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Problem-solving pedagogy and mathematics achievement in senior high schools: Implications for equitable and sustainable instruction

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Abstract

Sustainable education requires instructional practices that promote higher-order thinking and equitable learning outcomes, particularly in developing-country contexts. This quasi-experimental pretest–posttest study examined the effectiveness of a problem-solving instructional approach on senior high school students' mathematics achievement and gender-related performance differences in Ghana. Two intact classes were assigned to an experimental group (problem-solving pedagogy) and a control group (conventional instruction). Because normality assumptions were not fully met for some baseline measures, bootstrapped independent-samples *t*-tests were used to compare pretest and posttest scores. Results indicated no statistically significant difference between groups at pretest, supporting baseline comparability. At posttest, students who received problem-solving instruction achieved significantly higher mathematics scores than those who received conventional teaching, with a medium effect. Within the experimental group, male and female students did not differ significantly in posttest performance, suggesting that problem-solving pedagogy may support equitable achievement outcomes. The findings support problem-solving–oriented instructional reform as a practical approach for improving mathematics performance and promoting equity under Ghana's Standards-Based Curriculum. Implications for teacher professional development, curriculum implementation, and education policy are discussed.

Keywords: Gender differences; Instructional reforms; Mathematics achievement; Problem-solving pedagogy

1. Introduction

Sustainable education focuses on instructional practices that promote high-quality learning and equitable outcomes, particularly by strengthening higher-order thinking and meaningful understanding, which are essential for national development. Mathematics education is a primary contributor to the sustainable development goals, especially in developing-country contexts like Ghana where mathematical proficiency determines access to higher education, STEM jobs and economic activities (Hafni et al., 2020). Improving students' mathematics achievement therefore remains a persistent priority for researchers, educators, and policymakers (Gökçe & Güner, 2021). As a foundational subject in the curriculum, mathematics supports learning across STEM-related disciplines and shapes students' educational and employment opportunities (Aloraini, 2020; Hafni et al., 2020).

Despite its significance, Ghanaian Senior High School Students frequently face substantial obstacles when it comes to mathematics (Efa & Frimpong, 2023). As a result, many teaching methodologies have been investigated in an attempt to enhance mathematical proficiency (Khalid et al., 2020). Many have criticized traditional teaching methods for not engaging students deeply enough to develop a meaningful comprehension of mathematical ideas. These methods frequently rely on rote memorization and repetitive practice (Koskinen & Pitkäniemi, 2022).

In response, education stakeholders increasingly advocate student-centered approaches that develop reasoning, application, and problem-solving competence (Benabentos et al., 2021). In light of this, the Ghana Education Service and the Ministry of Education, through the National Council for Curriculum and Assessment [NaCCA], introduced the Standards-Based Curriculum [SBC] to build learners' 21st-century skills and core competencies for a fast-changing world. The SBC emphasizes competencies such as critical thinking and problem solving, creativity and innovation, communication and collaboration, and personal development and leadership (NaCCA, 2019).

Given this curricular emphasis, instructional approaches that explicitly cultivate problem solving warrant empirical examination in Ghanaian senior high school mathematics classrooms.

However, international reports indicate that students' performance in mathematics remains below expected standards in many contexts (Mullis et al., 2016). Consequently, educators and policymakers continue to call for improved approaches to mathematics instruction that can raise achievement and strengthen conceptual understanding (Anthony & Walshaw, 2009). Despite the subject's relevance, it continues to face obstacles that have a detrimental effect on students' performance in academic. Research has identified a significant relationship between students' mathematics achievement and the instructional practices employed by their teachers, highlighting the role of classroom pedagogy in shaping performance outcomes (Hill et al., 2005; Kunter et al., 2013).

