

A Comparative Study of Teaching Methods in Undergraduate Biostatistics Using Regression and ANOVA Techniques

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ABSTRACT

Purpose: This study aimed to compare the effectiveness of different teaching methods used in undergraduate Biostatistics courses and examine how instructional approaches influence student performance, engagement, and perceptions. It also sought to identify key predictors of Biostatistics achievement. **Method:** A comparative research design was used with a sample of 200 undergraduate students equally divided between a traditional lecture method group (Method A) and an alternative teaching method group (Method B). Data were collected through performance scores, validated engagement and perception scales, and demographic information. Analyses included descriptive statistics, ANOVA, t-tests, and multiple regression using SPSS. Reliability of scales ranged from 0.84 to 0.91. **Findings:** Results showed that students taught through the alternative teaching method scored significantly higher in Biostatistics performance, reported greater engagement, and held more positive perceptions of instructional effectiveness. ANOVA confirmed significant performance differences between methods, and regression analysis identified teaching method, engagement, perception, attendance, and prior GPA as significant predictors of student achievement. **Originality/Implications:** This research contributes empirical evidence supporting active-learning and student-centered pedagogies in quantitative education. The findings highlight the need for instructors and curriculum designers to adopt interactive, application-based teaching approaches to improve learning outcomes in Biostatistics and related subjects.

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1. Introduction

Biostatistics is now a fundamental element in undergraduate life sciences, health sciences, and public health programs as well as in programs in allied sciences (C. Li et al., 2024). As the importance of evidence-based practice, biomedical research, and decision-making founded on data continues to grow, undergraduate students are supposed to learn good statistical arguments and analytical reasoning at a very early stage of their educational process (Husar & Gašpar, 2023). Generally, biostatistics education is the knowledge of the concept of statistics, the usage of statistical techniques in biological and medical data and the interpretation of the findings in a meaningful manner (Hebeisen et al., 2025). Nevertheless, biostatistics is a problem that is still developing in the global sphere because of the preconceived anxiety of maths by the students, insufficient background to be familiar to quantitative courses, and being unable to relate the abstract statistical principles to the biological life (Chen, 2024). With the ongoing changes in programs, the urgent concern of educators is the adoption of their teaching method that would facilitate the degree of conceptual knowledge, encouragement of the active learning process, and adequacy of statistical instruments in solving the real research problem in students (Ordak, 2025). This situation highlights why biostatistics teaching in the undergraduate degree should be subjected to critical analysis.

The selection of effective approaches to teaching biostatistics is crucial due to the specifics of the topic since the subject does not only entail memorization of formulas; it also demands a clear understanding of the subject matter, the ability to solve problems, and practical implementation (Ordak, 2024). Conventional lecture based teaching, as popular as it is, may not adequately meet the needs of the various students in terms of their learning, or may not be effective at

promoting the higher of cognitive learning (Saha & Paul, 2023). Other pedagogies like collaborative learning, flipped classrooms, project based learning, technology enhanced learning, and simulation based exercises have been found to enhance student engagement, anxiety and performance on quantitative subjects (Lutz et al., 2025). Efficient instructional strategies also allow closing the divide between the theoretical and practical knowledge and make sure that students gain the skills of using statistical software, interpreting data, and thinking critically (Riyanto et al., 2023). The role of instructors thus is very important in choosing pedagogies which do not only make a complicated concept of statistics easy to understand but those skills that will be useful to the students in future research and in their professional practice.

Despite the implementation of different methods of instructions in undergraduate biostatistics, empirical evidence regarding the effectiveness of such approaches in enhancing learning outcomes in the students is limited (Sullivan, 2023). Most of the studies concentrate on one teaching method in isolated cases where it is hard to find out which strategies are effective in a wide range of students (Riyanto et al., 2023). Besides, a lot of available literature lacks the focus on the multidimensionality of learning, i.e., understanding of concepts gained by students, their motivation, statistical reasoning confidence, and possibility to use the biostatistical instruments to work with real data (Haycox & Tumin, 2024). Moreover, circumstances like the size of the classes, the experience of the instructors, the technology used, and the previous knowledge of the students are usually not addressed (Hosseini-Baharanchi et al., 2024). Due to this, teachers are not given the proper direction on how to choose the best approach to use in the classroom setting. The following gaps demonstrate the necessity of the comparative research, which would assess several teaching approaches at the same time and determine which of the strategies cause increased engagement, improved understanding, and overall performance between undergraduate students of biostatistics.

