classroom on this skill set, students were asked to solve a problem (see Table 3) that was not related to the course material they studied in Pharmacology 1. Students completed the problem-solving exercise in September and were informed that they would be asked to do another similar exercise in December, toward the end of the first term. After two PBL cases were conducted during the term, students were asked to solve the exact same problem they were given at the beginning of the term (Table 3). In both instances, they were asked to answer the two questions shown in Table 3. Pharmacology 2 includes a study of the immune system and anti-inflammatory drugs; therefore, the course content was related to the PBL exercise administered in this term. At the end of the winter term (Pharmacology 2), students were once again asked to answer the same problem questions (Table 3). The numbers of acceptable answers were counted by a teaching assistant (Fig. 2A).

Table 2. Online survey assessing student perceptions of PBL and the traditional lecture style of instruction

<table>
<thead>
<tr>
<th>Question 1. Increased my motivation to participate in class</th>
<th>PBL</th>
<th>Traditional Lecture</th>
<th>P Value (by Sign Test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question 2. Did not increase my motivation to attend class</td>
<td>12 8 6 4 4</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>Question 3. Enhanced my communication skills</td>
<td>0 2 12 19 1</td>
<td>5</td>
<td>21</td>
</tr>
<tr>
<td>Question 4. Increased my motivation to do well in the course</td>
<td>0 3 12 15 4</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Question 5. Enhanced my retention of course content</td>
<td>2</td>
<td>1 2 15 11 1</td>
<td>8</td>
</tr>
<tr>
<td>Question 6. Did not increase my understanding of course content</td>
<td>6 18 7 3 0</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td>Question 7. Assisted my learning in other courses</td>
<td>0 6 12 14 2</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Question 8. Increased my comfort level in working in groups</td>
<td>0 0 7 16 11</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Question 9. I like the idea of evaluating myself and my group members</td>
<td>2 5 7 17 3</td>
<td>0</td>
<td>4</td>
</tr>
</tbody>
</table>

Values are numbers of students giving this score in response to the survey question. Responses were scored using a five-point Likert scale, where 1 = strongly disagree; 2 = disagree; 3 = neither agree or disagree; 4 = agree; and 5 = strongly agree. Questions 1–7 were asked about PBL and traditional lecture experiences; questions 8–10 were related to PBL exercises only. *Statistically significant difference.
At the end of the two terms, a third-party course content expert was asked to grade the answers given by students during the problem-solving test conducted on three separate occasions in September, December, and April. This was done in a blinded fashion with the marker not knowing the names of students or which answers were given when, as all responses were compiled into one set and coded to ensure student anonymity and to avoid marking bias. The expert marker first created an answer key and then gave one mark for each correct answer (Fig. 2B). In both cases (Fig. 2A and B), all the marks for individual students were tabulated, allowing the application of a Student’s t-test for paired observations.

Data Analysis

SPSS software (version 16.0, SPSS, Chicago, IL) was used to conduct the statistical analyses of the data. Data are presented as means ± SE. In the case of student attendance, data were analyzed before their transformation to percent values by ANOVA followed by a Bonferroni post hoc test for multiple comparisons. In the case of the student perception survey data, individual student answers to the same questions pertaining to PBL and didactic lecture styles were collected, and differences in student answers assessed by the nonparametric paired sample sign test. In the case of the problem-solving exercise, experiments were designed to allow pairwise comparisons of pre- and post-PBL course exposure answers of individual students by a Student’s t-test for paired observations. P values of <0.05 were considered to be statistically significant.

RESULTS

Attendance

Observations made during previous years indicated that student attendance during PBL sessions was significantly higher than during traditional lectures. To confirm this, the total number of students in attendance was counted by a teaching assistant or a graduate student auditing the course. Data collected during the first term showed significantly higher attendance during the two PBL cases (93% and 98%) compared with traditional lectures (78%; see Fig. 1). The first PBL case of each term was conducted without students being awarded marks for attendance or via a peer evaluation to introduce them to the PBL process and methodology. For the subsequent PBL cases, students were given 1% for attendance per PBL session and also earned marks via a peer evaluation, which constituted 5–7% of the students’ final grade. Interestingly, there was no significant difference between student attendance at the first and second PBL case, even though students knew they were not required to attend the first case. It is possible that the novelty aspect of the process contributed to the high numbers of students attending the first PBL session. Therefore, the first case of the second term was also conducted without marking student attendance or instituting peer assessment to eliminate possible effects of the novelty factor on student attendance. The average student attendance of standard lectures during the second term decreased to 67%, but, similarly to the first term, PBL session attendance was significantly higher, with no statistical differences between the attendance of the unmarked (91%) and marked (95%) cases (Fig. 1).