In addition to overall achievement concerns, gender-related patterns in mathematics participation and performance remain an important equity issue. Numerous studies on mathematics and scientific achievement have included gender as a significant element (Acquandoh et al., 2022; Ali et al., 2010; Efa & Frimpong, 2023). As indicated by the gender parity index from 2011 to 2018, data from the World Bank (2019) demonstrates that there is still an uneven distribution of access to education between males and females in Ghana. The reason for this is probably the old-fashioned notion that boys are better at arithmetic than girls, which encourages more boys to enroll in math-related courses (Boateng, 2019). Empirical evidence on gender differences in mathematics achievement is mixed across contexts (Perie et al., 2005), making it important to examine whether instructional reforms support equitable achievement outcomes for both male and female students.

Examining the effect of the problem-solving teaching approach on students' academic performance in mathematics is crucial, considering the possible advantages of this approach. For instructors looking to enhance mathematics instruction, knowing how this instructional strategy affects learning results can be quite insightful. In addition, understanding gender's function in this context might aid in spotting any uneven impacts and guaranteeing inclusive and equitable teaching methods. Accordingly, this study investigates whether a problem-solving instructional approach improves Ghanaian senior high school students' mathematics achievement compared with conventional instruction, and whether post-instruction achievement differs by gender within the problem-solving group. By focusing on achievement gains and gender comparability, the study contributes evidence relevant to instructional reform aimed at effective and equitable learning outcomes.

1.1. Problem Statement

Studies across pedagogical research journals have shown that instructional approaches emphasizing problem-solving or problem-based learning tend to facilitate peer collaboration, social interaction, critical thinking, and deeper conceptual understanding, especially when contrasted with traditional lecture-focused methods (Ajani, 2024; Banus, 2015; Kök & Duman, 2023). Accordingly, examining problem-solving pedagogy as an instructional alternative is warranted in the Ghanaian SHS context, particularly under curriculum reforms that emphasize higher-order competencies. Problem-solving teaching approaches have been shown to enhance students' critical thinking, analytical reasoning, and the flexible application of problem-solving strategies, while also fostering creativity and autonomous learning (Hmelo-Silver, 2004).

Equity considerations further motivate this investigation. Although gender differences in mathematics achievement are widely debated, evidence remains mixed across contexts, and gender stereotypes and attitudes may influence students' engagement and outcomes (Else-Quest et al., 2010; Mozahem et al., 2021; Reilly et al., 2019). In Ghana, unequal participation patterns and societal beliefs about mathematics may shape students' learning opportunities and confidence (Boateng, 2019; World Bank, 2019). Additionally, studies have shown that girls do better in mathematics when taught by female teachers or in a more gender-inclusive manner, such as through collaborative learning activities (Acquandoh et al., 2022; Else-Quest et al., 2010). These findings suggest that instructional approaches promoting active participation and collaboration may support more equitable achievement outcomes.

Despite these studies, there remains limited quasi-experimental evidence in Ghanaian SHS settings comparing problem-solving pedagogy with conventional instruction while also examining whether achievement outcomes differ by gender within the problem-solving condition. This constitutes a practical and empirical gap given ongoing efforts to improve mathematics outcomes and promote equitable learning. This study aims to investigate the effects of problem-solving teaching strategies and students' gender on academic performance in mathematics in Toase Senior High School in the Atwima Nwabiagya Municipality in the Ashanti Region.

Within the scope of this research, the following hypotheses were examined.

H1: There is no statistically significant difference in mathematics achievement between the experimental (problem-solving) and control (conventional) groups at pretest.

H2: There is no statistically significant difference in mathematics achievement between the experimental (problem-solving) and control (conventional) groups at posttest.

H3: There is no statistically significant difference in posttest mathematics achievement between male and female students within the experimental (problem-solving) group.

2. Theoretical Framework of the Study

This study is grounded in Constructivist Theory of Learning, which posits that learners actively construct knowledge through experiences, social interaction, and reflection rather than passively receiving information (Almulla, 2023). In mathematics education, constructivist pedagogy emphasizes meaning-making, conceptual understanding, and reasoning, shifting instruction away from rote memorization toward deeper engagement with mathematical ideas (Fitriani et al., 2020). From a constructivist perspective, problem-solving pedagogy is particularly relevant because it encourages learners to connect new tasks to prior knowledge, explore multiple solution pathways, justify their reasoning, and refine understanding through discussion and feedback (Efa & Frimpong, 2023). In constructivist classrooms, the teacher functions as a facilitator who structures inquiry, provides scaffolding, and guides students' collaborative exploration to support productive struggle and conceptual development (Hiebert & Grouws, 2007; Vygotsky, 1978).