This study is aimed at comparing the efficacy of various teaching techniques in undergraduate biostatistics courses and ascertaining what teaching practices lead to better student learning outcomes, student engagement, and student conceptual learning. This study aims to answer the following research questions:

- RQ1: Is there a significant difference in students' Biostatistics performance between different teaching methods used in undergraduate classes?
- RQ2: How do different teaching methods influence students' engagement and learning experiences in Biostatistics?
- RQ3: Which factors (e.g., teaching method) significantly predict students' performance in Biostatistics as identified through regression analysis?
- RQ4: Does the alternative teaching method (e.g., flipped/active learning) lead to higher achievement compared to the traditional lecture method?
- RQ5: How do students perceive the effectiveness of each teaching method in supporting their understanding of Biostatistics concepts?

This research is very useful in enhancing the standards of biostatistics education. To instructors, the findings offer evidence-based information that may be used in the choice of pedagogical strategies based on the needs of the students and the purposes of the course. Knowledge about what sorts of teaching styles can improve learners and students will help teachers to optimize their teaching procedures and incorporate new methods into their classes. To students, the research will help in making the learning process to be more interactive, motivational and facilitating the learning of the complex statistical concepts. The study can be used to minimize the barriers to learning like math anxiety and enhance the confidence in using biostatistics to solve real-world problems by determining the effective strategies. On the curriculum level, the findings can guide program designers and academic policymakers to create or update biostatistics courses, incorporate a component of experiential learning, and align with the changing educational requirements. On the whole, the study offers the basis of supplementing the education of biostatistics and equip its students to academic research and clinical decision-making as well as the employment in data-driven health sciences.

2. Literature Review

2.1 Overview of Biostatistics as a Core Subject in Undergraduate Programs

The importance of biostatistics has been recognized in undergraduate education in health sciences, life sciences, public health, biotechnology, and even medical fields because of the inherent necessity to analyze, interpret, comprehend, and crucially understand biological and clinical data (Afridi et al., 2023). With the growing importance of quantitative evidence in the field of modern healthcare, undergraduate programs are starting to focus on the importance of students attaining statistical literacy, data analysis proficiency, and the capacity to make valid conclusions based on the results of empirical studies (Farnell & Mirra, 2023; Orsini et al., 2024; Yañez et al., 2023). Biostatistics offers the methodological basis of how to plan the experiment, how to undertake epidemiological research, how to test the hypothesis, and how to assess the medical intervention, which is why it is essential in research and practice (Xia et al., 2023). Although critical,

biostatistics has been known to pose a challenge to many students at the undergraduate level because of the lack of math background, fear of quantitative courses, and inability to relate the statistical concepts to the practical issues in health (Hebeisen et al., 2025). This has led to efforts by educators and curriculum developers to find ways of teaching biostatistics that are more learner friendly, engaging and applicable which explains the increased focus on reform in pedagogy in the teaching and learning of quantitative sciences.

2.2 Common Teaching Methods Used in Biostatistics

Undergraduate biostatistics courses have embraced a number of different teaching techniques all of which aim to enhance the understanding and minimize the cognitive obstacles linked with quantitative learning (Maia et al., 2023). The classic lecture approach is still highly popular because it is easy and efficient in the delivery of theoretical knowledge; but it tends to restrain interaction and practical aspects among students (Brearley et al., 2023). To overcome these constraints, new methods like the concept of the flipped classroom have become very popular, whereby the students are reviewed on the instructional content prior to the lesson and are then used to do problem solving tasks in the classroom time, thus providing the students with a more active involvement and learning (Hosseini-Baharanchi et al., 2024). Blended learning, whereby the in-person teaching method is integrated with the online elements, gives flexibility and gives the student power to adjust at his/her pace as he/she accesses digital materials and interactive simulation (Farnell & Mirra, 2023). Problem-based learning (PBL), common in the medical and health sciences learning, involves learners using statistical concepts in real-life situations, and promotes analytical thinking and learning in groups (Hu et al., 2025). Technological-enhanced learning with the help of some statistical software, simulation-based teaching, as well as the use of research projects as a part of experiential learning is another emerging method (Maia et al., 2023). All these varied approaches can be seen as the changing face of biostatistics education and the constant motivation to find pedagogies that are effective in promoting student learning.

