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THE INFLUENCE OF PRACTICAL INSTRUCTIONAL APPROACHES ON MATHEMATICS ACHIEVEMENT AMONG SECONDARY SCHOOL STUDENTS

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ABSTRACT

High-quality classroom teaching and learning is a critical component of student achievement in mathematics, especially in areas that demand conceptual knowledge and graphical reasoning. The present study investigated the relationship between mathematical achievement and practical instructional approaches of 608- grade 11 students, which included 291 students in the practical instruction group and 317 students in the conventional instruction group. Descriptive statistics, adjusted regression and sensitivity analyses were used to assess pretest–post-test assessments and classroom-practice indicators. In practical instruction, the achievement of mathematics rose 20.15 percentage points, while it rose 4.32 percentage points in the comparison group. The achievement difference for adjusted regression was 17.05 points (95% CI: 15.19–18.90; $p < 0.001$). Increased gains were noted for students starting with lower levels of achievement. Positive correlations were also found with practical instruction and indicators of mathematical comprehension and problem solving. While there are some constraints on the generalizability of the non-random allocation and classroom-level clustering, the results suggest that activity-based instruction with a structure could be beneficial for improving secondary mathematics education.

Keywords – Classroom Practices, Mathematics Achievement, Practical Instruction, Secondary Education, Teaching Strategies.

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1. Introduction

The teaching of mathematics is important in the analytical reasoning, logical thinking and problem-solving skills of secondary school students. But, the ongoing difficulties in mathematical comprehension and achievement underscored the need for effective instructions. Instructional quality, learning opportunities, learning dynamics, and individual learning characteristics all affect student performance. Classroom-level educational processes are also recognized as important factors of mathematics achievement, as teacher instructional practices are a crucial aspect that needs to be considered (Osborne, 2021). Instructional strategies also have an impact on students' academic performance and mathematical self-efficacy (Falebita, & Olofin, 2020). In addition to the conventional assessment approaches, using higher order thinking skills in assessments in the classroom can enhance mathematical reasoning and conceptual understanding (Azid et al., 2022). The results here point to the need for instruction which moves beyond rote learning toward substantive learning experiences in math.

The focus of practical teaching methods is on active learning, mathematical explorations, contextualized problem solving and on the transfer of the theory to the real world. Such strategies foster student understanding of mathematical relationships, the ability to create mathematical representations, to consider multiple solutions and to use independent thinking. Practical instruction has been noted as an effective pedagogical approach, but there may be constraints due to limited instructional resources, insufficient professional development, and classroom conditions (Murangira et al., 2024). In addition, guided inquiry and explicit instructional strategies have also proven to be relevant to mathematics performance, making it essential to have structured learning activities (Ogunjimi & Gbadeyanka, 2023). Moreover, contextual teaching methods facilitate meaningful mathematical learning by making mathematical content more meaningful, especially in vocational mathematics education (Mahmuti et al., 2025). These results confirm the significance of conceptual understanding in the context of applied mathematical problem solving for effective teaching strategies in practice.

The active learning spaces promote collective reasoning, participation, formative feedback, and opportunities to talk about mathematical solutions. The model collaborative mathematics learning has been proven to have relevance to academic achievement and students' attitude towards mathematics (Siller & Ahmad, 2024). Likewise, novel classroom activities have been related to better student engagement and mathematical performance (Kihwele & Mkomwa, 2023). The purpose of formative assessment practices can also be to help the learning itself by recognising conceptual challenges and make adjustments to the teaching (Boström & Palm, 2023). Another key aspect to discourse of classroom practice is the use of technology in education. The applications of artificial intelligence have shown minor positive overall impacts on elementary students' mathematics achievement, and mathematics instruction with artificial intelligence has also been studied in rural educational settings (Hwang, 2022; Khazanchi et al., 2025).

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Technological interventions are not hands-on instructional interventions, but rather represent the growing variety of resources used to help students understand mathematics. However, the impact of their use needs to be investigated in specific pedagogical contexts and not presumed in other contexts.