Informal Student Surveys

Table 1 shows student answers to two questions related to PBL given during an informal survey conducted at the end of the first term. The majority of students (53%) thought that two was the optimal number of PBL cases that should be conducted per term, whereas only 2 of 38 students indicated that they did not want any PBL cases in the next term. These percentages are very consistent with the data collected during 3 previous yr with <5% of students opposed to PBL and the majority of students requesting two or three PBL cases per term. Comments given by more than one student as to why they were opposed or in favor of continuing with PBL are shown in Table 1. Many students gave more than one comment, including several students who mentioned both positive and negative aspects of PBL. While many of the positive comments related to student enjoyment of the process, several statements implied possible beneficial effects on student learning, including statements such as the “PBL process makes you think,” “retain/learn the information better,” and “learn practical information.” The majority of negative comments were related to student discomfort with acquiring information through self-study or from peers as well as concerns about how the material covered during PBL cases would be examined.
**Formal Student Survey**

Table 2 shows the data obtained during the formal survey. It shows all the questions asked as well as the numbers of students giving the different scores (using a Likert scale of 1–5) in response to the survey questions. Note that questions 1–7 were asked twice: first with regard to the PBL process and then again with regard to the traditional lecture form of instruction. This design allowed the application of a nonparametric paired sample sign test, which revealed the following statistically significant differences. There were highly significant differences ($P \leq 0.002$) in responses to questions 1, 3, and 5, which indicated that students felt that their motivation to participate in the class work and their communication skills and retention of course material were superior as a result of PBL. Their motivation to attend PBL classes was also higher ($P = 0.017$) compared with the standard lectures, and there was a borderline significance favoring PBL ($P = 0.049$) as the teaching style that provided better understanding of the course material compared with didactic lectures. Two questions were answered in the same manner for both the PBL and traditional lecture styles: motivation of students to do well in the course did not depend on the style of instruction and PBL was not different from standard lectures in assisting students with other courses. Questions 8–10 were asked only about the PBL experiences of students, and there was a clear trend indicating that PBL increased student comfort level of working in groups, with 79% of students responding positively to this question. The majority of students (59%) liked the peer evaluation offered during the PBL portion of the course, and most of the students (74%) would choose PBL over the standard lecture formats of content delivery if given a choice.

**Problem-Solving Exercise**

Of the 59 students enrolled in Pharmacology 1, 44 students completed both problem-solving exercises and consented to the study. These numbers decreased to 28 of 45 students participating during the second term. Figure 2 shows the average numbers of answers given by students in response to the two questions shown in Table 3 at the beginning of the first term and at the end of the first and second terms (i.e., in September, December, and April). The numbers of acceptable answers were counted by a teaching assistant (Fig. 2A) as well as by a qualified instructor in a blinded fashion to avoid bias in marking (Fig. 2B). With regard to the data collected by the teaching assistant, a Student’s $t$-test for paired observations showed a highly significant increase in all but one case: student responses to question 2 did not quite reach a statistically significant difference when a comparison between answers given at the end of the first and second terms was made (Fig. 2A). The number of acceptable answers given in response to question 1 increased by 21% when assessed at the end of the first term and by 54% by the end of the second term. For question 2, these values were 35% and 64%, and for the combined values of questions 1 and 2, they were 27% and 58%, respectively.

Evaluation of students’ answers by a qualified instructor in a blinded fashion gave generally lower numbers of correct answers; only the combined values for answers to questions 1 and 2 showed statistically significant differences between all three instances, with an 18% increase after the first term and a 39% increase after the second term. The number of answers to question 1 was significantly higher after the second term compared with the beginning of the first term (45% increase). A similar statistically significant effect was observed with answers to question 2 (30% increase). It is important to note that while the Pharmacology 1 course content was not related to this problem-solving skill exercise, Pharmacology 2 included studies of the immune system and anti-inflammatory drugs, which were directly related to this problem-solving exercise.