2.3 Theoretical Foundations of Teaching and Learning (Constructivism, Active Learning)

Numerous educational theories have influenced teaching biostatistics; the major principles related to the theory include constructivism and active learning (Koolivand et al., 2024). Constructivists theory relates that, learners develop knowledge by constructing it through experience, reflection, and problem solving as opposed to being active receivers of information (Doolittle et al., 2023). This philosophy also encourages the teaching methods that help to make students work with data, investigate trends, and create a solution, which is compatible with analytical biostatistics (S. Li et al., 2024). The theories of active learning also focus on participation of students, collaboration, and practical assignments as key elements in learning. In the teaching of biostatistics, such theories are applied as methods of inquiry based learning, collaborative group work, exploration of real-world data, classroom methods where students have to use and not memorize (Hosseini-Baharanchi et al., 2024). Combinations of these theoretical frameworks can guide teachers to develop courses that improve conceptual clarity, critical thinking, and also giving students a chance to use statistical principle in a significant practical manner (Mitchell et al., 2024). Consequently, active learning and constructivist approaches are becoming more and more favored in some of the subjects that require complex thinking and data analysis.

2.4 Review of Previous Studies Comparing Teaching Methods in Statistics and Related Subjects

There is an already significant amount of research on the efficacy of various teaching strategies in statistics, biostatistics, and quantitative courses, with mixed results due to the difference in the design of teaching and the specifics of the students (C. Li et al., 2024). Experiments involving traditional lectures and active learning have continuously indicated that, students enrolled in active learning environments possess more conceptual knowledge, better performance, and greater engagement (Ordak, 2025). The studies done on flipped classrooms have revealed that students like the fact that they are given time to learn the basic material at their pace and be able to use classroom time to do applied work and discussion (Brearley et al., 2023; Javid & Sayyara, 2024; Xia et al., 2023). On the same note, research on problem-based learning and blended learning also results in a higher motivation level, improved analytical abilities and confidence in working with real-world data (Ghafar et al., 2023). Nonetheless, there are also some findings which show that the effectiveness of innovative methods is also reliant on the expertise of instructors involved in such procedures, technology accessibility, student willingness to engage in independent studies and classroom design (Hebeisen et al., 2025). Compared to the accumulating evidence, comparative research studies specifically in the area of undergraduate biostatistics are still infrequent with a majority of studies in medical school or general statistics programs (Farnell & Mirra, 2023). The latter gap reveals the necessity of the additional research on the comparative efficiency of different pedagogical techniques in

the field of biostatistics education, and its influence on various aspects of student learning.

2.5 Factors Influencing Student Performance and Engagement

The biostatistics performance and interest of students depend on a mixture of cognitive, emotional, teaching, and context elements (Trust et al., 2023). Among the most noticeable factors, there is the previous mathematical background, which commonly predetermines the level of confidence and understanding of the statistical concepts in students (Bustard et al., 2023). Anxiety in mathematics and in quantitative subjects can be a significant barrier to learning, which leads to decreased motivation and perseverance in the face of a complicated subject (Meng & Zhang, 2023). The quality of the instruction is also important, effective explanations, examples and possibilities to practice, and convenient teaching methods have a positive effect on the cognition of the students (Rehman et al., 2024). Engagement and understanding are also influenced by the learning environment such as size of the class, access to technological tools and incorporating real-world data (Knudson, 2023). Moreover, it has been established that interactive and learner-based teaching techniques, including collaborative tasks, and problem-solving exercises, as well as project-based learning, can increase student motivation by encouraging engagement and proving the applicability of biostatistics to practice (Knudson, 2023). The other valuable variables are the self-efficacy of students, study behaviors, feedback with instructors, application of quantitative learning statistical program, institutional reinforcement, and cultural attitudes towards quantitative learning (Pandita & Kiran, 2023). Collectively, the given aspects emphasize the necessity to implement holistic teaching approaches that require academic and psychological focus of learning.

2.6 Summary of Key Insights and Conceptual Framework

The literature review identifies that biostatistics is a fundamental course that must be taught in a manner that involves teaching the conceptual knowledge, practical skills, and student interaction. Although traditional lecture-based teaching is the norm, it in many cases does not assist in deep learning, so educators consider the new approaches including flipped classes, blended learning, and problem-based learning. The theories that underpin these approaches include constructivist and active learning, which contend that students learn optimally when they participate, explore and interact. The available research findings on the comparison of teaching approaches in statistics and other related subjects indicate that active, technology-based, and student-centered solutions tend to be more effective in terms of academic performance and increased engagement, but the outcomes of these approaches depend on the context, including the skill of instructors, the design of the classes, and the pre-existing readiness of the students. On the basis of these findings, the conceptual framework (Figure 1) of the current research makes teaching methods the main independent variable, which is likely to affect student learning outcomes, including understanding, performance, engagement, and satisfaction, but supplements this information with the possibility that such factors as previous knowledge, motivation, and learning environment could serve as mediators or moderators. This framework offers a systematic foundation of assessing the comparative efficacy of the teaching techniques in undergraduate biostatistics and directs the research of the influence of various pedagogical techniques on student learning.

