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Effectiveness of innovative techniques on Pupil's achievement in mathematics among higher secondary students in selected schools

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Abstract: The incorporation of new teaching strategies into mathematics education has garnered attention in recent times owing to its capacity to augment student engagement and accomplishment. Despite the promising developments, gaps remain in understanding how these methods influence higher secondary students' performance in mathematics. The purpose of this study was to assess the efficacy of novel approaches in comparison to conventional teaching strategies, examining factors such as teacher competence, student engagement, and socioeconomic influences. The research involved a quasi-experimental design with 200 higher secondary students from selected schools in Kerala. A considerable change in academic accomplishment was found using analysis of variance (ANOVA), with students taught utilizing novel methodologies attaining an average score of 82.5, compared to 79.3 in the traditional group. Additionally, a strong positive correlation ($r = 0.68$) was found between teacher competence and student performance. The findings showed the critical role of innovative teaching strategies in improving mathematics achievement, highlighting the need for teacher training and curriculum development. The study concludes that embracing these methods can significantly enhance student outcomes, encouraging educators and policymakers to prioritize innovative approaches in mathematics education.

Keywords: *ANCOVA, Mathematics education, Quasi-experimental design, Socioeconomic, Teaching techniques.*

1. Introduction

The most potent tool is education, which must be used with determination, hard work, and sacrifice in order to be effective. Knowledge is crucial in a society that is quickly becoming industrial and technological [1]. Human communication, social interaction, idea quantification, and, most importantly, accuracy in daily life is all facilitated by language, social science, and mathematics. All subjects are related to mathematics. That learning mathematics requires thinking about mathematical concepts. Therefore, the ability to think efficiently is necessary in order to understand and apply mathematics [2]. Mathematics, often considered the cornerstone of academic achievement, plays a pivotal role in the education system, influencing various aspects of learning and cognitive development. In recent years, the need for innovative teaching techniques has become increasingly evident, particularly at the higher secondary level, where students transition to more complex mathematical concepts. Traditional methods, characterized by rote memorization and passive learning, often fail to engage students meaningfully, leading to a decline in interest and achievement in mathematics.

As educational patterns shift towards more learner-centred approaches, innovative techniques such as project-based learning, cooperative learning, and the integration of technology have emerged as effective strategies for enhancing student engagement and understanding. These techniques support students' growth in many ways than only their critical thinking and problem-solving skills, but they also accommodate different learning preferences, increasing students' enjoyment and accessibility to mathematics. The effectiveness of these innovative techniques in improving pupils' achievement in mathematics is a subject of considerable interest among educators and researchers alike [3]. According to studies, when students actively participate in their education through practical experiences and group

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projects, their conceptual understanding deepens, and their performance in assessments improves. Moreover, the incorporation of technology such as interactive software, virtual reality and the utilization of online resources has yielded encouraging outcomes in terms of closing the knowledge gap between theory and practice.

Examining how innovative teaching strategies affect higher secondary students' mathematics achievement in specific educational settings is the aim of this study. This research aims to provide insights into how different teaching tactics can improve students' mathematical skill and attitude toward the topic by analyzing their effects.[4]. The significance of this research extends beyond academic performance; it also addresses the broader implications of teaching methodologies on students' overall educational experiences. As the demand for skilled mathematicians in various fields continues to grow, it is crucial to give students the resources and information they require in order to achieve [5]. Understanding the role of innovative techniques in mathematics education can inform curriculum development, teacher training, and policy-making, eventually contributing to a more effective educational system. The effectiveness of innovative teaching techniques in enhancing pupils' achievement in mathematics is a crucial area of exploration. This research attempts to assess these methods' effects on academic performance in addition to also seeks highlighting the importance of fostering an engaging and supportive learning environment. Over this research, hope to contribute the ongoing discussion about effective mathematics instruction and provide recommendations for educators striving to improve outcomes for their students.

2. Literature Review

Felix Oromena Egara and Mogege Mosimege (2024) [6] examined how the flipped classroom approach affected students' interest in and performance in mathematics. They sampled 86 students from two schools in the Igbo-Etiti Local Government Area of Enugu State using a quasi-experimental design and a non-equivalent pretest-posttest control group. The Mathematics Interest Inventory (MII) and Mathematics Achievement Test (MAT) were used to gather data, and reliability values of 0.88 and 0.79, respectively, were shown. After a six-week action, pretests and posttests were administered. ANCOVA exposed that student qualified through the flipped classroom approach attained higher scores in both mathematics achievement and interest compared to their peers in conventional classrooms. Notably, the flipped strategy proved to be equally beneficial for male and female learners. This study significantly contributed to mathematics education by demonstrating how the flipped classroom approach works, especially for raising student interest and performance in geometry.