Accordingly, constructivism provides a theoretical rationale for expecting that students taught through a structured problem-solving approach will demonstrate higher mathematics achievement than students taught through conventional instruction, because the approach promotes active engagement and deeper conceptual processing (Efa & Frimpong, 2023; Fitriani et al., 2020). In addition, constructivist learning environments can support more equitable learning opportunities by broadening participation through collaborative interaction and varied ways of demonstrating competence, which is relevant when examining achievement outcomes by gender (Almulla, 2023; Fitriani et al., 2020).

2.1. Problem Solving Teaching Strategy and Students' Academic Performance in Mathematics

The research on problem-solving teaching strategies indicates that incorporating structured problem-solving activities can improve students' mathematics achievement by promoting reasoning, conceptual understanding, and higher-order thinking. Rather than relying on routine procedures, problem-solving pedagogy engages learners in interpreting tasks, selecting strategies, justifying solutions, and reflecting on outcomes, which can strengthen both procedural and conceptual knowledge (Ali et al., 2010; Cai & Lester, 2021). Empirical studies generally report that students exposed to problem-solving–oriented instruction outperform peers taught through conventional, teacher-centered approaches, particularly when instruction includes explicit strategy teaching and opportunities for collaboration and reflection (Boaler, 2016; Hmelo-Silver, 2004).

However, the effectiveness of problem-solving instruction depends on implementation quality. Kirschner et al. (2006) caution that students may become overwhelmed when tasks are insufficiently scaffolded. Accordingly, teachers' facilitation—through timely feedback, structured questioning, and appropriate scaffolding—plays a critical role in enabling students to benefit from problem-solving approaches (Anthony & Walshaw, 2019). In developing-country contexts, these considerations are closely linked to sustainable education goals, as effective problem-solving instruction may support high-quality learning outcomes while promoting equitable participation in mathematics. Given Ghana's Standards-Based Curriculum emphasis on critical thinking and problem solving, evidence on the achievement effects of problem-solving pedagogy is especially relevant for instructional reform and curriculum implementation.

2.2. Gender and Students' Academic Performance in Mathematics

Gender differences in mathematics achievement have been widely debated, with research showing mixed and context-dependent findings. Some studies report minimal or no gender differences in earlier schooling, while others suggest gaps may emerge in secondary education as content becomes more abstract and as attitudes and confidence diverge (Harris et al., 2021). Beyond performance, gendered beliefs, anxiety, and self-confidence can shape students' engagement and persistence in mathematics, potentially influencing achievement outcomes (Schoenfeld, 2013).

Importantly, classroom practices and instructional design may moderate gender-related outcomes. Traditional teacher-centered approaches may unintentionally privilege participation patterns that disadvantage some learners, whereas student-centered approaches—such as structured problem solving and collaborative learning—can promote broader engagement and more equitable opportunities to demonstrate competence (Fufa et al., 2023). Because prior evidence is mixed, examining whether problem-solving instruction yields comparable achievement outcomes for male and female students is a meaningful equity-oriented question. In the context of sustainable education, such evidence can inform instructional reforms aimed at improving achievement while supporting fairness in learning outcomes.

2. Method

2.1. Research Design

The study adopted a quantitative research approach and employed a quasi-experimental pretest–posttest nonequivalent groups design to examine the effect of a problem-solving teaching strategy on students' mathematics achievement. A quasi-experimental design was appropriate because the researcher had limited control over classroom conditions and could not randomly assign individual students to groups. Two intact Form Two classes from Toase Senior High School were selected and assigned to either a control group (conventional instruction aligned with the standard curriculum) or an experimental group (problem-solving instruction).