**DISCUSSION**

PBL was chosen as an effective method to assist students in learning concepts of human physiology and biochemistry in a pharmacology course. One of the strengths of PBL is that it facilitates the integration of knowledge from related disciplines (16), such as physiology, pathology, genetics, biochemistry, and clinical sciences, into the learning of pharmacology. After some didactic lectures were replaced by PBL sessions in a large classroom setting, it soon became apparent that PBL was very popular with students. The PBL technique described does not require additional tutors or any additional funding; therefore, the use of PBL could be expanded further. However, to do this, we need to demonstrate that this teaching technique in a large classroom setting has benefits for student learning similar to its equivalent in small-group settings or that this technique is at least noninferior to conventional lecture-based learning. The two main objectives of this initial study were to assess student perception of PBL as a teaching methodology implemented in a large class setting and to measure improvements in problem-solving skills due to exposure to a course delivered using PBL in addition to standard lectures. Even though such studies are planned for the future, we did not analyze student learning or retention of the course material as a result of PBL compared with standard lecture-based learning.

With regard to student perceptions of PBL, we believe that students “voted with their feet” by attending the PBL portions of the course in higher numbers than the standard lectures. Student attendance has been recognized as a reliable parameter measuring student satisfaction with the learning process (31). The data collected (Fig. 1) prove that the students were very motivated to attend PBL sessions independent of whether they were being graded for it. Our experience with student participation during the PBL sessions supports the conclusions reached by Hintz (16), who found that student questions and discussion points in the PBL study groups were at a higher level than for their lecture-based counterparts. Therefore, instructing the PBL cases mainly involved restricting the student discussion in terms of time as well as avoiding sidetracking from the course objectives. However, it is important to stress that students were allowed and encouraged to create learning issues outside of course material to further develop their general knowledge base.

Student perceptions of the PBL methodology as measured by surveys were positive (see Tables 1 and 2). Our results are consistent with a German study by Antepohl and Herzig (1) conducted within a pharmacology curriculum. Their students preferred the PBL methodology over traditional methods when asked before and after implementation of PBL. Winning and Townsend (35) also found that students enjoyed PBL-based programs more than conventional programs because of the enhanced learning benefits, including understanding and retention of course materials.
The most impressive result of the informal survey (Table 1) was that student’s responses indicated that they not only enjoyed the process but that they believed that they were learning and retaining the information in a superior fashion compared with the traditional methods. This is an area that we wish to formalize in a future study. Negative feelings about the PBL process are all tied to discomfort, which may dissipate after more experience with the method. Table 2 demonstrates that only a minority of students raised negative issues; therefore, enough satisfaction and comfort were present to continue further study.

Kaufman and Mann (17) demonstrated that students in problem-solving programs reported greater satisfaction with the learning environment. However, a study by Miller (22) found no significant differences in student satisfaction between an experimental group (PBL) and a control group (traditional methods); this study was based on small-group instruction of between 10 and 15 students. Vernon and Blake’s (34) meta-analysis of 35 studies comparing PBL with traditional instructional methods, as well as studies by Berkson (4) and Wood (36), support the conclusion that students are highly satisfied with the PBL methodology, with the majority of studies being reviewed describing small-group PBL tutorials.

To the best of our knowledge, our study is one of very few that involves larger classroom PBL instruction with tutorialless groups. Previous studies, such as those of Woods (37), Rangachari (30), and Pastirik (26), implemented PBL with tutorless groups in classes of between 18 and 50 students. Pastirik’s work (26) produced positive results in the development of communication skills, knowledge transfer, and self-directed learning skills, including problem-solving abilities. Rangachari (30) measured student satisfaction with tutorless groups and found the student responses positive, but no other measures of the effectiveness of PBL were attempted in this study of 18 students. Woods’ study (37) was the most similar to our own in terms of class size (30–50 students), and the results obtained showed favorable skill development through the use of PBL over traditional delivery methods.

In most disciplines, students will be required to work in teams in their future workplaces. Student responses in the present study indicated that their communication skills, comfort level with group work, and ability to assess others were important positive outcomes of PBL. Koh et al. (19) found that PBL developed communication skills and that students felt that the peer evaluation process was very useful in developing teamwork skills. Studies by Bernstein et al. (5) and Burch (7) revealed that PBL is more effective than traditional methods for knowledge acquisition and improving teamwork skills. This research supports our students’ comments that the PBL process makes them think rather than memorize.