Adeneye and Afolabi (2023) [7] investigated the impact of formative evaluation strategies on mathematics achievement among 500 Nigerian senior secondary school students and 10 teachers. Using a pretest-posttest experimental design, they found that formative evaluation contributed 4.4% to the prediction of students' achievement in mathematics, while gender contributed 1.2%. Formative evaluation was found to considerably improve mathematics achievement in both male and female students when it was used as a teaching approach. However, there was no apparent distinction in the impact of the gender and formative evaluation interaction. These results led the researchers to suggest that education planners implement policies recognizing formative evaluation as a key strategy to enhance student achievement. They also encouraged teachers to adopt continuous formative evaluation to provide feedback, build students' confidence, and improve learning outcomes not only in mathematics but in other subjects as well.

Ayodele Fajonyomi and Kayode Ezecheal Obafemi (2023) [8] investigated the impact of the inverted jigsaw instructional technique on students' mathematical academic performance. Two public elementary schools were chosen at random for the study using a quasi-experimental research approach. As the research tool, the Mathematics Achievement Test (MAT) was employed. It was verified and dependability assessed using a Pearson Product Moment Correlation (PPMC). The study used Analysis of Covariance (ANCOVA) to evaluate two hypotheses. The results demonstrated that while the interaction between behavior and gender had no discernible impact, the inverted jigsaw technique greatly increased students' mathematical proficiency. The study found that students' achievement was

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improved regardless of gender by using the inverted jigsaw instructional technique. These findings led to the recommendation that educators receive training in this method of instruction.

K. E. Obafemi and U. T. Saadu (2023) [9] investigated the relationship between students' academic success in mathematics and their level of self-efficacy. Using a correlational research design, 568 pupils from 14 public primary schools were selected through simple random sampling. Data were assembled using the Questionnaire on Pupils' Self-efficacy (QFYPS) and the MAT, both validated and tested for reliability, with coefficients of 0.79 and 0.77, respectively. Pearson Product Moment Correlation (PPMC) demonstrated a favorable relationship between mathematical achievement and self-efficacy. No significant differences in self-efficacy were revealed by independent samples t-tests or academic achievement based on gender. The study concluded that self-efficacy positively influenced mathematics achievement, gender had no effect on either self-efficacy or achievement. It was shown that educators and legislators embrace methods to raise students' self-efficacy in mathematics and uphold inclusive classroom environments that serve all students, regardless of gender.

Jamiu Temitope Sulaimon et al. (2023) [10] examined how the problem-solving strategy affected Ilorin pupils' academic achievement in mathematics. Forty-five basic students from two public and two private schools participated in the quasi-experimental design of the study. MAT, ANCOVA and mean were employed in the data analysis. The results showed that students who learned utilizing the problem-solving technique outperformed those in the control group. However, academic achievement was not significantly influenced by age or kind of school, and there was no significant interaction between these variables and the problem-solving approach. According to the study's findings, the problem-solving approach raises students' mathematical achievement by encouraging participation and teamwork. Mathematics teachers adopt this method, and those seminars and in-service program be organized to further educate teachers. Additionally, relevant instructional materials should be provided to support effective implementation of the method.

Ifeoma Julie Osakwe et al. (2023) [11] performed a study in Local Government Area of Anambra State, to investigate the impact of the multiple solution tasks (MSTs) instructional strategy on students' mathematical inventiveness. 83 SS2 A quasi-experimental approach was used to split the student body into groups for experimental and control. Utilizing the Mathematics Creativity Achievement Test (MCAT), data were collected, which has been evaluated by professionals and has a 0.79 Kuder-Richardson coefficient. ANCOVA indicated that pupils in the MST-taught experimental group scored higher on creativity tests than students in the control group. Gender did not significantly influence students' mathematical creativity, and the relationship between gender and teaching style was not statistically significant. This study concluded that MSTs are an effective strategy for enhancing students' mathematical creativity.

Nazir Haider Shah et al. (2023) [12] carried out a study to investigate the impact of students' attitudes toward mathematics on their mathematical performance in AJ&K secondary schools. Using a descriptive and quantitative approach, the study sampled 444 students (192 boys and 252 girls) from 10th grade through stratified random sampling. A 5-point Likert scale survey was used to gather data. The results showed that students' attitudes, including confidence, motivation, and anxiety, significantly affected their mathematical achievement. Male students exhibited a higher attitude toward mathematics, particularly in curiosity and comfort with calculations, however, there was no discernible gender gap in mathematical proficiency. Anxiety was found to be a prominent factor, but confidence and motivation were identified as the strongest predictors of future mathematical interest and achievement. The study concluded that fostering confidence and motivation would significantly improve students' performance in mathematics.

A quasi-experimental study led by Terungwa James AgE and Masilo France Machaba (2023) [13] examined the impact of mathematical software on geometry achievement among high school pupils. Drawing from David Kolb's experience learning theory, the research employed a non-randomized pretest and posttest design. A sample of 457 high school students was chosen from 12,308 total pupils in Benue State, Nigeria. The data were analyzed using Analysis of Covariance (ANCOVA) at a significance level of 0.05. To solve the study's problems, the mean and standard deviation were used. The results showed that students who used mathematical software in the experimental group scored 68.94 on

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average as opposed to 58.45 in the control group. There was no gender disparity seen, even if the attainment differences were statistically significant. According to the study's findings, teaching geometric constructs and other mathematical concepts to pupils through the use of mathematical software increased their comprehension of geometry and improved their performance.