A pretest was administered to both groups to establish baseline equivalence in mathematics achievement prior to the intervention. After the instructional period, a posttest was administered to assess students' achievement following exposure to the respective instructional approaches. This design enabled comparison of post-intervention outcomes while accounting for initial group differences through baseline measurement.

2.2. Participants

The study examined the effects of problem-solving pedagogy and gender on Toase Senior High School students' mathematics achievement in the Atwima Nwabiagya Municipality, Ashanti Region, Ghana. Toase Senior High School had approximately 900 Form Two students at the time of the study. Two intact Form Two classes were selected, yielding a total sample of 277 students. In line with the quasi-experimental design, students were not individually randomized; instead, the intact classes were assigned to either a control group (n = 139) receiving conventional instruction or an experimental group (n = 138) receiving problem-solving instruction. Purposive selection was used to include intact classes that supported gender representation in both groups and to ensure feasibility within the school timetable.

Of the 277 participants, 132 were male (47.7%) and 145 were female (52.3%). Regarding age, 84 students (30.3%) were aged 11–15 years, 185 (66.8%) were aged 16–20 years, 5 (1.9%) were aged 21–25 years, and 3 (1.0%) were above 25 years, indicating that most participants were within the 16–

20-year age range.

2.3. Process

Instruction in the control group followed a teacher-centered approach characterized by explanation of concepts, worked examples on the board, and whole-class question-and-answer sessions focused on the arithmetic topic. Lessons relied on the textbook and teacher-led demonstrations. The teacher solved most example problems, emphasized correct procedures, and summarized key points at the end of each lesson. Student participation primarily involved responding to teacher questions and completing assigned exercises individually.

In the experimental group, lessons were organized around small-group problem solving. Students worked in groups to solve non-routine/unstructured tasks related to the arithmetic content. Group members were assigned roles (e.g., leader, recorder, presenter, timekeeper) to structure participation and accountability. Students were encouraged to share ideas, justify solution strategies, and compare alternative approaches during group discussion. The teacher acted as a facilitator by setting lesson goals, monitoring group work, and using open-ended guiding questions to prompt reasoning rather than providing direct solutions. In addition to group work, students completed brief individual tasks to articulate and reflect on what they learned, after which groups presented solutions and received feedback.

The intervention lasted three weeks, after which the posttest was administered to both groups.

2.4. Data Collection Instrument

In order to address the research question, test the hypothesis, and assess the results, data collection entails gathering information from all pertinent sources. The study employed Fifteen (15) standardized objective and three (3) easy questions labelled "Mathematics Achievement Test [MAT]" that were derived from the topic (commercial arithmetic) were taken into consideration. The experimental group received instruction utilizing the problem-solving teaching style over the three-week period naturally, while the control group received instruction using the conventional method. The topic yielded fifteen (15) objective and three (3) easy questions with four possible answers (A-D). Students were given the pretest and posttest questions; each test was scored and marked appropriately. The test instrument was divided into two Parts. Part A constituted the demographics data. Part B consisted Section A and Section B. The section A consisted of 15 objective questions and Section B consisted of three easy questions labelled "Mathematics Achievement Test" that were derived from the topic (arithmetic) was taken into consideration for the study. Validity and reliability are essential in assessing research quality. Validity ensures that a measure accurately reflects what it intends to evaluate, while reliability ensures consistent results under similar conditions. Validity types include content, construct, and external validity, among others. To enhance validity, the researcher sought feedback from math specialists on the questionnaire's ability to meet study objectives. Reliability, measured through the Cronbach's Alpha Coefficient, ensures the consistency of results. High reliability means the same results can be obtained repeatedly with the same instrument. Results of the reliability test were presented in the following section.

2.5. Data Analysis

The data collected from the study were coded and analyzed using IBM SPSS Statistics (Version 23). Prior to the main analyses, the dataset was screened for completeness and accuracy. Descriptive statistics (frequency, mean, and standard deviation) were computed to summarize students' mathematics achievement scores for both the experimental and control groups across the pre-test and post-test administrations.

