

PROBLEM-BASED LEARNING IN A LARGE CLASSROOM SETTING: METHODOLOGY, STUDENT PERCEPTION AND PROBLEM- SOLVING SKILLS

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Abstract

Problem-based learning (PBL) can be described as a learning environment where the problem drives the learning. Students are given a problem that is posed such that they realize the need to gain up to date, evidence-based knowledge before they can solve the problem. This drives the students to investigate and discuss identified learning issues in groups with the instructor as facilitator and coach. The following immediate benefits to students have been identified: increased retention of information; an integrated (rather than discipline-bound) knowledge base; development of lifelong learning skills; exposure to real-life experience at an earlier stage in the curriculum; increased student-faculty liaison; and an increase in overall motivation (Greening, 1998). These advantages of PBL could stem from the fact that this process is based on several modern insights on learning, including constructive, self-directed, collaborative and contextual learning. It will be demonstrated how a PBL approach has been used in the University of British Columbia Okanagan 3rd and 4th year undergraduate biology and biochemistry classes of 50 - 85 students, although this instructional methodology is not limited to life sciences and can be used in other disciplines. Problems are presented and solved through group discussion and independent study without the need for additional tutors. This technique was introduced to enhance the learning experience and effectiveness by supplementing standard lecture material with a novel, interactive course delivery technique.

It is becoming evident that PBL in a small group setting has a robust positive effect on student learning and skills. PBL studies develop student research and independent problem-solving skills. They also challenge students, show them the relevance of the material they are studying, and emphasize the benefits and importance of teamwork and effective communication. However, very little research has been done on the educational benefits of PBL in a large classroom setting. Furthermore, several studies have suggested that PBL may not be superior to conventional educational approaches in all aspects of learning. Therefore, it cannot be assumed that introducing the PBL technique to a large undergraduate class setting will lead to enhanced student learning as well as satisfaction. The superiority, or at least the non-inferiority, of PBL over the standard course delivery techniques must be proven for each individual PBL delivery method. We are therefore exploring various approaches that could be used to compare student learning during PBL exercises and standard didactic lectures, and to assess student perception of this process. We have performed a study that shows that student problem-solving skills are improved after they are exposed to PBL exercises in a large classroom setting. By using student surveys and other techniques, we have also identified a number of parameters that show increased student engagement and satisfaction during the PBL exercises compared to standard didactic lectures. Future studies aimed at assessing student learning during the large class PBL exercises will also be discussed. This research is needed to justify further implementation of PBL techniques in courses that are delivered to large undergraduate classes.

Keywords: Problem-based learning, biochemistry, biology, large classes, student perception, problem-solving skills, undergraduate courses.

1 INTRODUCTION

Current areas of emphasis regarding student learning in higher education include student engagement, critical thinking, self-directed learning, authentic learning, team skills development, problem-solving skills and interdisciplinary studies. Problem-based learning (PBL) addresses all of these targets. 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 in order to understand or solve the problem

(Rangachari, 1991). 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 (Kivela and Kivela, 2005). Problem-based learning has been implemented in many universities worldwide since its beginnings at McMaster University in Canada in the 1960's. 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 and has been practiced in many universities and colleges around the globe.

The methodology and application of PBL are not uniform. Some institutions choose to use single or multiple interventions of PBL within the traditional curriculum framework (e.g. University of British Columbia (UBC) Okanagan, California State University) while others choose whole curriculum transformation (e.g. McMaster University and Sherbrooke School of Medicine in Canada). 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 (Pease and Kuhn, 2011). The fact that a problem is introduced first (as the stimulus for learning) rather than following a 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, the students initially analyze a problem together as a group (e.g. patient case history) and identify and integrate the collective background knowledge the group has that pertains to the problem. The group brainstorms possible solutions/hypotheses based on the available knowledge and information. Then the group decides what further information is needed to solve the problem, prove or disprove hypotheses and they refine these ideas and suggestions into learning issues. Independent study follows as each group member is motivated to attain the desired information. The group reconvenes to share gathered information, discuss the problem further, test previous hypotheses in light of the new information obtained and attempts to solve the problem/case. 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 (Johnson and Finucane, 2000). Depending on the complexity of the problem, more research might be needed 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 sessions.

