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# Enhancing Mathematics Achievement through the Think Talk Write (TTW) Learning Model: The Mediating Role of Students' Critical Thinking Ability in Indonesian Senior High Schools

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**ABSTRACT**

Mathematics education plays a central role in developing students' reasoning, problem-solving, and critical thinking abilities. However, many students continue to experience low achievement due to traditional teacher-centered instruction. This study aimed to examine the effect of the Think Talk Write (TTW) learning model on students' mathematics achievement when viewed from their critical thinking ability. The study employed a quasi-experimental design with a 2 × 2 factorial structure (treatment by level), involving grade X students at SMA Negeri 6 Gorontalo Utara during the 2022–2023 academic year. Data were collected using validated instruments measuring mathematics achievement and critical thinking ability, and analyzed using Two-Way Analysis of Variance (ANOVA). The results indicated that students taught using the TTW model achieved significantly higher mathematics scores than those taught through direct instruction. A significant interaction was found between the learning model and critical thinking ability, showing that TTW was most effective for students with high critical thinking skills, while direct instruction benefited those with lower critical thinking ability. The discussion highlights that TTW promotes active engagement, reflection, and collaboration, which strengthen conceptual understanding and reasoning. In conclusion, the TTW model enhances mathematics achievement through student-centered learning but requires adaptation to students' cognitive profiles. The study contributes to the understanding of how instructional design and cognitive factors interact to improve learning outcomes, offering implications for adaptive and evidence-based mathematics instruction.

**Keywords:** *Think Talk Write, mathematics achievement, critical thinking ability, cooperative learning, adaptive instruction.*

## Introduction

Education plays a crucial role in shaping the intellectual, moral, and social capacities of individuals, forming the foundation for national development and societal progress. In Indonesia, the 1945 Constitution and Law No. 20 of 2003 on the National Education System mandate education as a means of fostering citizens who are intelligent, creative, responsible, and morally upright. Mathematics, as a core subject taught at all levels of education—from elementary school to university—serves not only as a fundamental discipline for scientific advancement but also as a vital tool for logical reasoning and problem-solving in daily life. It sharpens critical thinking, enhances accuracy, and develops students' capacity to analyze and evaluate phenomena systematically. However, despite the central role of mathematics in modern education, students often perceive it as a difficult and abstract subject, resulting in low achievement and a lack of motivation (Hamalik, 2014; Susanto, 2015).

In contemporary educational practice, mathematical proficiency is closely associated with the ability to think critically. The Indonesian curriculum (Permendikbud No. 59 of 2014) explicitly emphasizes understanding mathematical concepts, applying logical reasoning, recognizing patterns, and communicating ideas through mathematical representations. These competencies align with global educational objectives that view mathematics not merely as computational skill, but as a vehicle for cultivating analytical reasoning and problem-solving abilities. Nevertheless, national assessment reports such as the *Asesmen Kompetensi Minimum* (AKM) in 2022 indicate that 75.56% of students at SMA Negeri 6 Gorontalo Utara scored below the minimum competency level in numeracy. This reflects a widespread challenge in mathematics learning outcomes across Indonesian schools. Previous studies (e.g., Shadiq, 2017; Purwanto, 2014) suggest that conventional teacher-centered methods often fail to stimulate students' engagement and higher-order thinking, particularly in topics that require conceptual understanding such as trigonometry.

Given this background, the persistent issue of low mathematical achievement among high school students can be attributed to multiple interrelated factors, including limited student participation in classroom discussions, insufficient opportunities for independent reasoning, and teachers' reliance on direct instruction models. Interviews conducted at SMA Negeri 6 Gorontalo Utara reveal that students often struggle to identify the appropriate formulas or strategies to solve mathematical problems, primarily because they fail to grasp the underlying concepts. As a result, they become passive learners, dependent on teachers' explanations, and unaccustomed to critical inquiry. This teaching culture assumes that knowledge can be transferred directly from teacher to student, disregarding individual cognitive differences and the constructivist principle that knowledge must be actively constructed by learners. Consequently, students' inability to think critically hinders their capacity to internalize mathematical principles and apply them to novel situations.