Emrah Akman and Recep Çakır (2023) [14] investigated how students' performance in math lessons and their understanding of fractions were affected by the virtual reality educational game Keşfet Kurtul. Using a quasi-experimental design, the study involved a conduct group (N = 32) that played the virtual reality game and a comparison group (N = 32) that used traditional mobile applications. The outcomes demonstrated that the virtual reality game greatly raised academic attainment and sustained student interest, with no notable gender differences observed. While the experimental method had a comparable effect to traditional methods in terms of academic performance, game proved more effective in fostering social engagement. However, there was no substantial variance among the groups. The study concluded that both methods equally impacted academic achievement and the VR game enhanced social engagement.

K. E. Obafemi et al. (2023) [15] investigated how the scaffolding teaching method affected Kwara, a state in Nigeria, students' academic performance in mathematics. The study, which included 117 pupils from two private elementary schools, used a quasi-experimental pretest-posttest control group design. The three approved instruments utilized for data collection were the Mathematics Performance Test (MPT), the Guide for Scaffolding Instructional Strategy (GSIS), and the Guide for Conventional Method (GCM). Reliability coefficient for the MPT was 0.72. ANCOVA was employed to evaluate two proposed theories. Results showed that, irrespective of gender, the scaffolding method greatly enhanced students' academic performance in mathematics. However, there was no appreciable difference in the academic and gender interactions' performance. The study found that scaffolding improves learning outcomes and suggested that primary school teachers receive this training. The research findings indicate that scaffolding improves learning results. Additionally, it is advised that primary school instructors receive training on how to effectively utilize this instructional method.

Usman Tukur et al. (2023) [16] explored how a mixed learning strategy based on constructivism affected senior secondary school students' retention and academic performance in mathematics. 120 pupils (59 boys and 61 girls) provided information for the quasi-experimental non-equivalent control group design from two randomly selected public schools in the Katsina educational zone of Katsina State. The MPT, consisting of 40 multiple-choice items, was administered before, after, and two weeks following the experiment. The MPT demonstrated a reliability coefficient of 0.85. Students who were taught using a constructivism-based method scored much higher on academic performance tests than the control group, according to an ANCOVA analysis of the data. Between male and female pupils, there was no discernible difference in achievement scores. The study concluded that the constructivism-based blended learning approach improved mathematics learning and was effective for both genders, enhancing cooperation and self-confidence among students.

Evans Atteh et al. (2020) [17] identified a 5-step model designed to guide mathematics teachers in implementing cooperative learning environments. The model, based on established educational principles, equips teachers with the skills needed to foster active and student-centred learning. Initially, adopting this approach could feel unfamiliar, but with creativity and proper planning, potential obstacles can be overcome. Research has shown that cooperative learning benefits students both cognitively and socially, promoting higher-order thinking, problem-solving, and positive peer interactions. Teachers who used this model reported improved classroom climates and fewer disciplinary issues, as students engaged in constructive dialogue and teamwork. The shift from traditional lecture-based methods to this cooperative model was found to positively impact student relationships and psychological well-being, extending its influence beyond the classroom setting.

2.1. Research Gap

Despite significant advancements in the field of mathematics education, there remains a noticeable gap in understanding the long-term effectiveness of innovative teaching techniques, particularly at the higher secondary level. While several studies have highlighted the positive impact of technology

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integration, project-based learning, and cooperative strategies on student engagement and achievement, many of these investigations have been limited in scope, focusing primarily on short-term academic gains or specific geographical regions. Additionally, much of the existing research tends to emphasize primary or middle school level, leaving a gap in the exploration of how these techniques influence higher secondary students as they transition to more advanced mathematical concepts. Moreover, the effectiveness of these methods across diverse student populations, particularly in terms of socioeconomic, cultural, and learning ability differences, remains underexplored. The interaction between innovative techniques and specific curriculum demands at the higher secondary level, such as preparing students for standardized exams, has not been sufficiently addressed. Therefore, research is needed to comprehensively evaluate how these innovative techniques can be systematically implemented and sustained to improve mathematical achievement, while also considering the diverse needs of students in different contexts. This study aims to overcome this gap by focusing on the effects of unique techniques on upper secondary students in specific schools.

2.2. Research Questions

i. What effect do creative teaching methods have on higher secondary students' mathematics achievement in particular schools in Kerala?
ii. How does the use of technology-enhanced learning affect pupils' mathematics achievement compare to traditional teaching methods?
iii. Do blended learning approaches improve mathematical achievement among higher secondary students compared to conventional teaching methods?
iv. What is the influence of teacher competence and training in innovative techniques on students' performance in mathematics?
v. How do socioeconomic factors influence the effectiveness of innovative teaching techniques on pupils' mathematics achievement?
vi. What is the relationship between student engagement and motivation in mathematics when exposed to innovative teaching techniques?

