The Effects of Problem-Based Learning on Retention

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Abstract

Problem-based learning (PBL) is believed to benefit students academically and socially through small group work. An in-depth literature review has shown that PBL significantly improves retention of course content. This paper will discuss an analysis of retention on Arts and Science students at McMaster University. The study compares two groups of students participating in either a traditional or PBL tutorial of a second year statistics class. Mean differences in an initial survey question (exam question) and retention survey question (given one year following course completion) were analyzed, providing a p-value of 0.19. Although the data does not show statistically significant differences on retention when comparing the two groups, it is promising. Students in the PBL tutorial provided positive feedback, which is also encouraging. These findings suggest many benefits for PBL in the classroom; and with improved implementations of the study, a greater sample size may support significant results.

Introduction

Students typically learn to solve mathematics and statistics problems through a procedural approach, which prevents a deeper conceptual understanding of concepts. This understanding is required to solve novel problems and to make connections between other mathematical and statistical concepts (Ontario Ministry of Education, 2004). According to the Ontario Ministry of Education (2004), “Clearly the twenty-first century requires a greater focus on a wider range of problem-solving experiences and a reduced focus on learning and practicing by rote” (p. 7). The twenty-first century also requires students to learn a vast amount of knowledge in their undergraduate degree. The competitiveness of the job market entails that schools educate students on professional skills and attitudes in addition to technical-scientific knowledge (Ribeiro, 2011). Recently student’s motivation, retention, and achievement has declined in school (Anderson, 2007). One solution to increase attendance and foster a greater understanding in mathematical and statistical thinking is PBL. The general definition of PBL given by Woods (2006) is: “PBL is any learning environment in which the problem drives the learning” (p. 1). PBL addresses concerns regarding understanding, retention, engagement, and the application of knowledge (Klegeris and Hurren, 2011). Savery (2006) reports that PBL promotes students to think critically about a question, which provides a solution to the procedural approach when solving problems. In addition, Ribeiro (2011) notes that PBL shows students how to adapt to new situations professionally, “[and] is capable of providing students with opportunities to learn conceptual knowledge and develop the skills and attitudes valued in their chosen careers” (p. 1).

John Dewey developed PBL for medical education in the 1950s. This method of
teaching was created due to the unsatisfactory clinical performance of medical students, which failed to prepare student’s to problem-solve and learn life skills. In the Faculty of Medicine at McMaster University, Howard Barrows first implemented PBL during the 1960s. It was noticed across North America and Europe as an approach that promoted student-centered learning, and by the 1990s PBL became an accepted instructional approach (Savery, 2006; Anderson, 2007). Since then, PBL has expanded across multiple disciplines and various levels of education. What used to be limited to medical school has now been incorporated in elementary school, high school, undergraduate and graduate level courses of most subject areas (Spector, Merrill, Merrienboer, and Driscoll, 2008). Savery (2006) provides examples of the expansion of PBL: 1. Samford University, Alabama, uses PBL in undergraduate programs such as those in the school of the arts and sciences, business, nursing, and pharmacy. 2. Illinois Mathematics and Science Academy use PBL to teach their high school students. Instructors at the schools have developed a unique approach to the PBL method. Some institutions use single or multiple interventions of PBL, while some use whole curriculum transformation (Klegeris and Hurren, 2011).

Even with this variety Klegeris and Hurren (2011) note:

“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” (p. 2533).

It can be seen from Kelgeris and Hurren that presenting a student with a problem before teaching the concepts is the common feature in PBL, which allows students to take an active approach to their learning. “The most consistent finding from PBL research is the superiority of PBL-trained learners in life-long learning,” was stated by Spector, Merrill, Merrienboer, and Driscoll (2008, p. 488). Therefore, students learn the necessary skills to become life-long learners, while improving their understanding of concepts.

The original process to the PBL approach has four steps. First students are placed in small groups and given an exercise, which they brainstorm ideas on. Then students individually complete their tasks for the group through research and self-directed learning. Third, students share their findings with the rest of the group and revisit the question. Finally they summarize and integrate their learning (Spector, Merrill, Merrienboer, and Driscoll, 2008). As stated above, there are variations of this method depending on the discipline or year of study. Essentially students are given a real-life problem to solve in tutorial (or some cases in class) before concepts and theories are introduced in lecture (Ribeiro, 2011). The facilitator (a professor or teaching assistant) for the class/tutorial provides feedback to group members solving the given exercise. During feedback they
ensure students are analyzing the exercise correctly and encourage them to check their understanding. The facilitator does this by asking students open-ended questions, and allowing them to explain their ideas. Successful facilitation in PBL tutorials combined with traditional lectures promotes understanding (Wood, 2003).

Ribeiro (2011) discusses the importance of PBL:

“PBL is based on the assumption that learning is not a process of reception, but of construction of new knowledge. It is supported by cognitive science theory that spouses (sic) that previous knowledge about something can determine the nature and the amount of information students can process and elaborate in order to be internalized. In addition, PBL is supported by cognitive research results that suggest that meta-cognition and social factors have a strong influence on learning” (p. 2).

Based on Rideiro’s discussion, PBL allows students to internalize knowledge because it prepares them to build on their own knowledge in groups, which has a positive effect on learning.

In addition to preparing students for the work force, and having a positive effect on learning, PBL has other benefits. It is a student-centered approach that integrates theoretical knowledge with real-world examples. PBL fosters critical and logical thinking in students, by taking a constructivist approach. That is, students use prior knowledge and build on this to develop new frameworks. Since PBL encourages active learning, critical thinking, and a greater understanding of former concepts, this motivates students to attend class where they feel engaged (Wood, 2003). Wood (2003) explains, “[PBL] fosters active learning, improved understanding, and retention and development of lifelong learning skills” (p. 330). The improvement of retention is one of Dr. Lozinski’s goals for the student’s enrolled in Arts and Science 2R03 (ArtsSci 2R03). Some lifelong learning skills are: cooperation, communication, collaboration, problem solving, representation, and reasoning (Hmelo-Silver, 2004; Roh, 2003). Many of these skills are learned from group work and the absence of a provided formula and method. Overall, Roh (2003) has found that PBL leads to higher achievement on standardized tests and project tests that require students to problem solve. In addition, students in PBL lectures retain more knowledge, so the higher performance on standardized tests is still seen in posttests conducted after the completion of the course (Anderson, 2007). In contrast, Wood (2003) found that students were unlikely to achieve good standings on exams that only rely on factual recall. This supports the idea that the traditional lecture method simply encourages students to learn by rote, preventing higher order thinking (Ontario Ministry of Education, 2004).

With the many advantages, PBL also comprises of disadvantages, which is reflected
in the literature. Wood (2003) suggests that facilitators and students find PBL challenging and some find it frustrating because it requires new roles, approaches, different scheduling, workload, and some might not understand the method if it is something new to them. In addition, PBL requires a considerable amount of time, for planning and the class itself (Ribeiro, 2011). In using the PBL, completing the entire curriculum may not be possible due to the time constraints of the course. Also, classes may be rushed in the end of the term or simply at the end of the PBL class because groups have not finished answering the problem given to them (Kohlhaas, 2011). Even with this disadvantage, students are able to retain the knowledge better compared to the traditional teaching method that covers all required curriculum (Anderson, 2007).