Because the study aimed to compare mean achievement scores between two independent groups (experimental vs. control) and also examine gender differences within the experimental group, independent-samples t-tests were selected as the primary inferential statistics. Specifically, the analyses were conducted to: (i) determine whether the experimental and control groups were equivalent at baseline using pre-test scores, (ii) examine whether a significant difference existed between the groups' post-test achievement scores after the intervention, and (iii) investigate whether male and female students in the experimental group differed significantly in post-test performance.

Before conducting the t-tests, the assumptions required for parametric testing were evaluated. Normality of score distributions was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests across groups and, where applicable, by gender. Homogeneity of variances was examined using Levene's Test for Equality of Variances, while independence of observations was ensured by the study design, as the participants in the experimental and control groups were not paired and belonged to separate, independent samples.

Although some normality tests produced p-values below .05 (suggesting minor deviations from normality), the sample sizes in each group were above 30. In line with recommendations that parametric tests may remain robust with large samples—and that bootstrapping can be used to minimize the impact of normality violations—bootstrapped independent-samples *t*-tests were conducted in SPSS to provide more reliable estimates of standard errors and significance values. All hypotheses were tested at the 0.05 level of significance (α = .05).

To complement statistical significance, effect size was computed and reported using eta squared (η^2) to describe the magnitude of group differences. Effect sizes were interpreted using Cohen's guidelines (e.g., small, medium, and large effects), enabling practical interpretation of the findings beyond *p*-values. Results were then presented in tables, including group sample size (N), mean scores, standard deviations, *t*-values, degrees of freedom, significance levels, and effect size estimates.

3. Results

3.1. Preliminary Analysis

When conducting a parametric t-test, certain crucial assumptions must be met in order to guarantee both the accuracy and dependability of the test results. Before presenting the results of the *t*-test, it is essential to address the assumptions required for this test. Table 1 presents the results of the normality tests (Kolmogorov–Smirnov and Shapiro–Wilk) conducted for the pre-test and post-test scores across the control and experimental groups (and by gender within the experimental group) to determine whether the score distributions met the normality assumption required for parametric analyses.

Table 1
Test for normality across groups for various tests

Tests and Groups	*Kolmogorov-Smirnov*[a]			*Shapiro-Wilk*		
	Statistic	*df*	*Sig.*	*Statistic*	*df*	*Sig.*
Pre-test						
Control	.088	139	.011	.963	139	.001
Experimental	.094	138	.004	.970	138	.004
Post-test						
Control	.094	139	.005	.978	139	.023
Experimental	.066	138	.200	.986	138	.189
Post-test Experimental Group						
Males	.079	69	.200	.983	69	.474
Females	.090	69	.200	.981	69	.358

First, the assumption of normality was assessed for both groups using the Shapiro-Wilk test in the various tests. The experimental group's post-test Shapiro-Wilk test score was .189, indicating a normal distribution of the data. The post –test values for the experimental group both males (p = .474) and females (p = .358) group's Shapiro-Wilk test met the normality assumption. Nevertheless, the remaining tests conducted that is the pre-test both groups (Control and Experimental) and the control group in the post-test groups yielded *p*-values less than .05, indicating a marginal deviation from normalcy.

Second, the independence assumption was naturally satisfied because there was no association or pairing between the students from which the data for Experimental Group and Control Group were acquired. This guarantees that the results obtained by one group do not impact the results obtained by the other group. Table 2 reports the results of Levene's Test for Equality of Variances for the pre-test and post-test scores across the independent groups, assessing whether the assumption of homogeneity of variances was satisfied before conducting the independent-samples *t*-tests.

Table 2

Levene's Test for Equality of Variances on test scores for various independent groups

Test	*F*	*Sig.*
Pre-test	.270	.604
Post-test	.136	.713
Post-test-Experimental Group	.136	.712

Thirdly, the assumption of homogeneity of variances was checked using Levene's Test for Equality of Variances, which measures the homogeneity of variances. Table 2 shows that Levene's test was non-significant for the pre-test (p = .604), post-test (p = .713), and the experimental-group post-test by gender (p = .712), indicating that the homogeneity of variances assumption was met and the null hypothesis of equal variances could not be rejected. There are some assumptions that need to be met in order to perform *t*-tests. However, Sainani (2012) hinted that when using bootstrapping to run a *t*-test on a sample size larger than 30, it might be possible to break the assumptions of normality and homogeneity of variance. They added that when part of the data is not normally distributed which is possible when sample size is more than 30, either bootstrapping alternative or non-parametric alternative can be used to perform independent sample t-test. Based on this, SPSS version 23 Bootstrapping was used to run the t-test, and the outcomes are displayed in the sections that follow.