Many intriguing questions remain about the uniformity of achievement across mathematics environments and ability levels, even as more and more research has emerged on innovative mathematics teaching. The learning experiences, the collaborative activities, the instructional resources, and the formative assessment are interwoven yet different pedagogical aspects, and thus, comparisons across studies are difficult. Furthermore, the improvement in mathematics achievement could be due to the base level of achievement, or to the demographics and/or institutional factors. Instructional coaching, classroom implementation practices and student achievement support the significance of quality instruction and implementation effectiveness (Glover et al., 2023). Therefore, measuring mathematics achievement calls for baseline performance and pertinent educational attributes to be taken into account. Additional research is required to explore achievement gaps by starting ability and to explore the independent relationship between students' reported classroom practices and achievement. These questions apply especially to mathematical concepts and situations where conceptual, graphical and procedural reasoning are needed. The purpose of this study was to examine the relationship between the practical instructional strategies and mathematics achievement of secondary school students using the topic of linear programming. Specifically, it aims to test whether there are significant pretest to post-test achievement gains for the practical group compared to the conventional group; it aims to test whether the post-test achievement gains are the same across the two instructional groups; and it aims to test whether there is a significant interaction between the baseline mathematical proficiency and instructional group in terms of achievement gains. In addition, student-reported graphing activities, heuristic problem-solving skills and mathematical understanding are correlated to academic results.

Research Objectives:

- To evaluate the impact of instruction on mathematics achievement.
- To compare mathematics performance of instructional groups and baseline proficiency levels.
- To explore relationships between classroom practices and mathematics achievement.

2. Materials and Methods

2.1. Research Design and Educational Setting

The relationship between the practical instructional approaches and mathematics achievement of

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secondary school students was investigated through a quantitative quasi-experimental pretest & post-test comparison group design. The educational setting was comprised of a pool of eight secondary schools in the central and eastern districts of Uganda, namely, Mukono and Mbale districts. The curriculum was based on linear programming and the use of graphical problem-solving methods and real-world applications in mathematics. Four schools applied an active-learning heuristic problem-solving approach, whereas four schools applied the conventional mathematics instruction (Balimuttajjo et al., 2022). The observed time for instruction was from 2020-2021.

2.2. Study Population and Participant Characteristics

The study incorporated 608 students of grade 11 aged 17-22 years of which 291 were from the practical instruction group and 317 students from the comparison group. Instruction was allocated at the classroom or school level and participants were recruited from eight complete secondary-school classes. Recorded parameters were age, gender, school location, attendance type and institutional ownership. The group type of instruction was classified as practical or conventional instruction with a Coded value of (1) or (0) respectively. Data screening revealed that there were no duplicate records and complete observation of all 39 variables.

2.3. Two focus areas are instructional approaches and classroom activities.

The teaching of practical mathematics was focused on active learning, heuristic thinking, illustration and application of real-world problems. Students used 4 stages: Understanding problems, planning solutions, implementing procedures and Evaluating results. Activities involved in creating inequalities, finding feasible regions and solving optimization problems on graph paper, grid boards. Conventional teaching was provided to the comparison group for the same mathematical content. Changes in achievement were measured through pretest and post-test assessments.

2.4. Maths assessment & Outcome monitoring

Mathematics achievement was assessed using a test referred to as Linear Programming Achievement Test (LPAT). This test had two 80-minute tests: one pre-test and one post-test. In each of the tests there were questions on inequality, graphing, feasible region, mathematical model, and optimization. The instruments were thoroughly reviewed and piloted. The Achievement scores (0 - 100) were presented with the post-test performance (POST_T) serving as the main outcome and the pretest scores (PRE_T) serving as the baseline proficiency point. The individual achievement gains were computed as the difference between post-test and pretest for comparison across groups of instruction.

2.5. Evaluation of Pedagogical and Andragogical Approaches in the Classroom

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The classroom practices were observed by 12 items of student reported questionnaire on five-point Likert scale (1 = strongly disagree, 5 = strongly agree). Three assessed graphing activities (G), four assessed problem-solving competencies (PS), and five assessed mathematical comprehension and processing (NEA) were evaluated. The overall score for active-learning (AL) was the mean of all 12 responses. The internal consistency of AL was acceptable (Cronbach's α = 0.71), but low for PS (α = 0.48). Responses were based on what students think the classroom practices were.