ArtsSci 2R03 is titled, “Applied statistical inference,” which is a mandatory statistics course for Arts and Science students that is intended to be taken in second year. Prior to taking this course, Arts and Science students are required to take a full year calculus course in first year. This is typically the only preceding mathematical or statistical university level education these students have. The course runs for one semester and includes topics on data description, graphic methods, probability, confidence intervals, and statistical inference. There are three fifty-minute lectures per week, and one fifty-minute tutorial per week. Dr. Lozinski first taught ArtsSci 2R03 during the 2010-2011 academic year, and this was also the first time the course was offered as a one-semester course.

The purpose of the study is to view the effects of PBL tutorials in ArtsSci 2R03. In Dr. Lozinski’s second year teaching this statistics course (2011-2012 academic year), he decided to use the PBL method to improve the students grasp of the content. It was thought that this would be successful when offered to the Arts and Science students in the statistics class, because they are self-motivated and have past experience in courses requiring group work. This particular program is small, and thus these students are familiar with each other. The advantages allow for easier management of the small tutorial groups, with the prospect that students will find it easier to work together.

**Literature Review**

We reviewed research on PBL in the areas of mathematics, statistics, business, engineering, and science in various levels of education. Each study used slightly different variations of PBL. We focused on research which had similar PBL methods as our study. One review, a Meta-analysis, analyzed 82 studies. Most research was conducted using the cross-sectional research approach, although two used the longitudinal research approach. Every study had similarities and differences in their findings. Following is a summary of the literature review that was completed.

Walker and Leary (2009) analyzed a variety of PBL research and compiled the data
in one Meta-analysis. The 82 studies ranged from eight to 2469 participants per study in science and engineering. The studies they analyzed compared PBL lectures or tutorials with traditional lectures of tutorials. The results showed that students favoured PBL, especially when material did not include medical education. In addition, the analysis found that students performed to a higher degree in PBL with teacher educated design problem, diagnosis problems, and strategic-performance problems. The story problems did not appear to enhance grades compared to traditional lectures. Overall, students who received PBL lectures did better or as well as students in traditional lectures. From Walker and Leary’s (2009) Meta-analysis it can be seen that PBL lectures benefit students.

More specifically, Kohlhass (2011) completed a masters thesis studying PBL in a math middle level classroom. The purpose of the study was to see if PBL can increase student’s grades and interest in math. The teacher would either review the material and then pose a real life problem relating to the material, or the teacher would pose a real life problem before the material was taught. The students would work in groups solving the problem and then present the solution or discuss it as a class. The teacher would facilitate and walk around the classroom guiding the groups. They completed a pre and post-test (at the start and end of the school year). The seventh grade students were also surveyed, and their attitude towards math was measured. Occasionally lessons were rushed towards the end of class as some groups were not able to finish answering the problem assigned.

The results of Kohlhass’ (2011) study show no significant achievement on overall grades, and the comparison of the pre and post-tests did not necessarily show superior problem solving skills. Although those results were not significant, the survey illustrated improvements on the students’ attitude towards math; they indicated greater interest in math and were motivated to learn. Generally students were able to rely on each other about three weeks into the PBL method. They also understood the concepts more and some increased their grades. Kohlhass suggests that the use of both traditional and PBL style teaching would be optimal, thus resolving the disadvantage of time constraints.

The effects of time constraints on statistics have been seen in Slovenia. Here statistics is taught in math class, with little focus on statistics. To improve the education of statistics, it was decided to test if the use of PBL would be successful for an introduction statistics course for engineering students at the University of Ljudljana. A statistics problem relating to engineering was given for each new topic and solved in groups of five. It took students one week to a month to solve a problem using data search. The professor facilitated and presented real life problems, which were at first short and simple and then increased in complexity. This longitudinal study conducted by Vidic (2010) still continues today.

Thus far Vidic (2010) found that the students who received PBL teaching were able
to solve complex problems to greater success than the students who received traditional teaching. The PBL students also obtained better grades, and data transformation and display skills were more efficient. Vidic found that students’ were able to apply knowledge in real engineering situations. PBL allows for critical thinking and achieving broader goals, formation of questions, selection and use of appropriate statistical methods, developing inferences and evaluating them. Overall PBL increased student motivation since they were able to see the use of statistics in engineering. The students improved skills in teamwork, independent learning, and problem solving which are used in other courses.

Another research project tested the PBL method on undergraduate students was completed by Karpiak (2011). This study focused on the effects of retention and rating of an undergraduate research method statistics course for psychology majors at Jesuit University. There were 51 students enrolled, 36 were in the control group and 15 in the experimental (PBL) group. The PBL group worked in groups of three to four solving complex realistic problems instead of having lectures. A textbook was still used and notes were provided to the students by the professor. The professor was a facilitator and monitored groups. All students were given an exam eight weeks following course completion that tested knowledge of statistics.

The results of Karpiak’s (2011) study showed that scores were significantly higher on the exam for PBL students compared to the students who received traditional lecturing. The students rated PBL higher than the traditional class. Karpiak notes that the results could be due to PBL students having a deeper understanding of the material, more flexible application of statistics knowledge, better retention across time, or something else. Although a causal statement was not made, the results showed preference for PBL.

Siaw also found benefits in PBL. The study examines business students’ attitude of PBL in statistics and accounting. 87 postgraduate students were tested. They worked in the same small groups of six to eight in tutorials and asked to solve application problems. The students answered one to three short problems in two hours and the solutions were taken up at the end of tutorial by the tutorial assistant. The students filled out a questionnaire and the results were analyzed.

Siaw found that students favoured PBL with over 70% rating PBL positively. They enjoyed the flexibility and group discussion. In addition the students found PBL valuable, and worthwhile. In conclusion, Siaw noticed PBL was better suited for accounting rather than statistics, because the statistics concepts are difficult to master. With that said, Siaw noted that students were forced to think critically, which provided them with a deeper understanding in both disciplines.

Another paper testing PBL with business students is a longitudinal, quasi-
experimental design study that continues today. Hallinger (2001) assesses the use of PBL in Thailand, which was introduced due to the unsatisfactory application of student’s knowledge. The faculty’s goal was to create an active environment for students in the Graduate School of Business Master of Management programme. 10,031 students have taken the PBL courses, and 36,168 students have been enrolled in traditional courses. The students in the PBL courses were given eight projects to be completed in groups and were then graded for marks. The study has collected data looking at instructional effectiveness, action-directed learning, student engagement, and feedback.

Hallinger (2001) has found that the course effectiveness has improved over time and the PBL courses had significantly lower variance, which also decreased over time. PBL had significantly greater action-directed learning and engagement when compared to traditional classes. Course and instructor effectiveness showed no significant results, with the possibility that both courses were equally taught with high quality. With time the improvement of PBL courses has increased in the business programme, with consistently high overall ratings.