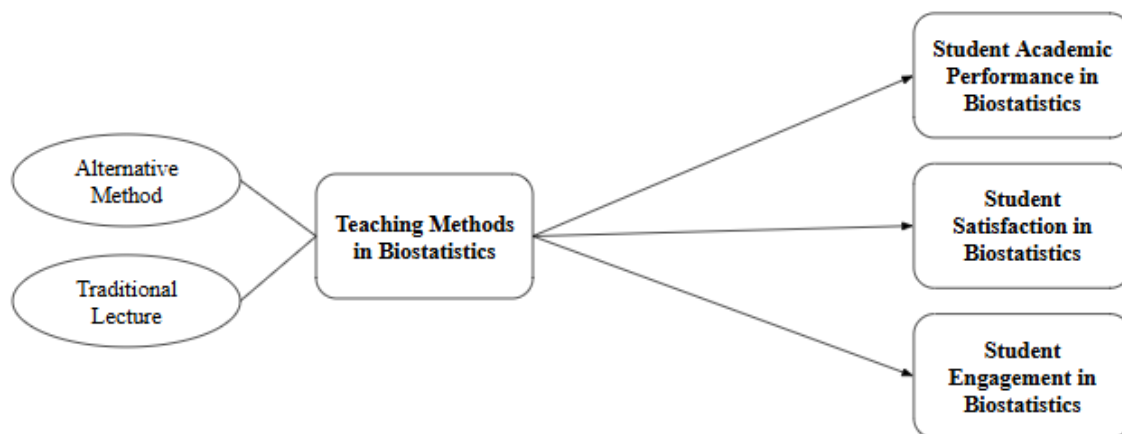


Figure 1: Conceptual Framework

3. Methodology

The current research was based on a comparative research design to determine the effectiveness of various teaching techniques in undergraduate classes on Biostatistics. The design made it possible to compare instructional strategies

directly and assess their effect on student performance and engagement. The research was done in the undergraduate courses where Biostatistics is a mandatory course and the data was gathered throughout the regular academic semester. The respondents were students taking Biostatistics courses that were delivered in two very distinct classes. The purposive sampling was used to only incorporate those students who had studied the entire course using a single identifiable teaching approach. The sample was finally selected to be 200 undergraduate students and the two instructional groups (traditional lecture and the alternative teaching method) were nearly equal. Ethics were observed by informing the students about the study purpose, anonymity and obtaining consent of academic performance data and survey responses.

The data collection entailed a variety of sources in order to get the academic performance and learning experiences of the students. The measure of academic performance was the end-of-semester examination scores or standardized measurements that were given to the two classes. A validated questionnaire with motivational, interest, participation and perception of clear understanding of Biostatistics concepts items was administered to measure student engagement and perceptions. The methods of teaching were operationally defined in such a way that they were easy to understand: Method A (Traditional Lecture Method) was based on the instructor-centered teaching, work on the board or presentations via slides and minimum interaction with the students. Method B (Alternative Method) also included elements of active-learning including flipped classroom activities, group problem solving, real-data projects and interactive classroom discussion. Data collection was conducted within the miners of course completion and it was also aligned with the course instructors to ensure uniformity across sections. Participation was on voluntary basis and responses of the students were only to be used in research purposes.

The analysis of data was done in SPSS. The descriptive statistics were calculated in order to generalize demographic factors, performance indicators, and degree of engagement, as well as the perception variables. A one-way ANOVA was used to compare the academic performance regarding the teaching methods. In order to establish the predictors of Biostatistics performance, multiple regression analysis was used the teaching method and other factors pertinent to it (engagement, attendance, prior preparation) were inputted as the independent variables. Cronbach alpha was employed to determine the reliability of the engagement and perception scales and the results indicated proper internal consistency corresponding to the recommended value. The validity was achieved by having survey questions reviewed by experts, relating to the course learning outcomes, and pilot testing to determine clarity and appropriateness. These processes provided an opportunity to compare teaching methods fully and understand what affects the way students perform in Biostatistics and learn.