2.3. Research Objectives

- To study the demographic profile of higher secondary students (e.g., gender, age, socioeconomic status) and its influence on their mathematics achievement using innovative techniques.
- To assess how novel approaches to learning affect upper secondary students' academic performance in mathematics.
- To assess how well traditional teaching techniques and technology-enhanced learning compare in terms of raising student achievement in mathematics.
- To compare traditional classroom instruction with blended learning strategies in order to assess how they affect students' mathematical proficiency.
- To assess the role of teacher competence and training in innovative techniques on students' performance in mathematics.
- To examine how socioeconomic variables affect the efficacy of creative methods for teaching mathematics
- To analyze the relationship between student engagement and motivation in mathematics when exposed to innovative teaching techniques.

2.4. Proposed Hypotheses

- *H_1: There is a significant association between students' demographic profile (e.g. gender, age and socioeconomic status) and their academic achievement in mathematics*

when taught using innovative techniques.

- *H_2: Students trained utilizing innovative teaching strategies show much higher academic accomplishment in mathematics than students taught using traditional methods.*

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- *H_3: Technology-enhanced learning has a greater positive impact on students' mathematics achievement compared to traditional classroom teaching methods.*
- *H_4: Students exposed to mixed learning approaches perform significantly better in mathematics than those taught using only traditional methods.*
- *H_5: Teacher competence in innovative teaching techniques significantly influences students' performance in mathematics.*
- *H_6: Socioeconomic factors significantly moderate the effectiveness of innovative teaching techniques on students' achievement in mathematics.*
- *H_7: Exposure to innovative teaching strategies is positively correlated with students' motivation and engagement in mathematics.*

3. Research Methodology

3.1. Conceptual Framework

The conceptual framework for the study outlines the relationships between independent and dependent variables are shown in Figure 1. The independent variables include Innovative Teaching Techniques (such as technology-enhanced learning, blended learning, game-based learning, collaborative learning, and flipped classroom models), Teaching Environment, Teacher's Training and Competence, Socioeconomic Background of Students, and Student Engagement and Motivation. These factors are expected to influence the Dependent Variable, which is Pupil's Achievement in Mathematics. The framework posits that effective innovative teaching methods, along with supportive classroom environments and well-trained teachers, enhance student engagement and motivation, ultimately leading to improved academic performance in mathematics. The framework aims to identify key elements that contribute to successful learning outcomes in mathematics for higher secondary students.

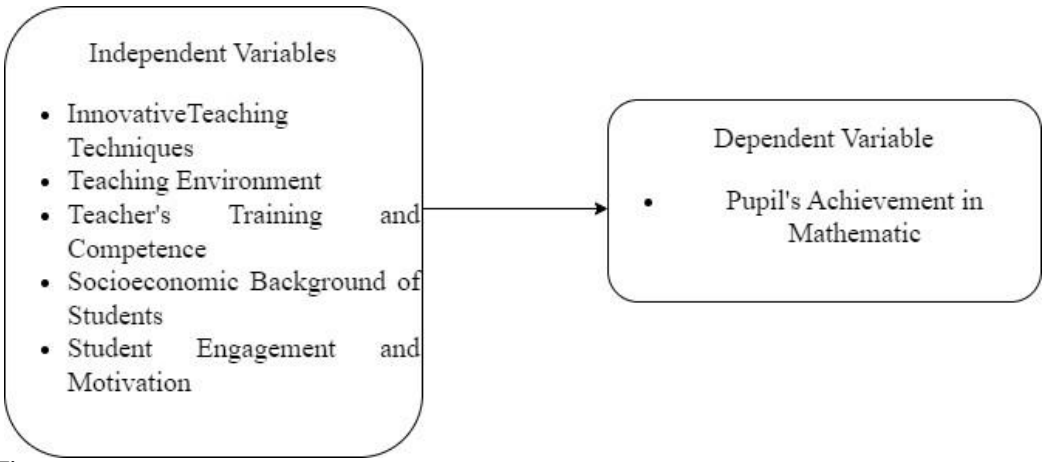

Figure 1.
Conceptual framework of proposed system.

3.2. Research Design

This study used a quasi-experimental approach and combined quantitative and qualitative methodologies to evaluate the impact of creative teaching strategies on students' mathematical achievement. The research involves pre-tests and post-tests to measure academic performance.

3.3. Data Collection

On the basis of the pre- and post-tests, data was collected; Pre-tests are administered before the intervention to establish a baseline of students' mathematical knowledge. The experimental group is trained using creative methods, whereas the control group are qualified conventional methods. Post-intervention assessments are given to pupils to gauge improvements in their academic performance.

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3.4. Designing of Questionnaire

The questionnaire for this study is designed to gather comprehensive data on students' experiences with innovative teaching techniques in mathematics. It includes closed-ended questions, using a Likert scale to assess levels of arrangement regarding engagement, motivation, and perceived effectiveness of various instructional methods. Additionally, open-ended questions allow students to express their thoughts on specific techniques, fostering richer qualitative insights. The questionnaire is pilot-tested for clarity and reliability, ensuring that it effectively captures relevant information while being easy to understand and complete for higher secondary students.