While PBL in business courses has showed many benefits, the practice of PBL in science courses has showed other benefits. Klegeris and Hurren (2011) completed PBL research for pharmacology students. Their objectives were to measure problem-solving skills and student perception of PBL in a large classroom setting without a tutorial assistant (TA). The first term class (September to December) had 59 students, and the second term class (January to April) had 44 students. The professor measured problem-solving skills by asking students to answer an exercise in September that did not relate to course material. They were asked to answer the same question in December. Two PBL sessions were conducted throughout each term, which the TA graded. To measure student perception, the researchers presented the students with a survey.

The results of Klegeris and Hurren’s (2011) study showed that the problem solving exercise grades increased from the beginning to the end of the term, with a greater increase in second term. The survey indicated significant differences for questions relating to motivation, communication skills, and retention; with higher ratings for PBL then traditional lecturing. Most students decided they would prefer PBL courses when compared with traditional courses. Klegeris and Hurren suggest that the real life exercises allowed students to develop problem-solving skills. Also, large PBL classes (up to 100 students) can operate without a TA to provide consistency; in this case the instructor needs to be comfortable facilitating large groups and discussions. The study concluded with the finding that PBL effects are largely positive.

Continuing in the science field, Hmelo-Silver and Barrows (2006) researched PBL for medical students. Their research involved five third year medical students and a
facilitator. The students worked over five hours in two sessions on a problem regarding a patient with pernicious anemia. The facilitator asked open-ended questions to assist the group, revoiced the students’ comments or suggestions, and asked the quiet students to summarize what the group was saying. Hmelo-Silver and Barrows found that PBL allowed the facilitator to ask questions, which is unusual for traditional tutorials. This promoted understanding, and encourages students to solve the problem on their own.

With the success of PBL at the university level, PBL has been used in high schools. Anderson (2007) led a study with 110 secondary students placed into four sections of an agricultural career and leadership course for two weeks. The study was carried out due to the increase in drop out rates and decline in academic motivation. These particular agricultural students were presented with a leadership course to determine if PBL would increase retention, motivation, and critical ability. There were two groups in the study: control group (TGL) that consisted of 56 students and the experimental group (PBL) that consisted of 54 students. Anderson measured knowledge acquisition, knowledge retention, and critical thinking. The teacher acted as a facilitator and guided the students throughout the leadership course. A content test was presented to the students as a final exam, and 3 months following the students were asked to fill out the content test again.

Anderson’s (2007) data showed the TGL group out performed the PBL group on the first content test. When analyzing the content test presented three months later, the PBL group did significantly better than the TGL group. The teacher had commented that students retain more in PBL, and the students had noted that PBL requires them to think deeper, apply concepts, and meet new people. In addition, some students found PBL frustrating because it required more time. On an ISAT test, which is a standardized test for reading, the scores for PBL students were significantly higher than the students in the TGL group. This studied shows that PBL has advantages and disadvantages. The main finding was that PBL style lecturing might have improved retention.

Taking a different approach to the literature review, we decided to review research that focuses on the teacher or professor’s view of PBL. The following two research papers discuss this approach. Lian wrote “Determining the Readiness of Staff for PBL Training and Development,” in 2010. She surveyed 207 staff of private higher education institutions and asked questions relating to awareness, informational, personal, and management of PBL. She discovered 27% were unaware of PBL as a teaching method, and most were interested. 88% of the staff surveyed would like further information of PBL and more training in the area. Many were willing to learn more about PBL and almost all were concerned and interested in PBL, so they could become better lecturers. Lian’s Findings indicate an interest in PBL with a need aimed at further PBL training for teachers and professors.
A final literature review paper discussed the benefits and difficulties of PBL based on a teacher's standpoint. At the University of Brazil, Ribeiro (2011) completed a study of a teacher conducting classes offered to engineering graduate students discussing General Administration Theory. Each class had 40 to 60 students who solved 13 problems a semester. The first half of class, students presented their solutions to a problem given in the previous class and the teacher would comment on the solutions. The second half of class students were posed a problem in class and asked to solve it in small groups while the teacher acted as a facilitator. The teacher enjoyed the PBL method, as it made learning fun and unique. At first the teacher found that PBL required more devotion and a challenge to manage class time. Although with the help of a graduate student who graded, the teacher allotted more time to focus on other aspects of the class. Some obstacles encountered with PBL were: reduced control over content coverage, increased vulnerability, and increased teaching-related workload. There were also benefits discussed: contributed to the teacher’s professional development, allowed for continued assessment of self, became a tool to investigate teacher’s practices, and made teaching and learning interesting.

From the literature review, students and teachers/professors seem to favour PBL as a teaching method. With its disadvantages and advantages, PBL is an overall method that improves retention, motivation, and students' engagement. However, it does produce some concerns about time management. With further research, perhaps the drawbacks can be improved.

In pursuing the research project supervised by Dr. Lozinski, we have used the findings and comments of the literature review in the ArtsSci 2R03 class.

Methods

Participants and Procedure

The ArtsSci 2R03 course that was offered during the 2010-2011 academic year, was used as a control group. The students received traditional tutorials (question/answer format) conducted by a TA, and traditional lectures presented by Dr. Lozinski. The TA conducted 2 tutorials per week, to create smaller class sizes. The tutorial material followed lecture material, so students had the opportunity to reflect on what they learned in class, giving students the opportunity to come to tutorials with questions. For lectures, Dr. Lozinski would prepare material and present the lesson to the class.

The ArtsSci 2R03 course offered during the 2011-2012 academic year was used as an experimental group. This class consisted of 72 Arts and Science students who were mostly in second year; the remaining students were in third or fourth year Arts and Science. These students received PBL tutorials directed by three TAs, and traditional
lectures offered by Dr. Lozinski. There were three PBL tutorials per week, and each TA conducted one tutorial. Each contained 20 to 25 students who were randomly placed in a different small group of about four students each week. The TAs were senior undergraduate students who previously took the ArtsSci 2R03 course. The student researcher also attended most tutorials to assist the TAs and students. Here the TAs and student researcher acted as facilitators, and all three tutorials ran equally.

The PBL tutorials ran for 11 weeks. Ten consisted of PBL exercises, with one focusing on an introduction to Minitab statistical software. They took place in a computer lab, giving students access to the Internet and Minitab if they required either. On Friday and Monday tutorials, the tutorial material preceded the lecture content. The first half of the tutorial was devoted to PBL exercises, and the second half would run as a traditional tutorial. Due to time constraints, the PBL portion usually took up the majority of the tutorial. During the PBL portion the TA would present the students with a problem, often with multiple parts, at the beginning of class, and then the students would work in small groups of four or five to solve the problem. The groups changed each week so they had an opportunity to work with other peers. The second half of the tutorial, the solution to the exercise was discussed as a class and then additional questions assigned from the textbook were taken up. If there was not enough time for the TA to discuss the solutions with the class, the formal answers were provided to students upon request. The exercises, created by Dr. Lozinski, included topics on normal distribution, conditional probability, confidence intervals, and hypothesis testing. A sample exercise is provided in Appendix A. Students' solutions to the PBL exercises were simply graded for participation; the accuracy of their solutions had no impact on their participation portion of their final grade.