4. Results

The demographic of 200 undergraduate students that took part in the study is given in Table 1. The sample of 46 and 54 percent male and female respectively ($n = 92$ and 108) is representative of a small number of female participants. Most students (59%), then 32 percent, were 21–23-year, and 24 years or older only 9 percent, indicating an undergraduate population which is predominantly traditional age. Participants consisted of four academic programs, which included Public Health (36%), Biotechnology (29%), Medical Lab Sciences (22%), and Nursing (13%), with a wide range of representation of the disciplines in health and biological sciences. In the case of instructional groups, students were divided equally (50/50) with 100 students (Method A) receiving traditional lecture instruction and the 100 students (Method B) receiving the alternative way of instruction. This equal dispersion gives equal comparative abilities on the teaching approaches. In general, the demographic picture shows the well-balanced sample with diversity to facilitate comparative analysis.

Table 1: Demographic Characteristics of Participants

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	92	46.0%
	Female	108	54.0%
Age	18–20 Years	64	32.0%
	21–23 Years	118	59.0%
	24+ years	18	9.0%
Program of Study	Public Health	72	36.0%
	Biotechnology	58	29.0%
	Medical Lab Sciences	44	22.0%
	Nursing	26	13.0%
Teaching Method Group	Traditional Lecture (Method A)	100	50.0%
	Alternative Method (Method B)	100	50.0%

The descriptive statistics of the student performance, engagement and perceived effectiveness of teaching methods by the two instructional groups were summarized in table 2. The average score of Biostatistics was $M = 68.42$ ($SD = 10.58$)

among students who studied using the traditional method (Method A), and $M = 75.63$ ($SD = 9.47$) among students who studied using an alternative method (Method B) indicating that students achieve better academic performance under the alternative method. The same pattern is found in engagement scores with students in Method A indicating moderate engagement ($M = 3.12$, $SD = 0.68$) and students in Method B indicating much higher engagement ($M = 3.89$, $SD = 0.71$). Method B was also better perceived in terms of teaching effectiveness with the participants rating it $M = 4.10$ ($SD = 0.66$) vs. $M = 3.25$ ($SD = 0.72$) of the traditional approach. Altogether, the descriptive findings highly suggest that the alternative teaching approach resulted in the positive performance, higher involvement, and the increased positive perceptions of the students.

Table 2: Descriptive Statistics of Key Variables by Teaching Method

Variable	Teaching Method	Mean (M)	SD
Biostatistics Performance Score (0–100)	Method A (Traditional)	68.42	10.58
	Method B (Alternative)	75.63	9.47
Engagement Score (1–5 scale)	Method A	3.12	0.68
	Method B	3.89	0.71
Perception of Method Effectiveness (1–5 scale)	Method A	3.25	0.72
	Method B	4.10	0.66

Table 3 shows the reliability coefficients of scales of measuring engagement, perception of teaching methods as well as learning experience. Engagement Scale proved to be of very high internal consistency with a Cronbach alpha of 0.88, which suggests that student engagement is reliably measured by the items. The highest reliability was recorded on the Perception of Teaching Method Scale with alpha of 0.91 indicating that the scale has high consistency in measuring the opinions of the students regarding the effectiveness of the teaching methods. It was also found that Learning Experience Scale had a high degree of reliability of $\alpha = 0.84$ which is considered as good reliability. These reliability scores affirm that the measurement tools employed in the study are not only statistically acceptable but also appropriate in sampling the attitudes and experiences of respondents in a similar consistent way.

Table 3: Reliability Analysis of Study Scales

Scale	Number of Items	Cronbach's Alpha (α)	Interpretation
Engagement Scale	10	0.88	Excellent Reliability
Perception of Teaching Method	12	0.91	Excellent Reliability
Learning Experience Scale	8	0.84	Good Reliability

The outcomes of a one-way ANOVA performed to determine the presence of a notable difference in the performance of the students using the two teaching strategies are presented in Table 4. The analysis showed that there was a statistically significant difference between groups $F(1, 198) = 23.87$, $p = 0.000$, which showed that the teaching method was significantly influential on Biostatistics performance. The effect size ($\eta^2 = 0.11$) indicates that there is a medium influence of the teaching method on student achievement. The between-group sum of squares ($SS = 2356.78$) shows there is significant variation which can be explained by teaching method, but the variability in the within-group ($SS = 19504.62$) indicates individual differences. Generally, the findings have shown that students who were taught using the alternative method had a significant better performance than those who were taught using the traditional lectures.

