Project-Based Learning in College-Level Statistics: Performance Analysis and Lessons Learned

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Abstract

The statistical awareness for a college-level student is critical in the era of a data-driven world. Unfortunately, research indicates that college students in need of serious support to grasp concepts in statistics class. This study discusses the success of an attempt to improve college-students 'statistical knowledge' by teaching the concepts through a project-based approach. Based on the findings of the quasi-experimental research, students who experienced project-based learning have significantly improved their knowledge compared to those who were exposed to the traditional teaching approach.

1. Introduction

Proper knowledge of statistics and probability is essential in various fields, such as science, engineering, economics, and social sciences. In addition, statistical knowledge is essential in daily activities as it improves critical thinking and reasoning abilities [19]. Hence, providing proper statistical education and the required training has become increasingly important within individual disciplines and across disciplines [12].

In a data-driven world, critical thinking and quantitative reasoning is considered increasingly important. Unfortunately, it is reported that the majority of people are not comfortable reading statistical data, mainly due to the statistical anxiety they experience [7]. Research findings showcase the issues and difficulties students experience with understanding statistical concepts [2]. Not only conventional students but even teaching preservice primary teachers with statistics is considered a complex endeavor [11]. Though there may be numerous reasons for students to find statistics challenging, the type of instructional technique also has a direct impact on students understanding [18]. Applying a student-centered active instructional approach will enable the elimination of most of the issues students find with statistical education, as such an approach has proven to be effective in improving the students' achievement levels in reading, math, and science [15]. Learner-centered is also called student-centered instructional approach, contrasting to the traditional approach in which the instructor is the primary authority and disseminator of knowledge. In such an approach, the main emphasis is the student's active participation in the learning process by personalizing education to meet their educational needs, interests, and learning styles. Literature provides evidence of the significant impact of the student-centered approach on student motivation, active engagement, and enhanced learning outcomes [9].

Project-based learning (PBL) is another student-centered instructional tool that has shown positive results in students' understanding of various domains [10]. PBL is characterized by engaging students in hands-on projects that require active inquiry, collaboration, and real-world problem-solving, while the focus of the traditional approach is to provide instructions through lectures, rote memorization, and individual assessments. The former is an active learning approach emphasizing skill development and practical application, whereas the traditional approach is passive and prioritizes content mastery and standardized testing.

This study discusses the successful findings, students' experiences, and the lessons learned after applying the PBL approach in a college-level statistics course. The rest of the sections are arranged as follows. Section 2 discusses the findings of the literature, while Section 3 discusses the methodology of this study. Section 4 provides the results, and section 5 discusses the challenges met while executing the project and the lessons learned. Finally, section 6 discusses the results and concludes the manuscript.

2. Literature Findings

Project-based teaching can improve students' knowledge in significant disciplines and improve student development. A study conducted by Balleisen [1] examined student development by cooperating project-based teaching at an undergraduate level. According to their experimental outcomes, the project-based approach allows students to explore and deepen the student's academic interests, build novel relationships, and sharpen future career-related skills. Using a group of students from an undergraduate civil engineering course, Paleenud [16] conducted an experimental study to identify what aspects of both project-based and lecture-based instructional methods help students to "deep" and "surface" approaches to student learning.

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The project-based approach is not limited to the in-class instructions; this can be effectively applied outside of the classroom using various tools to provide opportunities to gain knowledge about life-related issues [4, 13]. One such instance can be seen in the literature of using the project-based instructional approach to evaluate how internship opportunities impact students' motivation differently on male and female students [3].

Student collaboration at graduate school is imperative for a proper academic experience, as it provides various benefits for learners to develop essential skills. A project-based approach can be effectively used to improve students' collaboration skills, including interpersonal, interdisciplinary, and conflict management skills [8].

The focus group of project-based applications is only sometimes the students at the K-12 level or college. In an attempt to study how teacher's experience impacts the implementation of project-based teaching, Rogers [17] examines to what extent teachers' professional experience in teaching mathematics and science impacts when implementing PBL in the classroom.