ArtsSci 2R03 2012-2013 class was also an experimental group that had PBL tutorials and traditional lectures. The course ran in similar function as the 2011-2012 class. Two of the TAs were the same from the previous year, and one was a third year student who had taken ArtsSci 2R03 in the previous year. Another difference between the classes was that all three tutorials preceded the lecture material, giving students the opportunity to solve real life problems before having learned the content in lecture. The purpose of this was for students to develop ideas so they can make connections of their own. PBL was an alternative to memorizing a formula given in lecture and placing number values to obtain a value. The lecture would then formalize their own ideas with notation and equations.

It should be noted that all survey question and feedback questionnaire results for both groups were confidential. Students were given a code and an administrative staff member in the Arts and Science department wrote this code at the top of the survey question. The researchers were not made aware which student corresponded to which
code. The students were entered into a $50 gift card draw as an incentive to fill out the survey question. They completed the retention question in a room by themselves and were given five to ten minutes to write an answer. Students signed a consent form, although if a student decided (or decides) to opt out of the study then their data was (or will be) deleted from the analysis. The study was reviewed and cleared by the McMaster Research Ethics Board.

Proper procedure was followed when obtaining approval from the McMaster Research Ethics Board. It should be noted that the principal researcher (Dr. Lozinski) is a teaching professor in the department of Mathematics and Statistics and a current undergraduate chair. Although having followed pedagogical research by others in the field, this was the first time that an independent investigation was conducted in the area of pedagogical research. Since he taught both the control and PBL classes, this eliminated a potential teaching bias because his lectures were set up in a similar format with similar lecture notes. The student researchers possess no prior experience in educational or pedagogical research.

Students were recruited with permission from the Arts and Science department. They were recruited via email by the faculty researcher and student researcher. The email provided all students with a general overview of the study, and informed potential participants of their right to decline participation or withdraw from the study at any time. To obtain the consent from students in the study, the faculty researcher asked permission of the Arts and Science department to contact the potential participants about the study. Upon receiving approval from Arts and Science department, the student researcher sent an email to all students of ArtsSci 2R03 Fall 2010 requesting their consent to participate in the study. The email informed potential participants of what they would be asked to do, as well as how the results would be used, and of their rights to withdraw. Participants could choose to withdraw even if they initially granted consent. If a participant chose (or will choose) to withdraw from the study at any point, any data collected regarding that participant was not used. Participants were also given the option of being emailed a summary of the results of the study upon completion of the study.

There were also potential risks that were brought to the attention of the Ethics Board. Participants might have generally felt uncomfortable with being asked to recall knowledge that they have not used in one year. Participants might have also felt unnecessary pressure about needing to do well on the experimental task with the idea that poor performance jeopardized their chances at employment as teaching assistants or in receiving letters of reference from Dr. Lozinski. To manage this risk the data was collected in such a way that protects the participants from identification. The potential participants were assured that neither the faculty nor the student researcher were able to associate the
results with any individual student. To be confidential, each participant who granted consent was assigned a randomized, two digit letter-number code (e.g.: F3) that was written on the top of their survey question sheet. This code was used by the faculty/student researchers to associate the results on the experimental test question with the students’ performance on a similar question on the final examination for ArtsSci 2R03. The students were entered into a $50 gift card draw as an incentive to fill out the retention survey question, and participants were still eligible for the gift card even if they decided to withdraw following the completion of the survey question. They completed the retention question in a room by themselves and were given five to ten minutes to write an answer. With this information the McMaster Research Ethics Board reviewed and cleared the study.

### Collecting Results

Retention was tested using a survey question that was administered twice to both groups of students one year apart; thus controlling for the time duration between the initial and retention question. The initial question was given to both the control and experimental groups during their final exam. An identically structured question acted as the retention survey question to control for the differences that may be due to unlike questions. Students were not given notification of the survey content, so it was assumed students wrote the retention survey question without preparation. The survey questions both dealt with conditional probability, and this was the chosen topic because students could answer using Bayes’ Formula or intuition. A sample of the initial question used is provided in Appendix B, and a sample of the retention question is shown in Appendix C. The survey question acted as a baseline measure for retention. The difference between the initial survey question and the retention question is a measure of declining knowledge one year after course completion. Dr. Lozinski graded the questions on an overall scale from 0-5.2. In addition, he graded students based on other criteria: if they attempted to use a formula and if they used it correctly, whether they showed understanding of the topic, and if they demonstrated reasoning skills. Dr. Lozinski used a check mark (√) if a student exhibited a criterion. If they did not show the criterion then the symbol of an x was used (✗); otherwise a dash (−) was placed to say he could not tell. These symbols were converted into quantitative data, where √=1 or 2, − = 0, and X = (-1) or (-2). The control group data and experimental group data were compared for these criteria, as well as retention. To eliminate a grading bias, a double blind procedure was used. Dr. Lozinski mixed the control group survey questions with the PBL group’s survey questions and graded both the initial question as well as the retention question at the same time. This way he was unaware of the group the survey questions came from. In addition, by grading everything in one sitting, the marks provided were consistent.

To improve future ArtsSci 2R03 courses, feedback questionnaires were presented to
the students in the 2011-2012 class regarding the PBL tutorials. One was given three weeks into the course, and another questionnaire was given at the end of the term. An example of the first questionnaire can be seen in Appendix D. These results were analyzed and changes to tutorials were made throughout the year. Changes have also been implemented for the ArtsSci 2R03 2012-2013 class. This particular class was also asked to fill out two questionnaires within the same time frames as the class in the previous year. The feedback questionnaire for the 2012-2013 class was updated and included multiple choice style questions instead of open ended questions that was seen on the 2011-2012 questionnaire. An example of the first updated questionnaire can be found in Appendix E. This change was implemented so the results could be analyzed accurately and students were more inclined to answer all questions. These results will help to develop the course for the 2013-2014 Arts and Science students.

To obtain opinions one year following course completion, three feedback questions were asked on the bottom of the retention survey question. The questions asked: if students recalled seeing the retention question in class, if the concepts from ArtsSci 2R03 helped them solved the question, and if other math or statistics courses they have taken might have aided in answering the question. The responses will assist in determining the benefit of the course and tutorials.

**Hypothesis**

We hypothesized that when compared to traditional lectures and tutorials, exposure to PBL tutorials will increase students’ retention of probability and statistics one year following course completion.

**Results**

We began by collecting and analyzing the data from the control group. There were 22 responses for the retention question, which was graded on an overall 0-5.2 scale. In addition, categorized answers with regard to other criteria graded with ✓, ✗, or – as mentioned above in the methods section. A table of the control group’s raw data can be found in Appendix F. From this, the average score on the initial question was 4.7 out of a total of 5.2, with a standard deviation of 0.7. When comparing this to the results from the retention question we saw that the average was 3.1 out of 5.2 with a standard deviation of 2.2. Figure 1 represents a scatter plot of the difference between the overall grades for the initial question and the retention question (initial minus retention grade). The red data point in Figure 1 shows the mean difference in grades was 1.6; with a standard deviation of 2.3. The retention question score increased in three students compared to their initial question score. Everyone else who completed both survey questions showed a decrease in the overall scores one year later.
The results from the other criteria that were graded by Dr. Lozinski, showed that one student in the control group used Bayes Formula correctly on the retention question. This compares to the initial question, when 14 students out of the 22 relied on the formula to solve the question. When relating the concept criteria, the amount of students who showed conceptual understanding decreased slightly from 15 students to five students out of 22. For the reasoning criteria, the average amount of students who showed reasoning ability increased from nine to 14 students.