2.6. Statistical Analysis

Means and standard deviations were used to summarise continuous variables and frequencies and percentages to summarise categorical variables. Pearson's chi-square and Welch's t-tests were used to test for group differences, while paired t-tests were used to test for achievement changes. Cohen's d and 95% confidence intervals were used for the calculation of effect sizes. The post-test achievement was analyzed using regression with ANCOVA with robust standard errors, controlling for baseline achievement, age, gender, school location, status, and ownership. The differences between groups were tested using interaction analysis and associations between baseline proficiency and active-learning scores using exploratory regression; no mediation was specified. Median regression and Mann–Whitney U tests were used in sensitivity analyses. Significance level was considered as $p<0.05$ and these are analysed using Python.

3. Results

3.1. Baseline mathematics scores and student characteristics.

The subjects were 608 secondary school students, of which 291 students were in the practical instruction group, while 317 students were in the comparison group. There were no missing data or duplicate records for any of the 39 variables. The participants ranged in age from 17 to 22 years, with 59.5% and 53.0% being female, respectively. Day-school attendance (50.5% vs. 39.1%; p = 0.005) and the proportion of private schools (p = 0.003) as shown in Table 1 were significantly different between groups, but age, gender, and geographical location were not. There was a slightly higher mean of mathematics scores in the practical instruction group (45.76 ± 18.61%) than in the comparison group (42.79 ± 18.59%), with p = 0.0496. Adjustments were made for these differences in analyses.

Table 1. Demographic characteristics and baseline mathematics achievement of secondary school students

Characteristics	Comparison (n = 317)	Practical instruction (n = 291)	p-value

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Age, years, mean ± SD	18.38 ± 0.97	18.35 ± 1.00	0.726
Female, n (%)	168 (53.0)	173 (59.5)	0.109
Day school, n (%)	124 (39.1)	147 (50.5)	0.005
Private school, n (%)	124 (39.1)	149 (51.2)	0.003
Eastern Uganda, n (%)	147 (46.4)	144 (49.5)	0.443
Baseline achievement (%)	42.79 ± 18.59	45.76 ± 18.61	0.0496

3.2. Mathematics Achievement Across Instructional Groups

The results of the mathematics achievement showed an improvement in both groups, significantly larger in the practical instruction group (Table 2). Mean post-test scores were 65.91 ± 14.45% and 47.12 ± 16.58%, respectively, reflecting a significant difference of 18.79 percentage points (95% CI: 16.32–21.27; $p < 0.001$; Cohen's $d = 1.20$). The mean achievement gains were 20.15 percentage points (95% CI: 18.39–21.91) in practical instruction and 4.32 percentage points (95% CI: 2.95–5.70) in comparison ($p < 0.001$ for both). The between-group gain difference was 15.82 percentage points (95% CI: 13.60–18.05; $p < 0.001$) as shown in Figure 1. Of students, 95.9% and 71.0% had positive gains under practical instruction, respectively.

Table 2. Pretest–post-test mathematics achievement and between-group differences

Achievement measure	**Comparison group**	**Practical instruction group**	**Mean difference (95% CI)**
Pretest (%)	42.79 ± 18.59	45.76 ± 18.61	2.97 (0.01–5.94)
Post-test (%)	47.12 ± 16.58	65.91 ± 14.45	18.79 (16.32–21.27)

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Achievement gain (percentage points)	4.32 ± 12.41	20.15 ± 15.25	15.82 (13.60–18.05)