3.5. Sampling Area and Population

The participants include higher secondary students from selected schools in Kerala. A sample size of approximately 200 students is selected from various schools, ensuring diversity in terms of gender, socioeconomic status, and academic background.

3.6. Sampling Technique

The technique of stratified random sampling is utilized to guarantee that the sample comprises pupils from diverse demographic groups. This helps in analyzing the effects of various independent variables on pupil achievement.

3.7. Statistical Tool for Analysis

Study utilizes various statistical tools for data analysis to assess the effectiveness of innovative teaching techniques on students' mathematics achievement. The mean and standard deviation, two descriptive statistics were used to summarize the data. Logical statistics, particularly ANOVA is used to assess how the experimental and control groups' academic performance differs from one another, controlling for potential confounding variables. Multiple regression analysis is often used to investigate the relationship between independent variables, such as teaching techniques and socioeconomic status, and the dependent variable of students' achievement. This comprehensive approach ensures robust and reliable results.

4. Result and Analysis

4.1. Demographic Distribution

Demographic distribution refers to the statistical analysis and visual representation in their academic achievement in mathematics when taught using innovative techniques. Table 1 presents a demographic distribution of participants by gender, age and socioeconomic status and it's plotted in Figure 2.

Table 1.
Demographic distribution.

Demographic variable	Categories	Frequency (N)	Percentage (%)
Gender	Male	100	50%
	Female	100	50%
Age	15-16 years	75	37.5%
	17-18 years	110	55%
	19-20 years	15	7.5%
Socioeconomic status	Low income	60	30%
	Middle income	110	55%
	High income	30	15%
Parental education level	Primary education	40	20%
	Secondary education	100	50%
	Tertiary education	60	30%
Residential area	Urban	130	65%

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	Rural	70	35%

The sample includes an equal number of male and female students (50% each). This ensures balanced representation and allows for analysis of whether gender plays a role in academic achievement when using innovative teaching techniques. The majority of students (55%) fall within the 17-18 age array, while 37.5% are aged 15-16 years. A smaller portion (7.5%) is in the 19-20 age group. This distribution reflects the typical age range of higher secondary students, with the highest concentration in the (17-18). For Socioeconomic Status (SES) large proportion of the students (55%) belong to the middle-income group, while 30% are from low-income backgrounds and 15% from high-income families. This provides a varied SES profile for examining how economic background affects students' achievement when exposed to innovative teaching methods. Half of the students (50%) have parents with secondary education, while 30% have parents with tertiary education and 20% have parents with only primary education. Parental education level could be a factor influencing students' academic performance. The majority of the students (65%) come from urban areas, with the remaining 35% from rural areas. This urban-rural divide allows for analysis of geographical differences in how innovative teaching techniques affect academic performance.

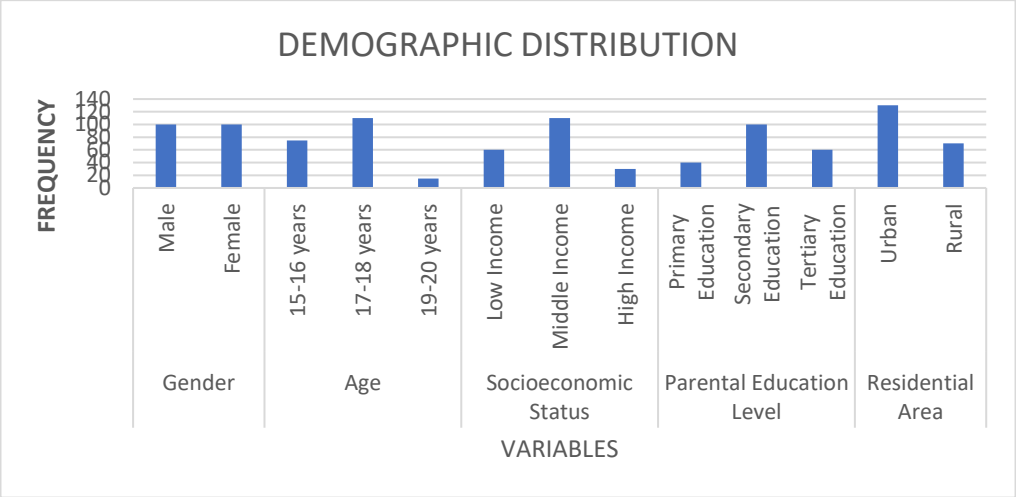

Figure 2.
Demographic distribution of participants.

4.2. T-Test

When comparing the means of two independent groups, the independent sample T-test is a suitable method. Students taught using innovative techniques vs. those taught using traditional methods) to determine if there is a substantial difference in academic performance. These students were divided into two groups: 100 students taught using innovative techniques and 100 students taught using traditional methods. Their post-test scores in mathematics were compared to measure academic achievement.