3.2. Pre-Treatment Academic Performance Differences between Groups

Table 3 presents the results of an independent-samples *t*-test comparing the control and experimental groups' pre-test mathematics achievement scores to determine whether the two groups were equivalent at baseline prior to the intervention.

Table 3

Independent t-test for pre-test comparison of academic performance between groups

Test	*Group*	*N*	*Mean*	*SD*	*t*	*df*	*p*	η^2
Pre-test	Control	139	11.17	4.10	−1.613	275	.108	.009
	Experimental	138	11.95	3.98				

The findings of an independent sample t-test, which was used to compare the mean scores of the pre-test for students' academic performance in mathematics between the control and experimental groups prior to the application of the treatment, are displayed in Table 3. The experimental group's pre-test results (M = 11.17, SD = 4.10) and the control group's (M = *11.95*, SD = 3.98) did not significantly differ from one another. [t (275) = −1.613, p > .05]. Effect size of 0.009 was noted and suggest a very negligible effect size signifying that, those students in the experimental group and the control group had similar performance (Cohen, 1988). This implies that prior to the intervention, the two groups' mathematical performance was comparable. This further shows that before the problem-solving teaching approach was put into practice, the two groups' initial academic performance in mathematics was similar. This comparability is important because it suggests that the intervention, rather than pre-existing variations in mathematical ability, is responsible for any discrepancies in post-test performance.

3.3. Post-Treatment Academic Performance Differences between Methods

Table 4 presents the results of an independent t-test conducted to compare the academic performance of students who were taught using the conventional method and those taught using the problem-solving strategy after the treatment.

Table 4
Independent t-test for post-test comparison between conventional and problem-solving methods

Test	*Group*	*N*	*Mean*	*SD*	*t*	*df*	*p*	η^2
Post-test	Control	139	12.38	3.80	−11.88	275	<.001	0.339
	Experimental	138	17.78	3.77				

The research hypothesis two of this seeks to determine whether there is a significant difference in the mean scores of academic performance of the students taught with conventional method and problem solving strategy or not. The independent t-test was used to compare the academic performance mean scores of the students taught with conventional method (Control Group) and the students taught problem solving strategy (Experimental Group) using the post-test. The post-test mean academic performance scores of students who were taught with the problem solving strategy (Experimental Group) and those who were taught with the conventional method (Control Group) were compared using an independent sample t-test. There was a significant difference in scores for the experimental group and control group. The Experimental Group's post-test results (M = 17.78, SD = 3.77) and the control group's (M = 12.80, SD = 3.80) did significantly differ from one another. [$t(275) = -11.88$, $p < .05$]. Effect size of 0.339 was noted and suggest a medium effect size signifying that, those students in the experimental group performed better in the post-test than the control group (Cohen, 1988).

3.4. Academic Performance by Gender in the Problem-Solving Group

Table 5 presents the results of an independent t-test conducted to compare the academic performance of male and female students who were taught using the problem-solving teaching method after the treatment.

Table 5
Independent t-test for post-test comparison between male and female students in problem solving

Test	*Gender*	*N*	*Mean*	*SD*	*t*	*df*	*p*	η^2
Post-test	Males	69	17.31	3.68	−1.148	136	.253	0.009
Experimental Group	Females	69	18.04	3.73				

The research hypothesis three of this study seeks to determine whether there is a significant difference in the academic performance mean scores of females and males students taught with the problem solving teaching method. In other, for to understand this, the independent t-test was used to compare the academic performance mean scores of females and males students taught with the problem solving teaching method. The males post test results (M = 17.31, SD = 3.68) and the females post- test results (M = 18.04, SD = 3.73) did not significantly differ from one another. [$t(136) = -1.148$, $p > .05$]. Effect size of 0.009 was noted and suggest a very negligible effect size signifying that, those males students in the experimental group did not perform better than the females' counterpart (Cohen, 1988). The fact that there is no statistically significant difference between the post-test scores of male and female students in the experimental group means that we are unable to reject the null hypothesis. This implies that when students are taught via the problem-solving teaching approach, gender has no discernible impact on their academic achievement in mathematics.