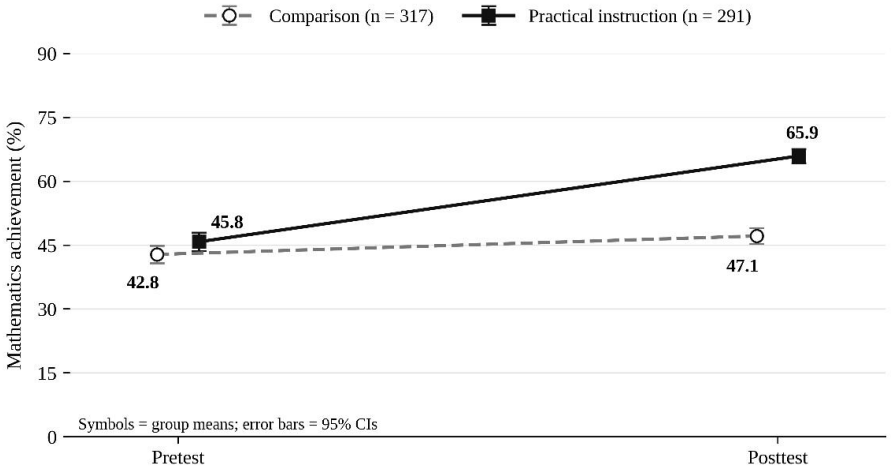


Figure 1. Mean Mathematics Achievement Before and After Instruction

3.3. Adjusted Association Between Instructional Approach and Mathematics Achievement

The practical instruction group had significantly higher achievement in the post-test after baseline adjustment (17.09 points; 95% CI: 15.22–18.95; $p < 0.001$) when compared by regression analysis as shown in Table 3. This association persisted after accounting for demographic and school characteristics (17.05 points; 95% CI: 15.19–18.90; $p < 0.001$), accounting for 63.5% of the variance in scores. An important interaction effect between baseline achievement was found ($\beta = -0.286$; $p < 0.001$). The group difference adjusted for attainment level, at baseline score of 30% was 21.17 points, at 60% was 12.61 points with higher advantages for students who perform lower at baseline as shown in Figure 2.

Table 3. Adjusted regression estimates for mathematics achievement

Statistical model or contrast	Estimate (95% CI)	p-value
Baseline-adjusted group difference	17.09 (15.22–18.95)	<0.001

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Fully adjusted group difference, without interaction	17.05 (15.19–18.90)	<0.001
Adjusted group difference at mean baseline score	17.11 (15.31–18.92)	<0.001
Group × baseline achievement interaction	−0.286 (−0.388 to −0.183)	<0.001
Adjusted difference at 30% baseline score	21.17 (18.44–23.90)	<0.001
Adjusted difference at 60% baseline score	12.61 (10.73–14.48)	<0.001

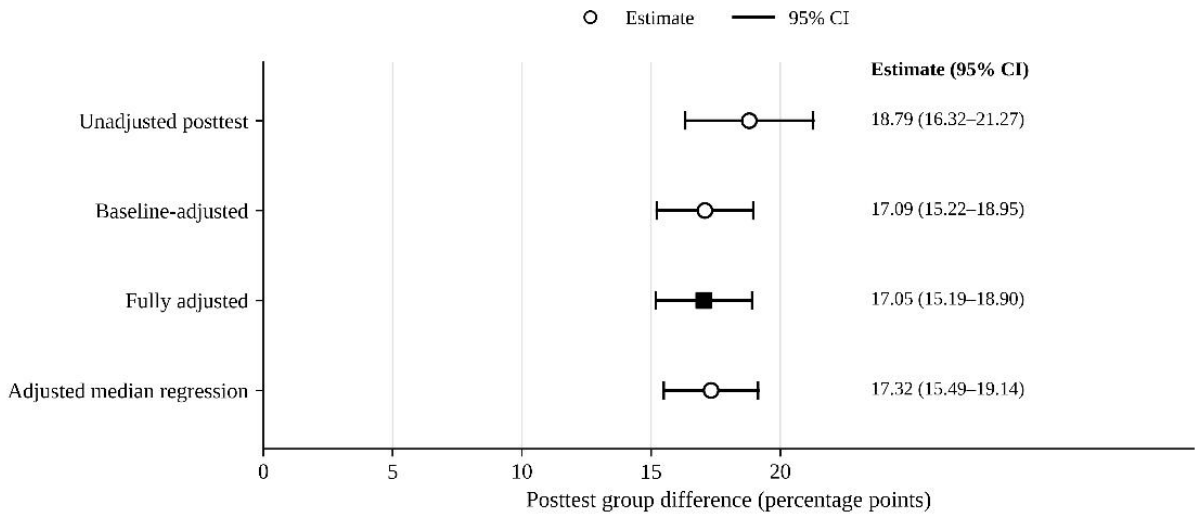


Figure 2. Between-Group Differences Across Statistical Models

3.4. Classroom Instructional Practices and Mathematical Problem-Solving

There were significant differences in classroom practice by the students across the instructional groups (Table 4). The practical instruction group demonstrated higher problem-solving scores (2.48 ± 0.73 vs. 2.10 ± 0.48; $p < 0.001$) and mathematical comprehension scores (2.56 ± 0.68 vs. 2.19 ± 0.47; $p < 0.001$). There was no significant difference ($p = 0.508$) in graphing-resource

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ratings. There were also higher scores under practical instruction for the overall active-learning composite (2.82 ± 0.52 vs. 2.53 ± 0.40; $p < 0.001$; Cronbach's $\alpha = 0.71$), with a relatively low reliability ($\alpha = 0.48$) as shown in Figure 3 for the problem-solving subscale.