Problem-based learning has several clear advantages over the more traditional lecture- and seminar-based course delivery techniques, including: increased retention of information; an integrated (rather than discipline-bound) knowledge base; development of lifelong learning skills; exposure to real-life experience at an earlier stage in the curriculum; increased student-faculty liaison; and an increase in overall motivation are some of the areas that have been previously pointed out (Greening, 1998). The self-study and group discussions develop the skills of self-directed learning, interdisciplinary knowledge creation and collaborative skill development. The entire process is very interactive achieving the goal of student engagement in learning which has been shown to improve retention and satisfaction (Berry, 2008). Therefore, it is not surprising that most studies have revealed a high level of student satisfaction with this learning technique (Vernon and Blake, 1993; Berkson, 1993).

However with regard to the effectiveness of PBL as a pedagogical intervention, the review of literature uncovers somewhat mixed results. There is evidence supporting positive effects from PBL on skills of knowledge application (Dochy et.al, 2003): PBL students are better able to transfer concepts to new problems. PBL also enhances self-directed learning skills (Norman and Schmidt, 1992). Prosser (2004), by looking at traditional measures of outcomes in a dentistry curriculum, found that PBL students do as well or slightly better than traditional students, and that PBL students report adopting deeper and less surface approaches to their learning. The idea that PBL promotes deeper rather than superficial learning is evident in the works of Norman and Schmidt (1992), Newble and Clarke (1986), and Engel (1992).

Even though there is a significant body of evidence demonstrating advantages of PBL over the classical didactic delivery methods, several studies have also suggested that PBL is not superior to conventional educational approaches in all aspects of learning (Larin et al., 2010). Furthermore, most of the studies on the effectiveness of PBL originate from observations made in a small-group setting. Therefore, it cannot be assumed that introduction of PBL as a course content delivery technique will automatically lead to enhanced student learning as well as satisfaction. The superiority, or at least the non-inferiority, of PBL over the standard course delivery techniques must be proven for each individual PBL delivery method.

Since the traditional PBL delivery to small groups of students involves supervision of group work by a tutor, this methodology is associated with considerably higher costs compared to traditional lectures to large groups of students. Here we describe an approach where PBL cases are delivered to large groups of up to 80 students facilitated by a single course instructor (tutor-less groups) within the 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 significant improvement of student problem-solving skills.

2 METHODS

2.1 Teaching method

Three years ago PBL was introduced in Pharmacology I and Pharmacology II courses that are taught to 3rd year undergraduate biochemistry, biology and chemistry students at the UBC Okanagan campus in Kelowna, British Columbia, Canada. These are required courses for students registered within the Medical Biochemistry stream (approximately 30% of the students) and elective courses taken by general biochemistry, biology, chemistry, microbiology and other science students. Traditionally, courses at UBC Okanagan involve 80 minute lectures twice a week. PBL was introduced by substituting some traditional lectures with PBL sessions. Each case is presented to students over three class sessions spaced at least one week apart, allowing enough independent study time. Two such cases are delivered during the fall term Pharmacology I and another two cases are delivered during the winter term Pharmacology II. Terms are typically 13 weeks long in Canada; the PBL sessions represent approximately 25% of the course delivery time. Pharmacology I is a prerequisite course for Pharmacology II, and since some of the science students opt to take just one of the pharmacology courses, the course enrolment for Pharmacology I is typically 30% higher than for Pharmacology II. Within these courses PBL cases are used to introduce new material; therefore, the lectures that are given in between the PBL sessions are not directly related to the PBL case materials and no answers to case questions are given. The class is randomly divided into groups of 7 - 9 students before the start of each case. Depending on the enrolment, 6 - 9 PBL groups are created. Students are randomly re-distributed for each of the subsequent PBL cases so that the students have an opportunity to experience four different group dynamics if they take both Pharmacology I and II courses.