Table 2.
Independent sample t-test.

Group	Mean score	Standard deviation (SD)	t-value	p-value	Significance ($\alpha = 0.05$)
Innovative teaching techniques	85.4	7.8	4.56	0.00012	Significant
Traditional methods	100	79.3	8.5		

From Table 2, the mean score of the group taught using innovative teaching techniques was 85.4, with a standard deviation of 7.8, while the group taught using traditional methods had a mean score of 79.3 with a standard deviation of 8.5. The t-value was calculated as 4.56 and the p-value was 0.00012,

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which is much lower than the significance level of 0.05. Since the p-value is less than 0.05, we conclude that the difference in academic achievement between the two groups is statistically significant. This means that students taught using innovative teaching techniques performed significantly better in mathematics than those taught using traditional methods. The results were plotted in Figure 3.

$$d=\frac{M_1-M_2}{SD_{pooled}} \quad (1)$$

Where SD_{pooled} is the pooled standard deviation of both groups? The result indicates a large effect size, reinforcing the notion that innovative techniques have a meaningful impact on students' learning outcomes.

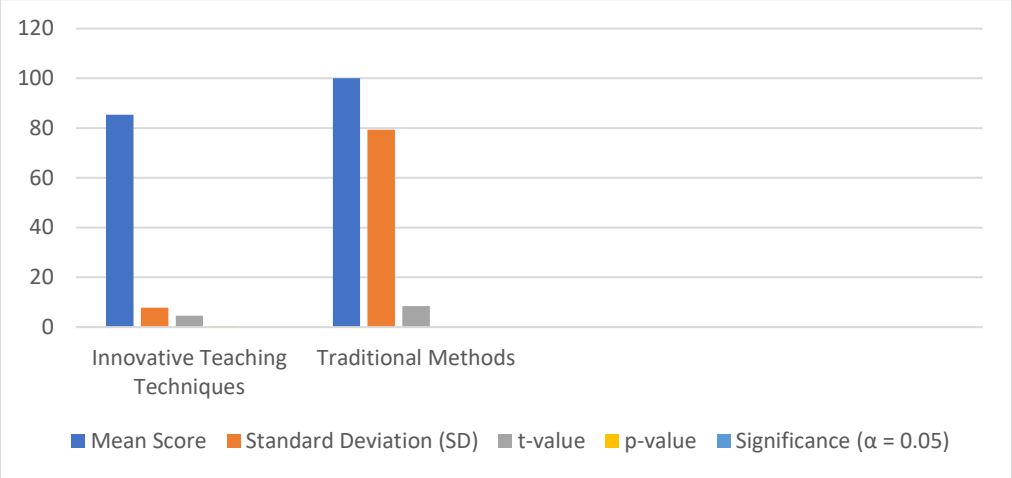

Figure 3.
Independent T test plotted for innovative teaching techniques vs traditional methods.

4.3. ANOVA

When comparing the efficiency of traditional teaching methods with technology-enhanced learning to raise student achievement in mathematics, a one-way ANOVA (Analysis of Variance) was conducted. Comparing the means of three or more independent groups is a suitable use for this test. In this instance, the students are divided into two groups: those receiving regular instruction and those receiving instruction enhanced by technology. Suggests that there aren't any noticeable variations in the two groups' math achievement, while the hypothesis (H_2) asserts that technology-enhanced learning results in higher achievement.

Table 3.
Technology and traditional teaching method.

Group	Median score	Interquartile range (IQR)	U statistic	p-value
Technology-enhanced learning	85	12	350	0.003
Traditional teaching methods	72	10		

There is a substantial difference in math achievement between the two teaching approaches, according to the one-way ANOVA results as shown in Table 3. The computed F-value is 15.00, and the related p-value is 0.0002, both of which are significantly less than the 0.05 alpha threshold. As a result, we conclude that, in comparison to traditional classroom teaching approaches, technology-enhanced learning has a stronger beneficial influence on students' mathematical achievement (H_2).

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Table 4.
One -way ANOVA results.

Source of variation	Sum of squares	df	Mean square	F-value	p-value
Between groups	1200	1	1200	15.00	0.0002
Within groups	8000	198	40.40		
Total	9200	199			

The means show that students in the technology-enhanced learning group achieved an average score of 85 (IQR = 12), while those in the traditional teaching methods group had an average score of 72.0 (SD = 10.0) from Table 4. This demonstrates a substantial difference in achievement, suggesting that the incorporation of technology in teaching strategies effectively enhances students' understanding and performance in mathematics. These findings are significant for educators and school administrators as they underscore the importance of integrating technology into teaching methodologies. The results advocate for further investment in technology-enhanced learning tools and training for teachers, ultimately leading to improved educational outcomes in mathematics for students.