Table 4. Student-reported classroom practices and mathematical learning processes

Learning indicator	**Comparison group**	**Practical instruction group**	**p-value**
Graphing-resource use	3.67 ± 0.75	3.71 ± 0.76	0.508
Problem-solving competencies	2.10 ± 0.48	2.48 ± 0.73	<0.001
Mathematical comprehension and processing	2.19 ± 0.47	2.56 ± 0.68	<0.001
Overall active-learning composite	2.53 ± 0.40	2.82 ± 0.52	<0.001

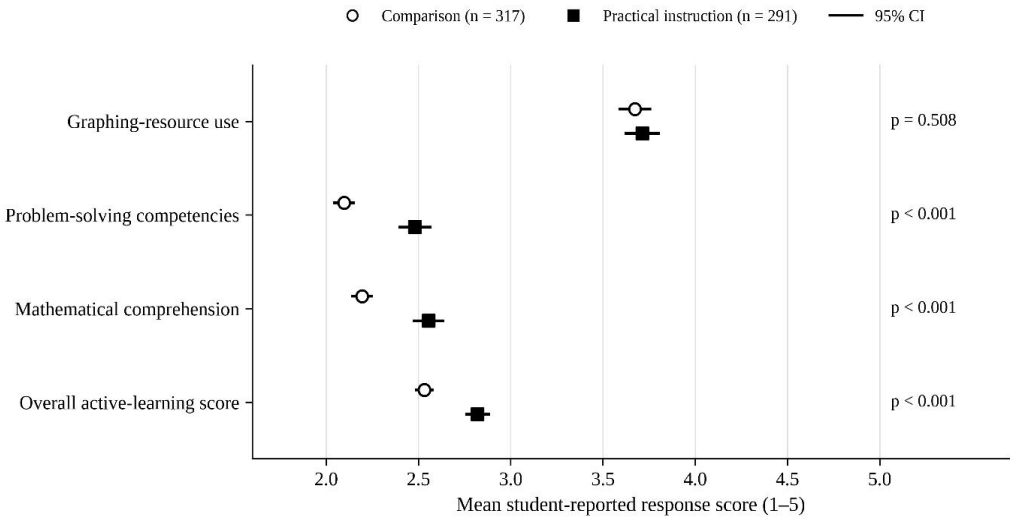


Figure 3. Student-Reported Classroom Practices by Instructional Group

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Supplementary and Robustness Analyses

Exploratory regression showed a positive relationship between active-learning scores and the post-test achievement, even after accounting for the instructional group, baseline performance, and student characteristics (β = 9.55; 95% CI: 7.38–11.73; p < 0.001), but it did not demonstrate mediation. Results were confirmed by sensitivity analyses including median regression which indicated an adjusted group difference of 17.32 points (95% confidence interval: 15.49–19.14; p < 0.001). Results of nonparametric comparisons also showed there were significant differences in achievement gains (p < 0.001). For the overall sample, consistent results were obtained across the analyses that practical teaching was associated with higher scores in linear-programming achievement.

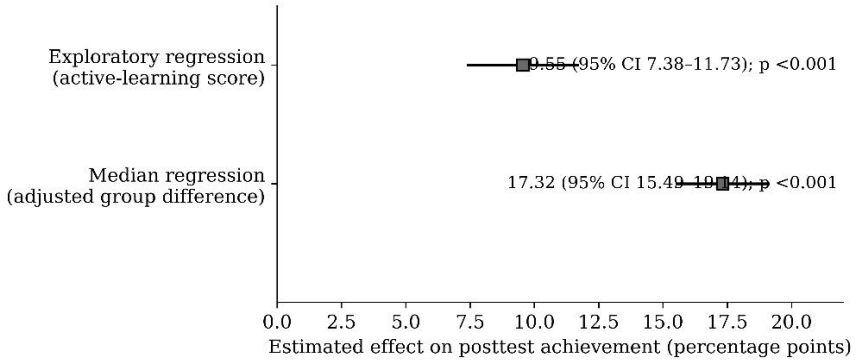


Figure 4. Exploratory and sensitivity analyses.