Case materials are displayed using slides projected to the large class with students sitting in their assigned groups. Usually 2 - 3 slides are shown per case per session. At the beginning of the class, the first case slide is presented and groups are asked to work independently first to assess the presented information, list various concerns, hypothesize and to identify issues that cannot be addressed without further study. The individual group discussions are not supervised since only one instructor is present in the classroom. The group discussion is followed by an open classroom discussion with all groups participating and the instructor as a moderator of the discussion.

The role of the instructor is limited to conducting the order of discussion, helping identify problems and making sure that the case objectives are brought up and discussed. The instructor is not supplying students with any information or answering case-related questions since the students are aware that it is going to be their job to research the unknowns of the case. During the open class discussion, detailed notes are taken on white boards by a teaching assistant present, although it is our experience that groups can also be assigned to take notes, which eliminates the need for a teaching assistant. Students are encouraged to formulate any outstanding questions as Learning Issues. The instructor utilizes guiding questions to make sure students come up with Learning Issues that are appropriate to the case and consistent with the learning objectives of the course.

After the case material shown on the slide is discussed, students are shown the next slide with additional information and the process is repeated 2 or 3 times depending on the number of slides. Usually all 80 minutes of the lecture period are used for the case, however if the case material is covered in a shorter period of time, normal lecturing is resumed. At the end of the first and second sessions students are asked to research the Learning Issues independently. After the case, all materials/slides as well as discussion notes organized in rubrics such as 'problems', 'hypotheses', etc., and Learning Issues are made available to the students through an online course management system (WebCT Vista used at UBC Okanagan). Case sessions 2 and 3 start with groups working on the Learning Issues from the previous session first, followed by open class discussion. More

information is revealed to the students and the process is repeated again until all case materials are exhausted. If outstanding learning objectives remain after the final case session, they become the responsibility of the students. One of the objectives of PBL is to introduce students to reliable sources of information and a list of such sources for general information is posted online. Also, students are directed to case-specific required reading materials, which are usually comprised from 2-4 primary research articles per case. A list of recommended reading material is also created.

Student performance during the PBL exercises is assessed by 1) the students evaluating other group members through an anonymous online evaluation tool according to the three criteria of preparation, participation and professionalism. The value of this assessment is 5 - 7% of the course mark per PBL case; 2) examining students on all case materials, discussions and the required reading materials via the midterm and final examinations.

2.2 Research Methods

The study presented in this paper was possible through voluntary participation of students enrolled in the Pharmacology I class in September 2010 and Pharmacology II in January 2011. The study protocols were approved by the UBC Human Research Ethics Board. Third party support was utilized to ensure that student's consent and responses were hidden from the course instructor.

2.2.1 Measuring Problem-Solving Skills

To assess the dynamics of student general problem-solving skills, and the effects of PBL in large classroom on this skill set, students were asked to solve a problem (see Table 1) that was not related to the course material they were about to study in Pharmacology I. The 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 actually asked to solve not a similar problem, but the same problem they were given at the beginning of the term (Table 1). In both instances they were asked to answer the two questions identified in Table 1. The numbers of reasonable answers were counted by a teaching assistant and these numbers were tabulated for each student, which allowed application of a Student's t-test for paired observations. The course instructor had access to the data, but not the names of the students, which were coded to ensure anonymity.