4. Discussion

4.1. Achievement Differences between Conventional Instruction and Problem-Solving Instruction

The study demonstrated that there was a significant difference in the post-test mean scores between the experimental group and control group. The experimental group's mean scores significantly improved when compared to the control group, indicating that the problem-solving teaching model is more effective than the traditional approach. A strong statistical difference is indicated by the p-value, which support the idea that the problem-solving technique had a major effect on students' academic performance.

The results are consistent with a constructivist view of learning, which holds that students develop stronger understanding when they actively construct knowledge through exploration, discussion, and reflection rather than relying on rote procedures (Piaget, 1970; Vygotsky, 1978). In this study, the experimental group’s higher post-test mean scores suggest that engaging students in problem-solving activities—where they propose strategies, justify solutions, and learn from peer interaction—can support meaningful learning processes associated with improved mathematics achievement (Schoenfeld, 2013). This outcome is corroborated by the constructivism theory of learning, which holds that knowledge is created by learners via experiences and reflections (Almulla, 2023). These kinds of experiences come from problem-solving exercises, which help students actively develop and improve their mathematical comprehension (Voon et al., 2022). The results provide support for the theory by showing that problem-solving strategies, which break up challenging tasks into manageable portions, can enhance academic achievement (Halpern et al., 2007). The findings more plausibly indicate that structured opportunities for reasoning and collaborative sense-making helped students interpret and apply mathematical concepts more effectively, leading to better performance than conventional instruction. This finding can be interpreted in relation to self-efficacy theory, which highlights the role of learners’ beliefs about their capability to succeed in shaping effort, persistence, and performance (Gerbino, 2020). Although self-efficacy was not directly measured in this study, problem-solving instruction may help students approach mathematical tasks with greater confidence by offering structured opportunities to practice strategies, receive feedback, and experience success in solving problems (Özkal, 2019). Such mastery experiences are widely viewed as an important source of increased self-efficacy, which may, in turn, be associated with improved mathematics achievement.

Problem-solving instruction and active learning have been widely associated with improved outcomes in mathematics education (Bimbim et al., 2026). Such approaches engage students in reasoning, strategy selection, and justification, which can strengthen conceptual understanding and support the application of mathematical ideas to unfamiliar or real-world contexts. Compared with lecture-based instruction, problem-solving pedagogy typically promotes deeper engagement because learners actively construct and communicate solution pathways rather than simply reproducing procedures. Prior research supports these benefits: Hiebert and Grouws (2007) reported that teaching practices emphasizing problem solving and conceptual connections are linked to stronger conceptual understanding and problem-solving competence than traditional approaches. Similarly, Boaler (2002) found that students taught through problem-centered instruction performed better on external assessments and were more likely to perceive mathematics as meaningful and dynamic, which may support more positive attitudes and sustained engagement. The outcomes of the present study are broadly consistent with this body of evidence. Students in the experimental group achieved significantly higher post-test scores than those in the control group, suggesting that problem-solving instruction can support students’ understanding and application of mathematical ideas more effectively than conventional teaching. This pattern aligns with research indicating that problem-solving–oriented instruction can be more effective than traditional teacher-centered approaches in improving students’ mathematical understanding (Hiebert et al., 1996; Hmelo-Silver, 2004). Similarly, Khatimah and Sugiman (2019), using a quantitative design and t-test comparisons, found that students taught through problem-solving strategies attained higher mathematics achievement than those taught through conventional instruction, with statistically significant differences between the approaches. Taken together, these results reinforce the practical implication that mathematics teachers may improve student outcomes by integrating structured problem-solving activities into lesson delivery. Shifting from predominantly teacher-centered instruction toward more interactive and student-centered problem-solving tasks may foster a more engaging learning environment and enhance students' mathematics achievement.