Next, data was collected and analyzed from the experimental (PBL) group. This group had 9 responses for the retention question. A table of the experimental group’s raw data can be found in Appendix G. The table shows that the average score on the initial question was 4.8 out of a total of 5.2, with a standard deviation of 0.7. Relating this average to the results of the retention question we saw that the average was 3.9 out of 5.2 with a standard deviation of 2. Figure 2 represents a scatter plot of the difference between the overall grades for the initial question and the retention question. The average difference was 0.8, which is shown by the red data point in Figure 2. The standard deviation of the difference was 2.1. Two student’s grades increased from the initial question to the retention question. The remaining 6 students showed a decrease in the overall scores one year later.
Figure 2: Mean Difference in Overall Grade for the PBL Group

The results from the other criteria of the PBL group showed that none of the students in the control group used Bayes Formula on the retention question. On the initial question though, six students out of the nine relied on the formula to solve the question, using it correctly. When determining if students understood the concept of Bayes' Theorem, the average amount of students increased slightly from five to six. The number of students who demonstrated reasoning skills improved from three to eight out of nine. Table 1 shows the data from the other criteria. Overall the proportion of all students who correctly used the formula on the initial question was 20/31. This contrasts to the proportion that used the formula correctly on the retention question: 1/31.

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td></td>
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<tr>
<td>Reasoning</td>
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Table 1: Number of students who showed other criteria on the initial and retention questions
A two-sample pooled t-test for difference of population means was the statistical test administered to compare the data from the control group and PBL group. The difference between the grades on the initial question and retention question was used for the comparison. The averages of the differences were analyzed to determine if there was a statistically significant change between the two means. The common sample variance \((S^2)\) = 5.1, and the t-value\(=\frac{x-y}{\sqrt{\frac{(m-1)+\frac{z^2}{n}}{n}}}=0.9\). With the degrees of freedom \((df)=22+9-2=29\), the t-statistic was 1.311 at a 10% confidence level. Therefore the differences in means were not statistically significant because \(t=0.9 < t_{0.1}^{29} = 1.311\). The p-value, calculated from this t-test, also shows that the data was not significant since \(p = 0.19 > 0.1 = \alpha\).

**Discussion**

The difference between the initial survey question and the retention survey question was used to test student’s retention over the course of a year. A two-sample pooled t-test was used to compare the difference. The hypotheses were:

\[h_0: \mu_1 - \mu_2 \leq 0,\]
\[h_a: \mu_1 - \mu_2 > 0,\]

where \(h_0\) represents the null hypothesis of the study, and \(h_a\) represents the alternative hypothesis of the study. Here \(\mu_1\) = mean difference of the control group’s overall grades and \(\mu_2\) = mean difference of the PBL group’s overall grades. The alternative hypothesis suggests a difference between the mean decline in scores between the control group and the PBL group (mean grade of the control group and PBL group).

The two-sample pooled t-test was used to compare the data because the test provides an exact significance level with a smaller type 2 error. Therefore there is a slightly decreased chance of not rejecting the null hypothesis when the null is false, compared to the two-sample t-test (Devore, 2008). Since the pooled t-test is under the null-hypothesis, which suggests no difference, we can say the value of the variance in not significant because we are looking at the standard deviation within the samples. Based on the pooled t-test results and the p-value, the null hypothesis cannot be rejected at a 10% confidence level. It should be noted that the p-value of 0.19, tells us that there was a 19% possibility that the average overall difference in grades between the control group and PBL group occurred by chance.

When looking at the other criteria data, it is important to note that the majority of students (65%) used the formula on the initial question, and not on the retention question (3%). This suggests that students do not seem to remember formulas given to them a year.
before. It questions whether providing formulas to students is beneficial, since only a small proportion of students attempted to use or derive a formula on the retention question. Perhaps there is another method that can be used to teach students how to derive formulas, or show them the importance of understanding how a specific formula is developed. With regards to conceptual understanding, the proportion of students who exhibited this quality decreased between the initial and retention question for the control group and increased for the PBL group. This finding is interesting because it appears that students in the PBL group demonstrated greater understanding of concepts one year following course completion. Finally, reasoning scores increased for both groups, with a greater improvement in the PBL group. Although reasoning skills are independent from participating in PBL tutorials, it alludes to the fact that working in groups to solve problems may have taught students proper reasoning skills. This increases confidence when solving problems through further expression of ideas, which may lead to further conceptual connections. However, we surmise that the higher use of the formula in the initial question made for answers where reasoning ability was not demonstrated. Therefore, little can be said about the findings for the other criteria, which must be looked at with minimal focus.

With this said, the results are promising. The average grade of the retention survey question was higher for the PBL group when compared to the control group (3.8 in contrast to 3.3). This may suggest that the PBL group retained more statistical knowledge. In addition, the proportion of student's who showed understanding of Bayes' Theorem and reasoning skills was greater in the PBL group compared to the control group. The results from the concept criterion show a decrease in the proportion of students from the control group who understood the concept, with an increase in proportion from the PBL group over the course of a year. Therefore, students in the PBL group may have had greater recognition of the concepts from ArtsSci 2R03. This also may have contributed to improved reasoning skills on the retention question.

In reviewing the feedback questionnaire given in the beginning of the term to the ArtsSci 2R03 class of 2011-2012, there was a general consensus that PBL helped students think critically and overall assisted in their learning. Students enjoyed the atmosphere of working in groups and having the support of TAs. They also liked the aspect of thinking logically and critically, as they were given exercises whose content was not yet covered in lecture. Due to this, it was seen as a positive since they had to think about how to solve the problem without having a formula to memorize; which helped them to understand the concepts once they were taught. As one student said, “I really enjoyed that the tutorial material precedes the lecture, I always feel I have some understanding of the material and can follow the lecture well.” Common ways students suggested to improve the tutorials was having shorter or less exercises to complete in tutorial. As one student says, “There are so many questions to get through, it’s a bit overwhelming.” Another student made the
comment to go through the solutions to the exercises, or have access to the solutions online. Whether solutions were discussed after each exercise or at the end of tutorial, this was a common issue brought forth by the students. Some students also wanted to have a review of the material before going through the exercises, although this would contradict the application of PBL style learning. In addition two students wanted to see a clear connection with the lecture material.