2.2.2 Student perception survey

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

Table 1. Problem-solving exercise used to assess student problem-solving skills

The presented problem	Questions asked
<p>Nolan is a healthy 25 year old male, who works as a Park Ranger in Florida. One day, he wakes up with a fever, stomach cramps, and nausea. Nolan goes to see his family doctor, and after a brief examination, the doctor prescribes a 5 day course of Tamiflu, along with Aspirin for his fever. Although Nolan's fever subsides, the nausea and stomach cramps persist. 4 days later, Nolan is still not feeling better, and notices a rash on his torso. Nolan goes to the hospital complaining that his symptoms have progressed. He is experiencing thirst, and occasional vomiting. Nolan's vital signs were taken, with the following results:</p> <p>Blood pressure: 120/80 mmHg Temperature: 39°C Respiration Rate: 20 breaths per minute Heart rate: 72 beats per minute Blood glucose level is within normal range.</p>	<p>1. List all the probable causes of these symptoms. Number your answers.</p> <p>2. List clinical and laboratory tests that could be performed to help the diagnosis? Number your answers.</p>

2.3 Statistical analysis

SPSS software (version 16.0; IBM SPSS, Chicago, IL, USA) was used to conduct the statistical analyses of the data. In the case of the problem-solving exercise, experiments were designed to allow pairwise comparisons of pre- and post-PBL exposure answers of individual students by Student's t-test for paired observations. In the case of student perception survey data, individual student answers to the same questions pertaining to PBL- and didactic lecture-style learning were collected and differences in student answers assessed by the non-parametric paired sample sign test. P values of <0.05 were considered to be statistically significant.

3 RESULTS

3.1 Problem-solving exercise

Out of the 59 students enrolled in Pharmacology I, 44 students completed both problem-solving exercises and also signed the consent forms for participating in this study. Fig. 1 shows the average numbers of reasonable answers given by students in response to the two questions listed in Table 1. Student's t-test for paired observations showed a significant increase in the number of reasonable answers given in response to Question 1 (21% increase), Question 2 (35% increase) as well as in the total number of answers (27% increase).

3.2 Student perception survey

Table 2 summarizes the survey data. It lists all the questions asked as well as the numbers of students giving the different scores (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 application of the non-parametric paired sample sign test, which revealed the following statistically significant differences. There were highly significant differences ($P=0.002$ or less) in responses to questions 1, 3 and 5, which indicated that students felt that their motivation to participate in the class work, their communication skills and retention of course material were superior as a result of PBL as opposed to standard lecturing. Their motivation to attend PBL classes was also higher ($P=0.017$) compared to standard lectures, and there was a marginal significance favouring PBL ($P=0.049$) as the teaching style that provides better understanding of the course material compared to didactic lecturing. Two questions were answered in the same manner for both the PBL and the lecture styles: motivation of students to do well in the course was not dependent on the style of instruction; and PBL was not different from standard lectures in assisting students with

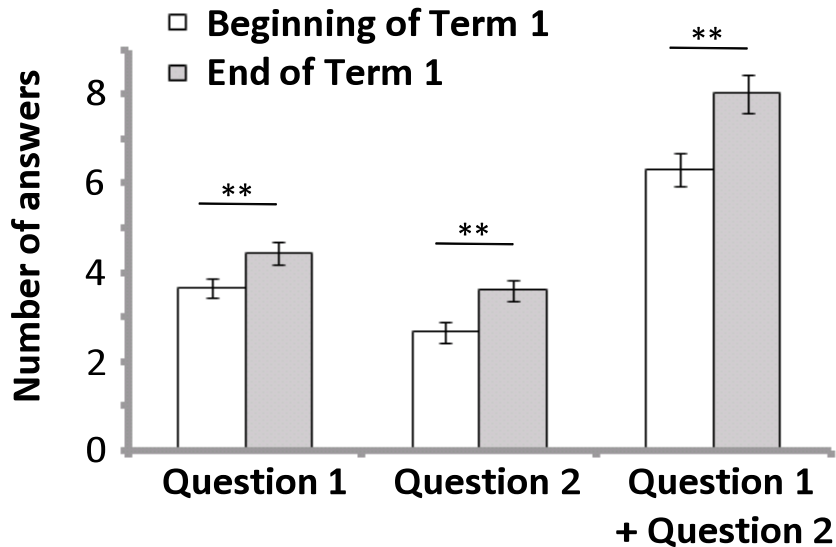


Fig. 1. Average number of reasonable answers given by students in response to the two questions presented at the end of the problem-solving exercise (see Table 1) was significantly higher at the end of term 1 compared to the beginning of the term. ** represents $P < 0.01$, Student's t-test for paired observations.