Table 4: One-Way ANOVA Comparing Performance Across Teaching Methods

Source	SS	df	MS	F	p-Value	η^2
Between Groups	2356.78	1	2356.78	23.87	0.000	0.11
Within Groups	19504.62	198	98.51			
Total	21861.40	199				

Table 5 indicates that there is a significant difference between the two instructional methods in terms of engagement scores. The mean score of engagement in the students of the conventional lecture group was $M = 3.12$ ($SD = 0.68$), and in the students taught with the alternative approach, it was much higher ($M = 3.89$, $SD = 0.71$). The t-test using independent samples produced $t(198) = -8.01$, $p = 0.000$, which means that the difference between the engagement is very significant. These findings indicate that other teaching strategies that are student-centered significantly enhance the student participation, engagement, and interest in Biostatistics as opposed to conventional lectures. This is where the importance of active-learning strategies comes in serving to facilitate more meaningful interaction with what is covered in courses.

Table 5: Comparison of Student Engagement Scores Across Teaching Methods

Teaching Method	N	Mean (M)	Sd	Test Value	p-Value
Method A (Traditional)	100	3.12	0.68	$t(198) = -8.01$	0.000
Method B (Alternative)	100	3.89	0.71		

Table 6 is a brief summary of the rating by students on the effectiveness of each teaching method in five main areas. In each perception item, the students educated using the alternative method rated their experience much higher as compared to those educated using the traditional method. As an illustration, the students in Method B rated the clarity of the explanation as 4.15 as opposed to 3.18 in Method A, relevance of example as 4.08 versus 3.10, level of interaction as 4.20 versus 3.05, confidence in solving problems as 4.12 versus 3.30, and overall satisfaction of 4.10 versus 3.25. All the comparisons were statistically significant ($p = 0.000$). The findings indicate that students find different forms of teaching more comprehensible, interactive, more relevant, and helpful in instilling confidence than conventional lectures. This is in accordance with performance and engagement outcomes that have been given above.

Table 6: Students' Perceptions of Teaching Method Effectiveness

Perception Item (1–5 Likert Scale)	Method A Mean (SD)	Method B Mean (SD)	p-Value
Clarity of Explanation	3.18 (0.71)	4.15 (0.62)	0.000
Relevance of Examples	3.10 (0.75)	4.08 (0.64)	0.000
Level of Interaction	3.05 (0.72)	4.20 (0.58)	0.000
Confidence in Solving Problems	3.30 (0.70)	4.12 (0.67)	0.000
Overall Satisfaction	3.25 (0.72)	4.10 (0.66)	0.000

Table 7 presents the multiple regression analysis conducted to identify factors predicting student performance in Biostatistics. The model was statistically significant, $F(5,194) = 31.82$, $p < .001$, and explained 45% of the variance in performance ($R^2 = 0.45$), with an adjusted R^2 of 0.43, indicating a strong predictive model. Teaching method emerged as the strongest predictor ($\beta = 0.41$, $p = 0.000$), showing that students taught through the alternative method scored significantly higher. Engagement ($\beta = 0.29$, $p = 0.000$) and perception of teaching effectiveness ($\beta = 0.16$, $p = 0.020$) were also significant predictors, indicating that students who felt more engaged and had positive perceptions performed better. Attendance percentage ($\beta = 0.13$, $p = 0.011$) and prior GPA ($\beta = 0.12$, $p = 0.039$) also contributed significantly, though to a smaller extent. The regression equation highlights that both pedagogical factors (method, engagement, perceptions) and student-level factors (attendance, prior GPA) collectively influence Biostatistics achievement. Overall, the analysis emphasizes that teaching method and engagement are the most powerful predictors of student success.