A project-based instructional approach can be effectively used even in disciplines with laboratory components, such as Biology, to improve students' self-confidence in laboratory technical skills [14]. A comprehensive discussion of the application of project-based learning in science and physics is available in [6].

Based on the findings of the literature, it is evident that more studies are needed on the direction of using project-based learning in teaching statistics.

3. Methodology

This section discusses the adopted methodology and highlights the steps taken to collect data.

3.1. Research Design

Quasi-experimental research was designed to study the effectiveness of the PBL approach to teach this college-level statistics course. The study comprised three stages: pre-intervention, intervention, and post-intervention. In the pre-intervention stage, pre-testing was conducted to test the student's initial knowledge about the content of the course. In the investigation stage, a project-based approach was used to teach the experimental group, and traditional teaching was used for the control group. In the post-intervention, post-tests and student surveys were administered. The main research questions of this study were to identify how effective the PBL approach is in teaching this statistics course and how students experience this instructional approach.

3.2. Probability and Statistics Course

Probability and Statistics is a three-credit course offered by the Department of Mathematics at Prairie View A&M University. This course is offered in both fall and spring. Usually, there or four sections of the course offered each semester, and two instructors teach these sections. The course comprises of topics such as probability, random variables and their distributions of discrete and continuous types, descriptive statistics, and inferential statistics. The average class size of this course is about 30 students.

3.3. Designing Projects

Instructions for the experimental group were conducted by designing five project assignments designed to cover topics of probability, distributions of random variables, descriptive statistics, and inferential statistics. Content of these projects were from different areas, such as biology, computer science, engineering, and nutritional science. Each project assignment was designed based on the recommendations provided by the Guidelines for Assessment and Instruction in Statistics Education (GAISE) Reports, which focuses on statistical thinking, the use of accurate data, promoting conceptual understanding and active learning, data analysis, and interpretation of statistical findings.

3.4. Data Collection and Intervention

Data collection was done in the year 2022 spring and the fall semesters. At the beginning of both semesters, pre-tests were distributed to the students in all sections of this course. One section out of the three sections offered in the spring was selected as the experimental group, while in the fall, two sections (one from each instructor) were selected out of the four sections offered as the experimental group. In the spring, there were 82 students in which 29 were from experimental group. In the fall, 76 students and 47 were in an experimental group.

Instructions were provided in the traditional way for the control group, while for the experimental group, the project-based approach was followed. Five projects designed using the GAISE recommendations from five different subject areas were utilized to teach the experimental group.

Each student was given three exams in both groups, and the final exam was administered at the end of the semester. All the grades were recorded for the analysis. In addition, a voluntary survey was distributed to students to gather their experiences with the project-based teaching approach.

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4. Results

The total of seven sections offered from this course in spring 2022 and fall 2022 are summarized in Table 1.

Table 1. Offered seven sections

Label	Semester	Group	Instructor
Section 1	Sp 2022	Control	1
Section 2	Sp 2022	Exp	1
Section 3	Sp 2022	Control	2
Section 4	Fall 2022	Control	1
Section 5	Fall 2022	Exp	1
Section 6	Fall 2022	Control	2
Section 7	Fall 2022	Exp	2

4.1. Impact of the Project-based Approach

Figure 1 illustrates the changes of the pre and post scores in each section. Pre-scores are represented in "green" dots, while post-scores are represented in "red" dots.