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 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 standard lecture forms of content delivery if given a choice.

4 DISCUSSION

The two main objectives of the study were to measure improvements in problem-solving skills due to exposure to PBL and to assess student perception of PBL as a teaching methodology that was implemented in a large class setting without the use of tutors. With regard to the first objective, the results indicate that exposure to PBL does indeed improve students' ability to problem-solve. Comparing the pre- and post-PBL exposure results showed significantly higher numbers of answers generated by students in response to the same problem at the end of the term compared to the beginning of the term. This study design has limitations. Even though the two exercises were written 3 months apart, it is possible that the higher numbers of answers at the end of the term are partially due to the fact that it was the second time these students were given the same problem exercise. An alternative approach would be to present students with two problems that have similar numbers of possible solutions but are different in content. We felt that this alternative approach would not be optimal since it would not allow direct comparison of the output data due to the fact that student would be solving two different problems. In our case we were able to apply Student's t-test for paired observations since the data generated could be considered to be pre- and post-PBL exposure.

A clearly better alternative approach would be to have a controlled study where a class would be randomly subdivided into two groups with one being exposed to PBL and the other studying the same course content without the PBL cases (the control group). There are difficulties with this alternate design also: if it is the same instructor for both the control and the experimental groups, there could be bias inherent in the material delivery by the instructor, but if different instructors are used there could be biases inherent in different teaching abilities (Colliver, 2000; Belland et al., 2008). We are planning to conduct such studies in the future, however we believe that the data obtained in this study indicate that PBL methodology is favourable for the development of problem-solving skills of students. The

Table 2. Online survey used to assess student perception of PBL and traditional lecture style of instruction

		Participación in Problem-Based Learning has:					Attending classes with traditional lecture formats has:					P value, sign test
		1 ^a	2	3	4	5	1	2	3	4	5	
1 ^b	Increased my motivation to participate in class	0	3	10	14	7	2	13	13	5	1	0.001
2	Not increased my motivation to attend class	12	8	6	4	4	0	8	16	9	1	0.017
3	Enhanced my communication skills	0	2	12	19	1	5	21	5	3	0	<0.001
4	Increased my motivation to do well in the course	0	3	12	15	4	1	3	17	11	2	0.480
5	Enhanced my retention of course content	1	2	5	15	11	1	8	11	13	1	0.002
6	Not increased my understanding of course content	6	18	7	3	0	2	18	10	3	1	0.049
7	Assisted my learning in other courses	0	6	12	14	2	1	5	11	16	1	0.630
8 ^c	Increased my comfort level in working in groups	0	0	7	16	11						
9	I like the idea of evaluating myself and my group members	2	5	7	17	3						
10	If given a choice, I would choose courses that used Problem-Based Learning over traditional lecture format	0	4	5	19	6						

^a 1 - strongly disagree; 2 - disagree ; 3 - neither agree or disagree; 4 – agree; 5 - strongly agree.

^b Questions 1 – 7 were asked about PBL and traditional lecture experiences.