4.2. Gender Differences in Achievement within the Problem-Solving Group

The study found no statistically significant difference in post-test mathematics achievement between male and female students within the experimental (problem-solving) group ($p > .05$). This suggests that, under a problem-solving instructional approach, male and female students achieved comparable learning outcomes, indicating that the intervention may support equitable achievement in this context. Importantly, this conclusion should be interpreted as gender comparability in performance rather than as evidence of broader "gender equity" outcomes, because the study assessed achievement scores only.

From a theoretical perspective, the finding aligns with constructivist learning theory, which emphasizes active participation, dialogue, and meaning-making as foundations for learning (Fitriani et al., 2020). Problem-solving pedagogy typically provides structured opportunities for students to propose strategies, justify reasoning, and learn through interaction, which can broaden participation and reduce reliance on passive, teacher-dominated participation patterns. Such learning environments may help create conditions in which achievement outcomes are less differentiated by gender, particularly when all students are supported to engage actively in reasoning and solution construction (Bernard et al., 2019; Fitriani et al., 2020).

Empirically, the present finding is consistent with studies reporting no significant gender differences in mathematics achievement when students are provided with comparable learning opportunities and effective instruction (Hyde et al., 2008; Harris et al., 2021). At the same time, the wider literature reports mixed results across contexts, with some studies showing advantages for boys or girls depending on social, cultural, and instructional conditions (Else-Quest et al., 2010). This variability reinforces the importance of examining gender patterns within specific instructional environments rather than assuming uniform gender gaps. Therefore, the current results suggest that problem-solving pedagogy may be a promising approach for supporting mathematics learning while maintaining comparable achievement outcomes for male and female students in the studied setting.

5. Conclusion

This study examined the effects of a problem-solving teaching strategy on Senior High School students' mathematics achievement and gender-related performance differences. The findings showed no statistically significant difference between the experimental and control groups at pretest, supporting baseline comparability and strengthening confidence that post-intervention differences reflect instructional conditions. At posttest, students taught using the problem-solving strategy achieved significantly higher mathematics scores than those taught through conventional instruction, indicating that problem-solving pedagogy can be an effective approach for improving mathematics achievement in the studied context. In addition, male and female students in the problem-solving group did not differ significantly in posttest performance, suggesting comparable achievement outcomes across gender under this instructional approach.

From a sustainable education perspective, these results support instructional reform that prioritizes high-quality learning and fair opportunities to achieve by engaging students in active reasoning, collaboration, and meaningful problem engagement. While the study does not assess long-term sustainability outcomes, the evidence suggests that problem-solving pedagogy is a viable classroom-level strategy for strengthening learning outcomes in alignment with competency-oriented curriculum implementation.

Based on these findings, it is recommended that school curricula be redesigned to more explicitly embed problem-solving and activity-based learning, ensuring that mathematics instruction systematically develops reasoning, explanation, and application skills. To enable effective implementation, teacher professional development should focus on task design, scaffolding, facilitation of group work, and formative assessment practices aligned with problem-solving pedagogy. In addition, schools should promote classroom and school-wide practices that help students cultivate positive attitudes toward problem solving, as productive dispositions toward challenge and persistence can strengthen mathematics learning and support students' capacity to contribute meaningfully to their communities and personal development.

Future research should extend this work in two key directions. First, longitudinal studies are needed to examine whether achievement gains from problem-solving instruction are sustained over time and how continued exposure influences retention and progression across grade levels. Second, comparative studies should evaluate problem-solving pedagogy alongside other instructional approaches (e.g., inquiry-based learning, direct instruction, and structured collaborative learning) to identify their relative strengths, implementation requirements, and suitability for different topics and learner profiles. Such research would provide stronger evidence to guide sustainable instructional reform and curriculum implementation in mathematics education.

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