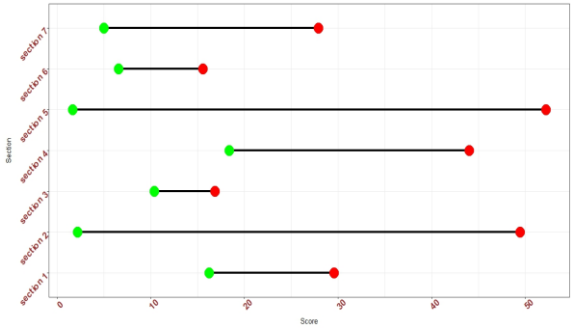

Figure 1. Changes of the pre and post test scores

A two-way ANOVA was conducted using the two factors of section and score (pre- and post-scores). According to the two-way ANOVA, the section number significant impacts on the students' score, $F(6, 282)=18.82$, $p<0.001$. Similarly, there is a significant difference between the post-test and the pre-test scores, $F(1, 282)=351.12$, $p<0.001$. Furthermore, there is a significant interaction effect, $F(6, 282)= 26.06$, $p<0.001$.

Based on the Tukey analysis, scores in sections 3 and 6 are significantly lower than in section 1. Scores in section 2 are significantly higher than in sections 3, 6, 7. Scores of sections 4 and 5 are significantly higher than section 3. Sections 6 and 7 are significantly lower than section 4. Section 7 has significantly higher grades than section 5.

Four exam grades for each section were recorded. Figure 2 illustrates exam grades 1, exam 2, exam 3, and the final exam for project-based learning (PBL) and the traditional instructional approach (NoPBL).

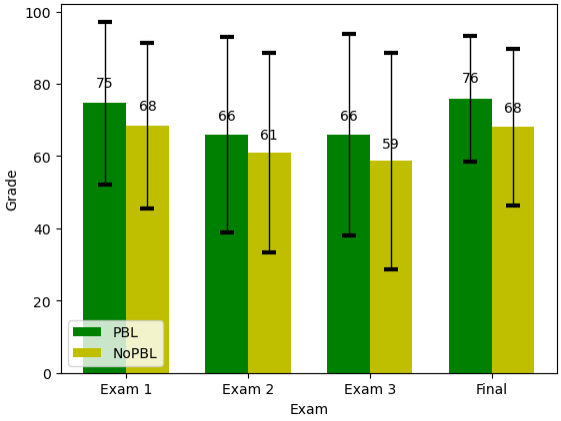

Figure 2. Exam scores for both PBL and NoPBL

Table 2. ANOVA results about exams

Exam	F(6,172)	p-value	Sig. Sections
1	1.7579	0.1105	
2	4.5274	0.0003	Sec 1> Sec 2 Sec 1> Sec 6 Sec 5> Sec 2 Sec 5> Sec 6
3	3.2312	0.0049	Sec 5> Sec 2
4	2.5349	0.0223	Sec 2> Sec 7

According to the ANOVA with exam grades, (as Table 2 indicates) there are no significantly different performances among the sections for exam 1. For exam 2, section 1 has significantly higher averages than sections 2 ($p=0.022$) and section 6 ($p=0.001$). Section 5 has a significantly higher average than sections 2 ($p=0.043$) and section 6 ($p=0.001$). This is illustrated in Figure 3. For exam 3, the average of section 5 is significantly higher than section 2 ($p=0.05$), and for the final exam, the average of section 2 is significantly higher than that of section 7 ($p=0.025$).

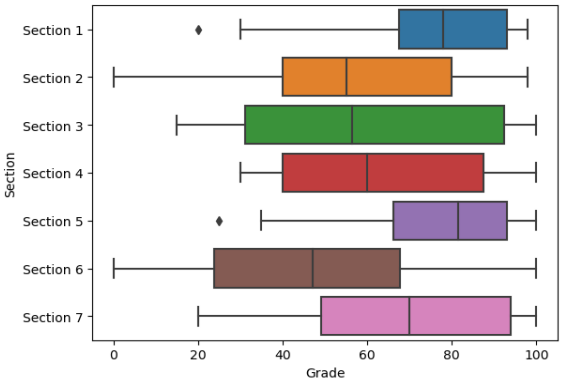

Figure 3. Exam 2 grades for all sections

4.2. Student-feedback Survey Results

The students' experience of PBL was collected

using the voluntary feedback survey. In addition, they were asked to rate their experience and state what they liked and did not like about the teaching approach.