^c Questions 8 - 10 were related to PBL exercises only.

immersion into real-life problems or cases allows students to practice and develop their skills in a meaningful context so the motivation to improve is provided by the competitive nature inherent to the problem-solving process. Pease and Kuhn, 2011 found that the benefit of PBL is attributable to the engagement that students have with the problems. Other studies have shown that students believe that PBL enhances their problem-solving skills (Uhlin et al., 2007; Lieux, 1996; Gallagher et al., 1992). Further testing could be used to more narrowly define the extent and nature of the possible improvement in problem-solving skills due to the PBL methodology. Miller (2003) noted that measurements of improved skills or knowledge is skewed by the fact that students are adapting to a new method of learning and if given time and experience with the method (as the control group has with its 'traditional' methods), perhaps more realistic comparisons could be made between control and experimental groups. We hope to refine our measurements in further studies. For example, in our next study we will look more closely at the quality of responses to a particular case both pre- and post-PBL exposure as opposed to weighting quantity of responses. This could be done with the help of independent content experts evaluating the answers of students in a blinded fashion.

Student perception of the PBL methodology was overwhelmingly positive (see Table 2). Our results are consistent with a German study in Pharmacology by Antepohl and Herzig (1993). Their students preferred PBL methodology over traditional methods when asked before and after implementation of PBL; even students from the control group answered similarly that they would have preferred PBL. This indicates that students who had been exposed to PBL were not disappointed and those in the lecture-based course had not been convinced it was superior to PBL. It was noticed, but not measured for this study that the attendance on 'PBL case days' was higher than on traditional lecture dates.

There was not only significantly more of the classroom discussion on the course content during the PBL class time, but the quality of classroom discussion was also elevated and we believe this to be due to the fact that the students had more of a vested interest in the outcome of each case because of their independent research into the case. Hintz (2005) found that student questions and discussion points in the PBL study groups were at a higher level than for their lecture-based counterparts. It is also important to note that the classroom during the PBL sessions was highly interactive and students were motivated to participate in discussions and to solve the case. Informal surveys showed that students resisting PBL did so because of the perceived extra work associated with preparing for PBL sessions. Some students believed that didactic lectures are a more effective form of content delivery and therefore preferred to be "taught" the answers rather than research them.

Kaufman and Mann (1996) demonstrated that students in problem-solving programs reported greater satisfaction with the learning environment. However, Miller (2003) found no significant differences in students reporting on satisfaction between an experimental group (PBL) and a control group (traditional methods). Miller's study was based on small group instruction of between 10 and 15 students (Miller, 2003). Vernon and Blake's (1993) meta-analysis of 35 studies comparing PBL with traditional instructional methods, in addition to studies by Berkson (1996) and Woods (1996) 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 tutor-less groups.

Our experience has shown that PBL can operate successfully in a large class setting without the use of additional tutors, therefore no additional funding is needed for implementation of this technique. Woods (1996) demonstrated success with PBL in classes of 30-50 students without tutors; however, he did note that measures were implemented to deal with issues of tutor-less groups (Woods, 1996). Accountability, attendance and fair distribution of workload are issues that need additional attention when using tutor-less groups; however, Woods' and our own study put in measures like peer evaluation to prevent or alleviate these problems (Woods, 1996). To successfully implement this technique, the instructor does have to be comfortable with managing 6-10 groups of students during the open discussion phases of the PBL sessions, which requires a good rapport with students. We estimate that up to 100 students could be managed by the technique described in this paper. In the classrooms with more than 100 students, the communication between the groups and the instructor will become challenging. In addition, the frequency of participation by individual groups will be low, which might have negative effects on the dynamics of the classroom discussion. Advantages of PBL conducted in a large classroom compared to small group sessions include the fact that that all students are exposed to the same case information during the classroom discussion. Therefore, there is no need for detailed tutor manuals that are used for instruction of students in small tutor-led group meetings conducted in different rooms. The single instructor method (tutor-less groups) also

guarantees the consistency of information and thus leads to less frustration for students during their independent research time and in preparation for the midterm and final examinations.

5 CONCLUSIONS

Our data establish that using PBL, in addition to didactic lectures, in large classroom setting has several positive outcomes on student satisfaction with the learning process. Our data indicate that the PBL methodology described may have positive effects on the problem-solving skills of students or at least it 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 research techniques and methodologies and most importantly attempt to measure improvements in student learning and retention of 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 for their own development.

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