The second set of feedback questions was given at the end of the term with additional questions to the first set. Figure 3 displays a bar graph with regard to the frequency of answers to the question: What worked well with the exercises? Here the students continued to enjoy working in groups because it allowed them to figure out solutions by bouncing ideas off of each other. Students benefited from the TA walking around to help them and receiving feedback on their process. As a student commented, “Helps having TAs circulate-can catch your major errors before going too far into the problem.” Students continued to feel that tutorials were assisting in their understanding of concepts. This involved having the material precede the lecture and reinforcing what was learned. Some students also mentioned that there were shorter questions towards the end of the term, which was a good improvement in the tutorials. The data from the second question (What could be improved with the exercises?) is represented in Figure 4. On this question a student felt that the exercises were not clear, and that there was too much time spent on group exercises. As in the first questionnaire, students still commented on the necessity of taking up solutions to the exercises at the end of tutorial. Although students liked having the TA walk around the room, some found that the TA wasn’t giving enough guidance. Part of this was because students want the TA to tell them when they were wrong. For example: "It is perfectly ok for us to be told that we are simply wrong-we don’t need to be told that we have ‘good’ or ‘interesting’ ideas if they’re not correct."
Figure 3: Frequency of Student’s Responses to the Question: What worked well with the exercises?

Figure 4: Frequency of Student’s Responses to the Question: What could be improved with the exercises?
In another question, which was not asked on the first questionnaire, students were asked if the tutorial helped with a specific test/assignment question. More than half of students agreed that it helped, especially with more challenging problems. We believe this was the case because the tutorials helped with understanding the concepts, which related to tests and assignments. When asked if the group exercises created any misconceptions about the material 15 students said no, one had said yes and three said some. Overall it appears that the students were not mislead or confused by the exercises given in tutorial. With the few who had some concerns relating to this topic, it was due to not having enough time to solve the exercises or working in groups of people whom they did not get along with. Time seems to be the main concern when using PBL. The final question students answered related to balance of tutorial time on small group work and other questions. 46% of students felt this balance was met at the end of the term, although 54% did not. Some felt it improved over the term, although there is still room for enhancement. Five students commented that tutorials spent too much time on group work and not enough time on answering questions or solving the tutorial exercises.

By addressing some of the concerns from the ArtsSci 2R03 2011-2012 tutorials, it seemed to improve the overall ArtsSci 2R03 2012-2013 student experience based on the first feedback. Students seemed to be enjoying the PBL tutorials, because they were fun and relaxed. There was a response rate of 50 students out of a possible 72 students who were enrolled in the course. The students were given seven possibilities to circle in response to: What is working well with the tutorials? It was noted that 40 students enjoyed working in groups during the tutorials. The second most common response was talking things out followed by thinking critically. The next question asked: What could be improved with the tutorials? Once again students were asked to circle as many answers that applied when given a possibility of seven responses. Overall, the most common circled response was more time on traditional tutorial help followed by answers spelled out in more detail at end. Therefore students were looking for answers to be taken up in more detail, with time also spent on a question and answer period at the end of class. For the ‘other’ section for this question, students commented that exercises should be more challenging, there should be strategies for approaching problems, and less group work to develop critical thinking.

The students also had the opportunity to provide additional comments on the feedback. Many comments were made with regards to the set up of the room; although this could not be changed in the middle of the semester. Many students suggested the TAs speak up, because it is hard to hear them at the back of the classroom. In addition, students seemed frustrated with the display when taking up the solutions. There were some students who did not seem to enjoy the tutorials as one stated: “I sometimes feel the smarter people in the group end up understanding quickly and * get me ‘problem-solving-
learning’ * its and I leave worried more confused then before.” Another student also made this observation and provided a potential solution, “Some groups I have been in have been very quiet, while others very productive→ maybe have the leaders play a more ‘active’ role in leading group discussions (could give them a sheet with discussion starters).” With this said there were many positive comments regarding the tutorials, as one student remarks: “I really enjoy the problem-based learning aspect of tutorials, it makes the course content very appealing to learn.”

Following the comments made on the first set of feedback questions for the 2012-2013 class, improvements were made regarding the volume level of the TAs, zooming into the answers to provide better visual presentation, and increasing the level of difficulty of the exercises. There was a response rate of 28 students out of a possible 72 students for the second feedback from ArtsSci 2R03 2012-2013. The first question simply asked students when their tutorial took place. The purpose of this question was to see if there was a difference between Monday and Tuesday tutorials. The second question asked students how many tutorials they have missed, to give an accurate analysis of the data collected from the feedback. In the third question students were asked: What worked well with the tutorials? The trend of this data can be seen in Figure 5, indicating that 17 students enjoyed working in groups during the tutorials and also understood the concepts better. One student commented that they enjoyed teaching concepts to other members in the group, which helped them check their understanding. The probable reason why ‘discovering concepts did not receive high prevalence was partially due to Tuesday’s tutorial. Since the material from the Tuesday’s tutorial sometimes followed lecture material, Tuesday tutorials did not always allow students to discover new concepts. A student from the Tuesday tutorial mentions, “Being in the Tuesday tutorial, the material we were supposed to ‘discover’ was usually learned that morning, hence our tutorial probably lacked this ‘discovery element. But this helped us apply concepts on our own and reinforced learning, like a traditional tutorial.” Therefore, the students still seemed to benefit from the reinforcement of concepts. The graph of the fourth question is displayed in Figure 6, asking students: What can be improved with the tutorials? Overall, the most common circled response was more guidance from the TA. One student said, “[The] TA should be more involved in a larger capacity than just taking up answers.” In the beginning of the term students wanted answers to the exercises to be taken up in more detail, and this was achieved. In comparing both questions, there were 74 responses circled for question three and 59 responses circled for question four; showing a general positive experience in the PBL tutorials.
**Figure 5:** Frequency of Student’s Responses to the Question: What worked well with the tutorials?

**Figure 6:** Frequency of Student’s Responses to the Question: What could be improved with the tutorials?
Another question, which was not asked on the first questionnaire, asked if the tutorial helped with a specific test/assignment question. 68% of students agreed that it helped. They found it assisted in their understanding of concepts of tests/assignments rather than specific questions. Therefore, the tutorials prepared students for the assignment and test questions. When asked if the group exercises created any misconceptions about the material 27/28 students said no. Students said they were not mislead or confused by the exercises given in tutorial because the solutions to the exercises or challenging test questions were solved at the end of class. Similarly to other feedback questionnaires, time seems to be the main concern when using PBL. Finally students circled yes or no if they felt there was a balance of tutorial time on small group work and other questions (traditional tutorial). 36% of students felt this balance was met at the end of the term, and 64% did not. This shows there is still opportunity for improvement because the previous years feedback also suggested that the balance was not met. The reason students felt there wasn’t a balance between traditional tutorial time and group work was due to the lack of questions. However, one student honestly wrote: “Often most students didn’t have questions (question period was during the last 5-10mins of the class).” Since the TAs did not have questions to answer in relation to the textbook examples or assignment/test questions, the majority of the tutorial time was spent on group work. This was an improvement from the 2012 PBL tutorials because they were given the opportunity to ask questions related to the course content.

The students provided additional comments on the feedback, which was very useful. Overall they were positive and the negative comments about the logistics of the room and low volume of the TA’s voice did not appear in the end of term feedback. One student remarks: “Overall I felt the tutorials were both helpful in understanding course content and a good guidance for the course.” With this said, some students had a more critical view of tutorials.