Table 7: Multiple Regression Analysis Predicting Biostatistics Performance

Predictor Variables	B	SE	β	T-Value	P-Value
(Constant)	32.45	4.12	—	7.88	0.000
Teaching Method (0 = Traditional, 1 = Alternative)	6.85	1.25	0.41	5.48	0.000
Engagement Score	4.12	0.98	0.29	4.20	0.000
Perception Score	2.05	0.87	0.16	2.35	0.020
Attendance (%)	0.18	0.07	0.13	2.57	0.011
Prior GPA	1.90	0.91	0.12	2.08	0.039

Model Summary:

- $R = 0.67$
- $R^2 = 0.45$
- Adjusted $R^2 = 0.43$
- $F(5,194) = 31.82$, $p < .001$

5. Discussion

This study has shown clearly that in the case of undergraduate Biostatistics the teaching method used has a great influence on the performance of the students. Students who were taught under the alternative method of learning, i.e. flipped, active or project-based, scored significantly higher as compared to those taught a traditional lecture-based method. This result is in line with vast literature that indicates that active-learning methods help students to gain a better conceptual grasp of quantitative subjects. Indicatively, [Hu et al. \(2025\)](#) established that active learning has a great impact on performance and low failure rates in STEM courses. In the same manner, [Maia et al. \(2023\)](#) suggested that students in the conventional lecture-based course tend to have difficulty in abstracting quantitative concepts and learning them, but an interactive course encourages students to think more and thus have higher retention. The superior performance of the present research makes it possible to believe that Biostatistics, being an applied and analytical field, could use instructional methods that would go beyond passive listening.

The other important revelation is that there is a big difference between the level of engagement between the two instructional groups. The increased level of engagement in students taught using the alternative method is very much congruent with the constructivist theories of active involvement in the learning process. [Brown et al. \(2023\)](#) believes that knowledge is best built by social interaction, exploration, and practical work because all aspects are designed to enable

students to learn. This is also supported by empirical research; [Trust et al. \(2023\)](#), also showed that active-learning classrooms significantly boost cognitive and emotional involvement of the student in quantitative courses. The good predictive nature of engagement in the regression analysis of the current study also coincides with [Kozanitis and Nenciovici \(2023\)](#) who reported that engagement is among the key determinants of academic success. The overall result of these findings is that students who are motivated to interact, collaborate and practice the concepts do not only find learning more enjoyable but also, they excel academically.

The effect of teaching on students was also positively rated at the alternative approach, with the ratings always being better in terms of clarity, relevance, interaction, confidence and overall satisfaction. These findings are in line with previous reports that students find active and flipped classes engaging and student centric. According to the [Lutz et al. \(2025\)](#), students who attended flipped classes indicated that they understood better because of more in-class problem solving. Similarly, [Bustard et al. \(2023\)](#), has found out that interactive learning methods help in the reduction of statistics anxiety and increase the perceived competence of students. The considerably higher perception scores in the alternative method group demonstrate the awareness of students that participation teaching strategies and real-life examples are useful in helping them to perceive the practical application of Biostatistics in a better way. These results indicate that methods of teaching that engage the students in the learning process more are more positive and conducive to learning.

The results of the ANOVA reinforce the conclusion that the teaching method is a significant and statistically significant factor on academic achievement in Biostatistics. This is in agreement with the wider literature on statistics and mathematics education that constantly points to the drawbacks of the traditional lecture on its ability to promote profound learning. [Van den Beemt et al. \(2023\)](#), also claimed that teaching statistics should cease to focus on rote learning and focus on inquiry-based teaching based on data to enhance understanding and practice. Other researchers like [Shahzad et al. \(2024\)](#), also found that flipped-classroom models cause an increase in achievement and confidence in students studying quantitative subjects. The results of the current research are consistent with these views and add to the ever-growing body of evidence regarding the idea of pedagogical reform in the field of Biostatistics teaching. They present a strong argument about changing the current forms of instruction where a teacher delivers information to the students to active, collaborative, and application-based learning.

Lastly, the regression model provides useful information on the factors that are the most significant predictors of the Biostatistics performance. The most influential one was teaching method, proving that instructional design is the focus of student achievement. Perception and involvement in teaching method also strongly predicted performance, which aligns with the social cognitive theory ([Bandura, 2001](#)) in which self-efficacy and affective variables play an important role in academic performance. Also, attendance and previous GPA were significant predictors of performance, which is consistent with the results of [Lampropoulos and Sidiropoulos \(2024\)](#), who found that academic behaviors and previous performance were common predictors of academic outcomes. These findings combined bring out the fact that successful learning in Biostatistics is affected by both the teaching factors and the learner factors. Nevertheless, the high influence of teaching technique implies that there is a lot of room that can be leveraged by teachers and curriculum developers to enhance learner performance by adopting student centred learning pedagogies.