According to this survey, over 40% rated their PBL experience as “Excellent” and 50% rated it as “Good”. About 5.9% were undecided about their opinion while the remaining 2.9% were not happy about the PBL approach. Figure 4 summarizes the students' rating of their PBL experience and their majors. In the survey, another question asked was "What do you like about project-based learning in this class?".

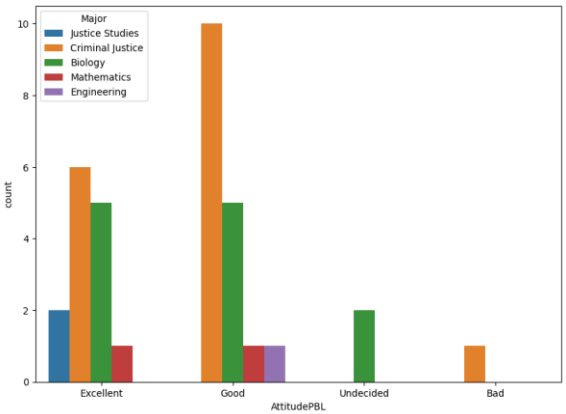

Figure 4. Students’ satisfaction with PBL

The majority of the students who experienced PBL stated the following about the PBL approach. Easy to learn, no stress, chance to work on projects, opportunity to learn statistical s/w, ability to learn from peers, and solving practical problems are the notable things they experience with PBL approach.

5. Challenges and Lessons Learned

During the execution of this project, several challenges were encountered. One of the main challenges was the impact of the COVID-19 pandemic. Due to this, arrangement of the lab sessions and conducting group work were hindered. In spring 2022, we offered only three sections due to the low enrollment of students. If we were able to offer additional sections during the spring and fall of 2022, we would have executed the PBL in more sections. Another challenge was the time management. This was mainly due to the time taken with the lab sessions with the PBL instructions. Compared to the traditional instructions, significant time was lost in executing the project assignments that were planned to be done using the statistical software. Other issues hindered the project's progress were technical issues with the computers and software issues.

Proper planning before executing project-based learning is the key to success. It is vital for both the faculty and the students to understand the principles of the PBL. We realized that it would have become more productive if the students had understood this study more so that the process would run smoothly. In a similar project in the future, organizing a workshop or a separate information session would be a better way to overcome such an issue. With such an attempt, both students and the faculty would be on the same page, which would enable us to proceed according to the deadlines set up at the beginning.

6. Discussion and Conclusion

The pre-scores shows that students in sections 1 and 4 had higher prior knowledge of the course, and they progressed well with their knowledge at the end of the course. Though sections 2, 5, and 7 had low prior knowledge, they have progressed significantly well with the project-based instructions. Overall, sections that were given project-based instructions indicated significantly improved performance.

Based on the ANOVA analysis of the exam grades, the grades of exam one did not change across each section significantly, the rest of the exam grades changed. The exam two grades changed significantly across the sections. Sections 1 and 5 have shown significantly higher grades than 2 and 6. Though section 5 indicates better performance in exam 2 compared to section 1, it is not statistically significant. Even in exam 3, section 5 showed significantly better grades than section 2. Overall, sections 2, 5, and 7 showed higher performance in both the improvement of post-test grades and individual exam grades than the rest of the sections. As the exams were designed to test students understanding the statistical concepts, we can assume that students who experienced PBL showed higher understanding about the statistical concepts. Furthermore, as over 90% of students who experienced the PBL approach enjoyed the course. This indicates that PBL creates a good environment that improved student understanding in a student-friendly manner.

While seeing the success of this project, it is noteworthy to state the uncontrollable issues, such as the impact of COVID-19 and technical and computer laboratory issues that hindered the progress of the successful completion of this project.

Finally, PBL can be considered a productive student-centered approach to teaching statistics. Notably, careful planning, professional development, and a supportive learning environment can mitigate the challenges faced when implementing project-based learning.

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