An example of this was the comment made by a student:

“Personally, I would have preferred solo work rather than group work. I think I would have benefitted more from looking through my notes and trying to work things out on my own. I am also confident that I would have found traditional tutorial time extremely useful. Lectures are fast-paced and full of information. Reinforcement other than through collaborative work would be beneficial.”

We believe that part of the concern with working in groups came from a decrease in student motivation to complete the exercises towards the end of the term. This might have impacted the mood of other group members. A students expands on this by saying, “I really liked the problem-solving aspect of tutorial. Very rewarding to ‘discover’ concepts.
However, the culture became ‘I don’t understand so I’ll just wait for the TA to tell us the answer,’ which was disappointing.” Students would rather wait until the end of tutorial for the answers, which tells us that the students do not see the benefit in PBL. They would rather think the way the TA or professor wants them to think and thus they emulate the TA. A reason for this might be low attendance rates, which may have caused students to fall behind with the material. Dr. Lozinski noted that the ArtsSci 2R03 2012-2013 class appeared to have the lowest attendance and motivation rates (asking questions) in lectures compared to past years, which could be the result of 8:30am classes. Therefore the students might have been confused when attempting the PBL exercises.

Overall, the feedback seemed to be more positive than the feedback from the previous year of study. This shows that the changes that were implemented for the 2012-2013 school year, have made a positive impact on the students. Through further modifications (listed in the recommendations section), ArtsSci 2R03 will become a class which students will enjoy attending, while retaining important statistical knowledge.

Students also answered feedback questions presented on the bottom of the retention survey question; as mentioned in the methods section. The first illustrates that 12 students from the control group and five from the PBL group recalled solving a similar question, to the retention question, in class. The data implies that most students remembered completing a conditional probability question in tutorial or in class, and the remaining students either did not reply or were unsure. Students were then asked to what extent they felt they were able to use concepts learned in ArtsSci 2R03 to answer the retention question. In the control group, one student commented, “I don’t feel I used many concepts from class to answer this question because I don’t remember how I was supposed to do it.” There were many students in the control group who felt this way. There were also many students who simply said they used reasoning and logic to figure out how to solve the problem, even though they recalled doing a similar question in the past. For the students who mentioned the use of a formula, all said they could not remember it (even the one individual who used it correctly). All students in this group made the comment that they could not remember how to solve the question and/or that they were not able to use the concepts learned in ArtsSci 2R03. Only one student said the course helped distil the problem at hand.

In comparison, the PBL group mentioned that the course gave them more confidence to answer similar questions, as one students writes:

“I feel like the concepts in 2R03 helped me to analyze the form of the question to distil what I needed to find, but I got to answer using applied general reasoning (but this
might be due to a recall bias, so all in all I think 2R03 was quite helpful, at least in improving the confidence in my solution.”

In general, students from the PBL tutorials felt more comfortable answering the retention question because they were exposed to many problem-solving questions during the year. As was seen in the control group, many students commented that they used common sense or logic to answer the problem. It is interesting to note that only one person in the PBL group mentioned the use of a formula, which suggests that the retaining conceptual knowledge (the goal of PBL) may be of more importance to them.

The overall PBL feedback results were positive and students seemed to gain confidence, life skills, and enjoyment from group work. However, with the lack of statistically significant data little can be said in terms of the differences in overall grades and other criteria. The low significance may be due to biases and limitations in the study.

**Biases and Limitations**

Possible biases should be mentioned, because these could have affected the results of the study. First, there were selection biases: under-coverage and nonresponse, because the samples in the control and PBL group failed to include all of the target population (the entire ArtsSci 2R03 class of 2010 and 2012) in the sampling frame (Lohr, 2009). This is due to some students being unreachable if they do not check their email or use it anymore, some may refuse to respond and come into complete the survey question, or some may be unable to respond if they already graduated or transferred schools/programs. Since we were relying on students to come into take the retention question by choice with a chance to win a $50 gift card to Title Bookstore, some students may have felt that was not enough incentive to come in and complete the retention question. Also, students may not have come in because of the timing; the retention question was administered during the midterm season for most students. Therefore, part of the target population was not sampled. Having nonresponses distorts the results of many surveys because non-respondents tend to differ critically from the respondents (Lohr, 2009). It is unknown the extent of this difference, but difficult to conclude anything about the greater population with only 13% of the targeted population being represented (Lohr, 2009).

Another possible bias was sampling error. This is due to taking one sample from the population instead of the whole population. Similar to above, by taking a different sample the results may have been different (Lohr, 2009). The sample of students who completed the retention question may have been interested in the study or felt confident in their statistical knowledge. These particular groups may have also had a higher intellectual capacity, though it cannot be fully known.
A possible limitation in the study was testing different students over the course of three years. Therefore students in one particular year may have had a different intellectual ability, reasoning capability, etc. It was decided to separate the control and PBL groups into different years to be consistent to everyone taking the course; this way all students in the same year received the same education, so their grades were not affected. To try to compensate for this, Dr. Lozinski was the professor for all three years and used similar lecture notes and tests.

Considering other possible limitations, we should refer back to the final feedback question given on the retention survey question. Some students had greater mathematical or statistical knowledge from previous or current courses, which may have influenced their performance with an increase in the overall grade or other criteria on either the initial or retention question.

The final limitations consisted of extraneous variables. The first variable may have altered the results because it was not consistent in both groups. The control group had one TA and two tutorials (attendance in one was optional) for the entire class of 55 students, and students were not required to attend tutorials. This differs from the PBL groups because they had three different TAs and three different tutorials (attendance in one was mandatory); thus making the tutorials small. Since the TA from the control group differed from the TAs for the PBL group, they may have had different styles of teaching. Furthermore, the second extraneous variable produced variances in attendance between the control and PBL groups. The optional control group tutorials created varied attendance, while the mandatory PBL tutorials emitted consistent attendance. One final variable may have impacted student’s learning in the first PBL group. The first student researcher (Alexander) attended and assisted with the first PBL group’s tutorials, which was equivalent to having two TAs per tutorial. Therefore the tutorials were not fully controlled due to these extraneous variables. To minimize the effect that was not in the researchers control, the TAs and student researcher met each week to discuss the take home message for the students and how to effectively run the tutorials.