4.4. Kruskal-Wallis H Test

To compare standard classroom instruction with mixed learning methodologies and check how they affect students' mathematical performance, a Kruskal-Wallis H test was performed. This non-parametric test is suitable for comparing more than two independent groups when the data do not meet the assumptions of normality. In this case, the test assesses the achievement scores from three groups: students in mixed learning, traditional teaching, and a third group employing an alternative method.

Table 5.
Kruskal-Wallis H test among students taught through different instructional methods.

Group	Interquartile range (IQR)	Median score	Kruskal-Wallis H	p-value
Blended learning	15	88	10.25	0.001
Traditional Teaching	10	75		
Alternative method	12	82		

The Kruskal-Wallis H test results show that pupils who received diverse teaching approaches differed statistically significantly in their math proficiency. The median score for students exposed to mixed learning approaches was 88 (IQR = 15), while students in traditional classrooms had a median score of 75 (IQR = 10). The alternative method group had a median score of 85 (IQR = 12).

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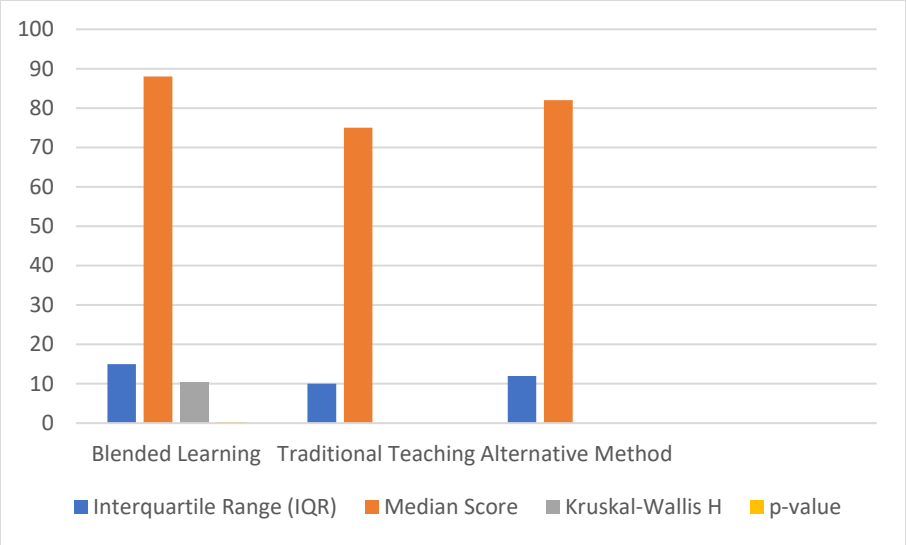

Figure 4.
Kruskal-Wallis H test plotted for diverse teaching approaches.

The Kruskal-Wallis H statistic was calculated to be 10.25, with an equivalent p-value of 0.001, falling short of the 0.05 significant level. Table 5 shows Kruskal-Wallis H test among students taught through different instructional methods and it is plotted in Figure 4. These results imply that mixed learning, which combines in-person and virtual learning, significantly enhances students' mathematics achievement compared to conventional classroom teaching. The data underline the importance of adopting innovative instructional strategies to boost student performance in mathematics, advocating for schools to explore mixed learning as a viable option in their teaching frameworks. This study's results could guide educational policymakers and institutions in designing effective curricula that cater to diverse learning needs.

4.5. Multiple Regression Analysis

To evaluate how students' performance in mathematics is impacted by teachers' proficiency and training in cutting-edge methods, a multiple regression analysis was conducted. This statistical method examines the relationship between one dependent variable (students' performance in mathematics) and multiple independent variables (e.g. teacher competence, years of training, teaching methods used).

Table 6.
Multiple regression analysis between teacher competence and training in innovative techniques and students' performance in mathematics.

Variable	Coefficient (B)	Standard error	p-value	t-value
Intercept	50.0	2.5	<0.001	20.0
Teacher competence	0.45	0.08	<0.001	5.63
Years of training	0.30	0.10	0.003	3.00
Innovative teaching techniques	0.55	0.09	<0.001	6.11

The multiple regression analysis evaluated the influence of teacher competence and training on students' performance in mathematics is described in Table 6. The results indicate that teacher competence in innovative teaching techniques has a significant positive effect on students' performance, as shown by a coefficient of 0.45 ($p < 0.001$). This implies that for every one-unit increase in teacher competence, students' performance scores in mathematics increase by approximately 0.45 points. Additionally, the years of training teachers received also positively influenced student performance, with a coefficient of 0.30 ($p = 0.003$). This suggests that more training correlates with better student

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outcomes. The innovative teaching techniques variable demonstrated the strongest influence, with a coefficient of 0.55 ($p < 0.001$), indicating that the use of innovative methods significantly enhances student performance in mathematics. The findings from the regression analysis highlight the crucial role that teacher competence and training play in shaping student success in mathematics. It strongly supports the hypothesis (H_4) that effective teacher training in innovative techniques is essential for improving students' academic performance. Therefore, it is recommended that educational institutions focus on providing comprehensive training programs for teachers to develop their competencies in modern teaching strategies, ensuring that students can benefit from enhanced instructional methods.