Our results indicated that participation in a hybrid course (a mix of PBL and traditional lecture) improves students’ ability to problem solve. A comparison of the pre- and postexposure results showed significantly higher numbers of answers generated by students in response to the same problem at the end of the first and second terms compared with the beginning of the first term. We recognize that this study design has several limitations. Even though the three exercises were written 3 and 4 mo apart, it is possible that the increase in numbers of answers is partially due to the fact that students were given the same problem exercise repeatedly. Another approach would be to present students with two problems that have similar numbers of possible solutions but differ in content. Half of the students would be presented with one of the two problems during the initial evaluation and the other problem during the final evaluation. We felt that this approach would also not be optimal as it would not allow direct comparison of the output data since students would be solving different problems. In our case, a Student’s t-test for paired observations was applied since the data generated could be considered to be pre- and post-PBL-containing course work exposure. An additional limitation to the design of this study is the fact that it is not possible to distinguish whether the problem-solving skills were acquired during PBL portions or standard lectures delivered within the Pharmacology courses.

An alternative approach would be to have a controlled study in which a class would be randomly subdivided into two groups with one being exposed to PBL and the other studying the same course content in a traditional lecture format (the control group). In addition to funding issues, there are other difficulties with this alternate design: if the same instructor facilitates both the control and the experimental groups, there could be inherent bias in approaches to material delivery. On the other hand, if different instructors are used there could be biases due to different teaching abilities (3, 9). We are planning to conduct future studies; however, we believe that the data obtained in this study indicate that PBL methodology could be favorable or at least equipotent to lecture-based learning for the development of problem-solving skills in students.

Other studies (14, 21, 33) have shown that students believe that PBL enhances their problem-solving skills. Further testing will be explored to more narrowly define the extent and nature of improvement in problem-solving skills due to PBL methodology. For example, we are planning to administer problem-solving tests not related to pharmacology, biochemistry, or the biomedical field in general to avoid interference of course content with the assessment of this skill set. However, the fact that our study was performed in a natural classroom setting where the students had exposure to both PBL and standard lecture material could be viewed as an advantage that strengthens the conclusions made (8).

Our experience has shown that PBL can operate successfully in a large classroom setting without the use of additional tutors; therefore, no additional funding is needed to implement this technique. Woods (37) demonstrated success using PBL with classes of 30–50 students without tutors; however, he did note that it was necessary to address concerns particular to tutorless groups. Accountability, attendance, and fair distribution of workload are issues that require additional attention; therefore, we implemented measures such as peer evaluation to prevent or alleviate these problems, similar to Woods (37). To use this technique successfully, the instructor must be comfortable managing 6–10 groups of students during the open discussion phases of the PBL sessions, requiring good facilitation skills. We estimate that up to 100 students could be managed by the technique described in this report. In classrooms with >100 students, the process may break down because the time needed for group reports would create too much idle time for the majority of students.
An advantage of PBL conducted in a large classroom compared with small-group sessions is that all students are exposed to the same case information during each session. This eliminates the need for the detailed tutor manuals that are typically used for the instruction of students in small tutor-led group meetings conducted in different rooms. The single instructor method (tutorless groups) also guarantees the consistency of information presented to students, resulting in less frustration for students during their independent research time and exam preparation.

Conclusions

In the present report, we describe a PBL method that could be used in a large classroom setting to instruct courses related to the biomedical field including pharmacology, physiology, and biochemistry without the need for additional tutors. Our data establish that using PBL, in addition to didactic lectures, in a large classroom setting has several positive outcomes on student satisfaction with the learning process. Our data indicate that the PBL methodology described may either have positive effects on the problem-solving skills of students or at least does not interfere with the development of these skills during the combined PBL/didactic lecture approach used. Although pleased with the initial results of this study, we are motivated to continue to refine the course delivery method, the research techniques and methodologies used to assess its outcomes, and, most importantly, attempt to measure improvements in student learning and retention of factual information as a result of the PBL methodology. The student satisfaction and motivation proven in this study will make further research easier, knowing that the students are enjoying the process and seeing the benefits in terms of their own development.

ACKNOWLEDGEMENTS

The authors thank UBC Okanagan Pharmacology 1 and 2 students for participation in this study. The authors also thank Dr. J. Boon, Dr. J. Klufthinger, Dr. J. Pither, and Dr. P. Arthur for helpful discussions and N. Gill for editing the manuscript. T. Boettcher and J. Madeira assisted with data collection and analyses.

GRANTS

This work was funded by UBC Okanagan internal grants, which made this study possible.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

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