We believe that the data was not statistically significant due to these biases and limitations. The main factor that affected the study was the small sample size (nonresponse) of the PBL group, which happened to differ from the control group. Larger and similar sample size for both the control and PBL groups would give a better prediction and generalization of the findings for the general population. Although biases and limitations cannot be completely eliminated, they can be reduced. With the following recommendations, the biases of the study could be condensed and applicable to the general population, or at least to the ArtsSci 2R03 class.
Recommendations and Next Steps

Although many aspects of the study were controlled, there were other factors that led to biases and limitations in the data that could have been controlled. The first recommendation to avoid the main bias in the study is vital since sample size is important in obtaining accurate results. To increase the response rate for the retention survey question, it should be given during a break in the student’s academic life with a greater incentive for completion. This could include administering the retention question during reading week or during the exam ban week, while providing students with a larger sum of potential winnings. To avoid or minimize the testing of different cohorts, it would be beneficial to split one group of students from the same course and year into a PBL and control group. This would give more accurate findings, which controls for other factors. Unfortunately the next limitation (imbalanced mathematical/statistical knowledge) cannot be controlled. Students have the option to minor or specialize in math, thus they may take further studies relating to ArtsSci 2R03 before or during the time they participate in taking the retention question. Also, students are not required to take data management in high school, and the ones who do may have an advantage since they have come across some material before. A final recommendation for future studies would be to use a consistent amount of the same TAs while making the tutorials mandatory for both groups. This way, the extraneous variable with regards to teaching style, imbalanced TA-student ratio, and inconsistent attendance can be eliminated. The implementation of these changes to future studies will presumably increase response rates, eliminate the extraneous variable, and control for cohorts.

To increase the value in the course, there are some recommendations based on the feedback that can be used in future PBL tutorials. The tutorial exercises can be graded for participation marks and handed in before the TA takes up the solutions. This way students are given an incentive to work on the exercise before the TA takes up the solution. Also, when the TA walks around the room, he/she can observe and encourage students to answer the question. Another recommendation is to make the exercises relevant to a student’s life, thus strengthening their motivation and engagement in tutorial. Finally, since time is one of the disadvantages of PBL, setting additional time for tutorials (or PBL exercises) will diminish the rush experienced towards the end of class.

Next steps for the study will follow the above recommendations in the ArtsSci 2R03 2013-2014 class. Before this occurs, the current PBL group will complete the initial survey question this April that is on their mandatory exam. Dr. Lozinski will grade the questions and have the same group come back April 2014 to fill out the retention survey question. In using the recommendations, we hope that there will be a higher presence of students coming to fill out the retention question. The data will be collected and analyzed to
compare the differences between the control group and experimental groups. While data analysis is proceeding, Dr. Lozinski will lead a new group of Arts and Science students through the second year statistics course with the goal to foster retention.
Appendix A – Sample PBL Exercise

Small Group Exercise 2: Conditional Probability

Suppose the Arts and Science dept and the Engineering dept have been teaming up to pick one random second-year student to be "student of the day" each day since the beginning of the term (5 days a week for 12 weeks). Each day they roll one die to choose which department the student will come from. If they roll a "1", a random Arts and Science student is selected, any other number and it's a random student from engineering. Students could be randomly selected multiple times. The percentage of women in the engineering department is "p".

a) On how many days do you expect the student to be female?

b) If today's student is a female, what is the probability she is from Arts and Science?

c) If this program ran for only x days, and today's student was female, what's the probability that she is from Arts and Science? Does the value of "x" change your answer?

d) Suppose this ran only once, for one day. If today's student is female, what is the probability she is from Arts and Science?

e) If A is the event that the student is chosen from Arts and Science, and B is the event that the student chosen is female, can you write a formula for your answer?

f) Suppose there were 5 departments involved, with A1 being the event the department chosen was Arts and Science, and A2 through A5 being the events that each of the other departments were chosen (B still being the event the student is female). If today’s student is female, write a formula for the probability she is in Arts and Science.
Appendix B – Initial Question Delivered during the Exam

11. [5 marks]
At a popular picnic area, free cans of Copsi cola have been handed out to 4% of the people present. Assume that 90% of those people are still carrying around those cans. Of the people that did not get a free can, 6% of them are carrying cans of Copsi that they bought for themselves. If you find that a random individual is carrying a can of Copsi, what is the probability that it is one of the free cans?
Appendix C - Retention Question Delivered One Year after Completion of Course

Question:
At the train station, free local newspapers have been handed out to 5% of the people present. Assume that 90% of those people are still carrying around those newspapers. Of the people that did not get a free newspaper, 8% of them are carrying copies of the newspaper that they bought for themselves. If you find that a random individual is carrying the local newspaper, what is the probability that it is one of the free papers?

Please provide some additional honest feedback:
Do you remember learning how to do a question like this in ArtSci2R03?

To what extent do you feel that you were able to use concepts learned in ArtSci2R03 to answer the question?

Please provide any additional comments that you feel may be of use in interpreting answers, including the nature of any additional courses you took this last year that you feel have influenced your situation. Thank you for your participation!
Appendix D – First Feedback Questionnaire for ArtsSci 2R03 2011-2012

Feedback on Small Group Learning in the tutorials:

What is working well with the exercises?

What could be improved with the exercises?

Additional comments:
Appendix E – First Feedback Questionnaire for ArtsSci 2R03 2012-2013

Feedback for ArtsSci 2R03 Tutorial

This feedback will be used to better enhance ArtsSci 2R03 in the upcoming classes.

Q1) What day is your tutorial? (Please circle one):

1. Monday
2. Tuesday

Q2) What is working well with the tutorials? (Please circle all that apply):

1. Working in groups
2. Thinking critically
3. Understanding concepts better
4. Discovering concepts
5. Challenging
6. Talking things out
7. Other (Please specify): ________________________________

Q3) What could be improved with the tutorials? (Please circle all that apply):

1. Shorter exercises
2. More exercises
3. More time on traditional tutorial help
4. More feedback during group work
5. Answers spelled out in more detail at end
6. Answers left more open
7. Other (Please specify): ________________________________

Q4) Additional Comments:

_______________________________________________________________________________________
_______________________________________________________________________________________
_______________________________________________________________________________________
_______________________________________________________________________________________
### EFFECTS OF PBL ON RETENTION

#### Appendix F – Raw Data, ArtsSci 2R03 2010-2011 Cohort

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**Average**: 4.7318182  
**Variance**: 0.4545455  
**Standard Deviation**: 0.7378839  

Legend for Other Criteria (formula, concept, and reasoning):

-1 or -2  The quality was lacking in their work
0     No indication
1 or 2   Exhibits the quality

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**Average**: 3.109909  
**Variance**: 0.863636  
**Standard Deviation**: 2.3344076
### Effects of PBL on Retention

Appendix G - Raw Data, ArtsSci 2R03 2011-2012 Cohort

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**Student Codes:**

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**Average:**

- Grade: 4.755556
- Formula: 0.666667
- Concept: 0.555556
- Reasoning: 0.333333

**Variance:**

- Grade: 3.975
- Formula: 0.5452778
- Concept: 0.555556
- Reasoning: 0.333333

**Standard Deviation:**

- Grade: 1.9937402
- Formula: 0.7384293
- Concept: 0.333333
- Reasoning: 0.333333

**Legend for Other Criteria (formula, concept, and reasoning):**

- [-1] or [-2] The quality was lacking in their work
- 0 No indication
- 1 or 2 Exhibits the quality

### Appendix G - Retention Chart

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References


Ribeiro, L. (2011) The Pros and Cons of Problem-Based Learning from the Teacher’s


Vidic, A. (2010). The Impact of Problem-Based Learning on Statistical Thinking of Engineering and Technical High School Students. *International Association of Statistical Education (IASE)*. Available at: www.stat.auckland.ac.nz/~iase/