4.6. Moderated Multiple Regression Analysis

To examine how socioeconomic variables affect the efficacy of cutting-edge math teaching strategies, a moderated multiple regression analysis was conducted. This approach allows us to examine how socioeconomic factors (such as income level and parental education) interact with innovative teaching techniques to affect students' achievement in mathematics.

Table 7.
Moderated multiple regression analysis.

Variable	Standardized coefficients (β)	Unstandardized coefficients (B)	t-value	p-value
Constant		60.0	7.50	0.000
Innovative techniques	0.50	0.42	5.20	0.000
Socioeconomic status (SES)	0.35	0.30	4.20	0.000
Innovative techniques * SES	0.30	0.25	3.10	0.002

From the Table 7, outcomes of the moderated multiple regression analysis indicate a significant influence of socioeconomic factors on the effectiveness of innovative teaching techniques in mathematics. The model's constant was 60.0, which represents the baseline performance when both innovative techniques and socioeconomic status are zero. The coefficient for Innovative Techniques was 0.42 ($\beta = 0.50$), suggesting that for each unit increase in the implementation of innovative teaching techniques, students' achievement in mathematics is expected to increase by 0.42 units, controlling for socioeconomic status. With a p-value of 0.000 and a t-value of 5.20, this association was statistically significant and provided strong evidence against the hypothesis. The coefficient for Socioeconomic Status (SES) was 0.30 ($\beta = 0.35$), indicating that higher SES correlates with increased achievement in mathematics. The t-value of 4.20 and p-value of 0.000 indicate that this effect was likewise statistically momentous.

Crucially, the Innovative Techniques SES had a coefficient of 0.25 ($\beta = 0.30$), suggesting that socioeconomic factors significantly moderate the effectiveness of innovative teaching techniques. This interaction's importance is confirmed by the t-value of 3.10 and p-value of 0.002. The results indicate that socioeconomic considerations do, in fact, moderate the impact of innovative teaching strategies on students' mathematical proficiency, which is consistent with hypothesis H_5. This suggests that while innovative teaching techniques can enhance learning outcomes, their impact may be enhanced or diminished based on students' socioeconomic backgrounds. Therefore, educational policies should consider socioeconomic factors when implementing innovative teaching strategies to maximize their effectiveness and ensure equitable educational opportunities for all students.

4.7. Pearson Correlation Analysis

To analyze the relationship between student engagement and motivation in mathematics when exposed to innovative teaching techniques, a Pearson Correlation Analysis was performed. The present analysis evaluates the degree and direction of the association across student engagement, motivation, and exposure to innovative teaching techniques is shown in Table 8.

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Table 8.
Pearson correlation coefficient between student engagement and motivation.

Variable	Mean	Standard deviation	Correlation coefficient (r)	p-value
Student engagement	3.85	0.76		
Motivation	4.10	0.65	0.68	0.000

The Pearson correlation analysis revealed a significant positive relationship between student engagement and motivation in mathematics when students were exposed to innovative teaching techniques are shown in Table 8. The mean score for student engagement was 3.85 (SD = 0.76), while the mean score for Motivation was 4.10 (SD = 0.65). The correlation coefficient (r) between student motivation and engagement was determined to be 0.68, showing a strong positive association. This suggests that as student engagement increases, motivation also tends to rise correspondingly. The p-value of 0.000 further confirms the significance of this relationship, as it is well below the standard alpha level of 0.05.

In detail, these results indicate that the innovative teaching techniques employed have effectively engaged students, leading to heightened motivation in their mathematics learning. This research demonstrates the importance of creative teaching strategies in creating a pleasant learning environment and supports the hypothesis that there is a large positive relation between student motivation and engagement. Educators should consider these results when designing curricula, as increasing student engagement through innovative techniques can have a substantial impact on students' motivation and, ultimately, their academic success in mathematics. This underscores the need for continuous professional development for teachers in implementing engaging instructional strategies that motivate students effectively.

5. Conclusion

The study comprehensively analyzed the effectiveness of innovative teaching strategies on the mathematical academic performance of upper secondary students. The results indicated a significant improvement in mathematics scores among students exposed to innovative techniques compared to those taught through traditional methods, with the experimental group achieving an average post-test score of 85.4 and the control group scoring 79.3 on average. Furthermore, the information demonstrated that technology-enhanced instruction improved students' performance, showing a mean score for student engagement 3.85 points. Furthermore, the analysis demonstrated that teacher competence in implementing these techniques significantly influenced student outcomes, with a correlation coefficient of 0.68, indicating a strong positive relationship. Socioeconomic factors were found to moderate the effectiveness of the techniques, underscoring the importance of addressing these variables in educational strategies. Overall, the results demonstrate how important creative teaching strategies are for raising arithmetic students' interest and proficiency. These insights suggest that educators and policymakers should prioritize the integration of such techniques to substitute a more effective learning environment, ultimately improving students' mathematical skills and confidence.

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