4. Discussion

There is a significant relationship between practical instruction methods and mathematics achievement of secondary students. The mean of the practical instruction group was 65.91% while that of the conventional instruction group was 47.12% for the post-test. This achievement difference was not eliminated by the adjustment process, as the difference was still statistically significant at 17.05 percentage points (p < 0.001) after the adjustment was made. These findings align with previous research showing that practical-work instructional strategies achieve good mathematics performance and retention (Sochima, 2021). On a similar note, secondary school students who were being taught higher mathematics using the flipped-classroom method achieved better performance in higher mathematics (Egara & Mosimege, 2024). Comparisons illustrate the education value of student-centered and interactive pedagogies, but the pedagogies vary in how they are used in the classroom.

In the students who received practical instruction, higher scores were found in problem solving and mathematical comprehension. The differences indicate that there might be some functions of active participation, heuristic thinking and contextualization in mathematical activities that could

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assist in applying mathematical concepts. A deep-learning instructional approach was also found to positively impact high school students' mathematical achievement and practical intelligence. Student reported class practices should not be assumed as confirmed mechanisms that account for achievement differences, however. Furthermore, some direct associations between classroom instructional quality and socioemotional support and mathematics related learning outcomes were reported, although they were not statistically significant (Zhu & Kaiser, 2022). The difference highlights the relationship between instructional quality, student engagement and measurable academic outcomes and its complexity.

However, the connection between instructional treatment and post-test success was significantly modified in terms of the participants' initial level of mathematical skill. In the current case, the difference between the two groups was greater for those having lower initial level of performance (21.17 points at 30% achievement but 12.61 points at 60%). It can be said that the discovered connection means that for students having more difficulties with mathematics initially, practical approaches to teaching may be crucial. Mathematics achievement at different levels of proficiency was found to improve after using manipulative instruction (Ahmad & Siller, 2024). The current study involved younger participants, but the outcomes may be helpful for differentiated instructional materials. Within practical tasks, there is an opportunity to visualize mathematical connections, enrich and consolidate conceptual knowledge and develop problem-solving skills. Nevertheless, interaction revealed in the current analysis does not refer to particular processes leading to these differences.

The significant correlation between consistently greater achievement and the practical instruction lends support to the consideration of active-learning strategies in secondary mathematics classrooms. However, the statistically non-significant difference in graphing resource ratings suggests that variations in mathematics achievement cannot be attributed solely to differences in access to instructional resources.

Similarly, positive instructional experiences and increased mathematical self-efficacy are not guaranteed to lead to significant achievement gains (Algarni & Lortie-Forgues, 2023). Given the findings above, it is clear that the impact of instruction is dependent on the implementation of the pedagogy, curriculum alignment, and the context in which the instruction is being done. Therefore, the teachers of mathematics can take advantage of the practice by engaging students in problem-based learning and giving necessary assistance, guidance and feedback.

The study faces various methodological issues worth discussing. First, the nonrandom allocation of the instruction subjects makes it possible to introduce the selection bias. Residual confounding may arise because of the school differences even when adjusting the analysis statistically. The lack of classroom identifiers means that cluster inference could not be made in this study. Moreover, the problem-solving subscale is not very reliable, which reduces confidence in interpreting each individual indicator of the learning process.

Achievement assessments were limited to linear programming, which is a specific domain of mathematics. Future research should include classroom level analytical structures, reliable measures of achievement, and follow-up measures to determine if gains in achievement are maintained in various educational contexts. In general, the findings indicate that the pragmatic approaches applied in mathematics attainment are pertinent and have to be fully evaluated for their educational value.

5. Conclusion

There is a strong relationship between the practical instructional methods and mathematics achievement of secondary school students. The difference between the students who were taught linear programming practically and the students who were taught conventionally in linear programming achievement had an adjusted difference of 17.05 percentage points. This is because the achievement gap was more pronounced among students with lower baseline skills, indicating the possible impact of hands-on teaching on mathematics learning challenges. Importance of practical work, heuristic thinking and contextual tasks becomes even more apparent due to better problem-solving skills and understanding of mathematical concepts. Absence of non-random distribution of instructions, limited mathematical topics and lack of class identification limit the possibility of causal interpretation and generalization. The findings confirm the necessity to incorporate structured practice-based tasks into the process of teaching mathematics in secondary school but taking into consideration the fact that proper use of teaching aids and differentiation is necessary. Further research should be based on longitudinal design, analysis of class performance and comprehensive mathematics evaluation.

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