6. Implications

6.1 Theoretical Implications

The findings of this study contribute meaningfully to the theoretical understanding of teaching and learning in quantitative subjects, particularly through the lens of constructivism and active learning theories. The significant differences between the traditional and alternative methods of teaching, supports the constructivist idea that learning best takes place in the form of students newly building knowledge and interacting, discussing and engaging with information as opposed to passive receivers of information. The research paper is empirical evidence of the social constructivist worldview proposed by Vygotsky, which focuses on the importance of team learning and facilitated involvement in the acquisition of higher-order thinking skills. Also, the high predictive value of engagement and perceptions in student achievement supports the notions of cognitive, affective, and behavioral aspects of the learning process, including the social cognitive theory, by Bandura, and the multidimensional engagement model, by Fredricks. The study contributes to the current theory of education by showing that the design of instructional activities is not only a mode of delivery, but also a key determinant of learning outcomes because it ensures that psychological involvement and learning outcomes in students are mediated by instructional design. Generally, the study validates the theoretical hypothesis that student-centered pedagogies are an inseparable part of the effective learning in complex and application-based fields of study such as Biostatistics.

6.2 Practical Implications

The practical implications of this research are highly relevant for educators, academic departments, and curriculum planners seeking to improve Biostatistics education. The findings strongly point to the fact that other teaching approaches,

including flipped classes, active-learning techniques, and project-based learning, result in the improvement of academic achievement, engagement rates, and favorable learning experiences of student groups. Such results prompt the instructors to abandon the traditional lecture-driven model and instead integrate more interactive teaching methods based on the use of real-data, collaboration with peers, problem-solving, and continuous feedback. As an institution, the research offers an empirical rationale to invest in training of teachers, classroom technologies, and efforts to redesign courses which promote an active-learning environment. Curriculum developers can also explore the incorporation of structured activities, digital learning tools, and experiential elements to the course of learning Biostatistics to improve the learning outcomes. Moreover, the role of engagement and perception is so great that the learning could be enhanced considerably by increasing the classroom atmosphere, facilitating the involvement of students, and developing the friendly relations between the instructor and students. Together, these practical suggestions could provide practical measures to enhance the effectiveness of teaching and increase student achievement in Biostatistics and other quantitative courses.

7. Limitations and Future Research Directions

Despite the fact that the given research provides the valuable information about the comparative effectiveness of teaching techniques in the university level of Biostatistics, one must admit several limitations. To start with, the study was based on information of one semester of study and the departments which might limit its application to other institutions, fields or even academic settings. Second, purposive sampling though suited to a comparative design can provide a selection bias since the behavior of each group of students within a teaching method could be different in aspects not accounted by the measured variables. Third, the research concentrated on cognitive performance and indicators of self-reported engagement and perceptions, which could be affected by the social desirability or subjective meaning. Also, it was not found whether the knowledge was retained in the long term or whether knowledge or learning outcomes could be retained after the course. These limitations ought to be overcome in future studies by use of longitudinal designs, randomization of teaching states and multi-institutional samples. Researchers can also consider other variables like motivation, learning styles, and digital literacy, instructor factors, and classroom practices specific as mediating or moderating the efficiency of the methods of teaching. The qualitative methods, like classroom observations or interviews, might contribute to learning more about the ways and reasons why particular pedagogies are effective in teaching Biostatistics. Additionally, further research may examine the potential of technology-based interventions (e.g., simulations, virtual labs, AI-driven platforms) in an attempt to evaluate how the digital innovations can be used to improve quantitative learning in various educational settings.

8. Conclusion

To summarize, this paper presents some convincing findings that teaching approach is a key factor of student achievement, interest, and learning experiences in undergraduate courses in Biostatistics. The other instructional practice-active-learning, flipped classroom and interactive instructions- was found to be superior to the traditional lecture mode in all the major outcomes such as academic achievement, student interaction and perceived instructional efficacy. These results support theoretical assumptions of constructivism and active learning and prove the idea that meaningful involvement, collaborative inquiry, and real-world practice make a great difference in the conceptual learning of Biostatistics in students. Engagement and positive perceptions, as also noted by the study also, are also mentioned among the key predictors of student achievement, and so there is a need to build learning environments that are interactive, motivating and student-centered. Finally, this study supports the importance of pedagogical innovation in quantitative education and offers viable recommendations to educators and curriculum developers who would want to revise teaching of Biostatistics. Active and learner-centered methods can equip undergraduate students with the analytical skills, confidence and applied competencies needed in data-driven health and science, and improve institutions in offering these skills.

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