To address these learning challenges, researchers and educators have sought innovative pedagogical models that encourage student engagement, communication, and reflective thinking. Cooperative learning models, which emphasize social interaction and shared responsibility for knowledge construction, have been recognized as effective alternatives to traditional instruction. Among these, the Think Talk Write (TTW) model has gained prominence for its emphasis on the sequential processes of individual reflection (*think*), collaborative discussion (*talk*), and written articulation (*write*). Developed within the framework of cooperative learning, TTW fosters cognitive and metacognitive engagement by guiding students to process information, articulate reasoning, and consolidate understanding through communication (Siswanto & Ariani, 2016; Shoimin, 2014).

The TTW model integrates constructivist and social learning principles. In the *think* phase, students engage in independent reading, problem analysis, and conceptual reflection, allowing them to form preliminary understandings. In the *talk* phase, students discuss their interpretations with peers, negotiate meanings, and collaboratively refine their reasoning. Finally, in the *write* phase, students express their conclusions in written form, reinforcing their comprehension and allowing teachers to assess the development of their conceptual understanding. This cyclical process promotes not only comprehension but also critical reflection, as writing compels learners to synthesize and articulate ideas coherently. According to Hamdayama (2015), TTW enhances students' ability to construct knowledge, fosters active learning, and encourages communication skills, thus aligning with the goals of 21st-century education that prioritize collaboration, communication, critical thinking, and creativity.

Empirical studies have demonstrated that the TTW model can effectively improve learning outcomes and foster critical thinking. For example, Amardi, Aprinawati, and Mufarizuddin (2023) found that the implementation of TTW significantly enhanced elementary students' critical thinking skills and overall learning performance. Similarly, Damayanti (2023) reported that the cooperative TTW model had a positive influence on mathematics achievement among high school students, while Wa Ode Oni (2020) observed a significant improvement in students' mathematical understanding following the application of TTW at SMA Negeri 2 Pasarwajo. These studies suggest that TTW facilitates meaningful learning by engaging students in interactive and reflective processes. However, most existing research focuses on general improvements in achievement and participation, with limited exploration of how TTW interacts with students' individual cognitive traits—particularly critical thinking ability—as a moderating variable influencing learning outcomes.

Critical thinking itself represents a fundamental intellectual skill that enables learners to analyze information, evaluate arguments, and draw logical conclusions (Irdayanti, 2018; Facione, 2013). It encompasses interpretation, analysis, evaluation, inference, explanation, and self-regulation—skills that are indispensable in mathematical reasoning. Students with strong critical thinking abilities can better identify patterns, construct arguments, and justify solutions. Conversely, those with low critical thinking skills tend to rely on memorization and mechanical procedures, which impede conceptual understanding. Previous studies (Rasiman & Kartinah, 2018; Lestari, 2016) highlight that critical thinking contributes directly to students' ability to reason abstractly, solve problems, and communicate mathematical ideas effectively. Consequently, it becomes essential to investigate whether learning models such as TTW can accommodate different levels of critical thinking and thereby influence learning outcomes in distinct ways.

Despite the growing body of evidence supporting TTW, there remains a research gap concerning the interaction between teaching models and students' cognitive abilities. While prior studies have independently examined the effects of TTW on achievement or the role of critical thinking in mathematics learning, few have integrated both variables within a unified analytical framework. The relationship between the TTW model and students' learning outcomes may not be uniform across all learners; it is plausible that the model's effectiveness varies depending on students' critical thinking levels. For instance, students with high critical thinking skills may benefit more from TTW's emphasis on discussion and reflection, while those with lower critical thinking abilities might struggle to engage effectively in such cognitively demanding tasks. Thus, understanding the moderating effect of critical thinking provides important pedagogical insights for differentiated instruction and targeted learning support.

In light of these considerations, the present study investigates the effect of the Think Talk Write (TTW) learning model on students' mathematics achievement when viewed from their critical thinking ability. Specifically, this study aims to: (1) determine whether there are differences in learning outcomes between students taught using TTW and those taught using direct instruction; (2) examine whether there is an interaction effect between the learning model and students' critical thinking ability on learning outcomes; and (3) identify how TTW influences students with high and low levels of critical thinking. The research employs a quasi-experimental design (treatment-by-level 2×2) involving high school students in Gorontalo, Indonesia, with trigonometry—specifically the sine and cosine rules—as the subject matter.

## Methodology

This study adopted a quasi-experimental design (Quasi-Experiment), which was selected because the random assignment of participants to groups was not feasible due to institutional constraints. Instead, intact classroom groups were maintained to preserve the natural learning setting. The research applied a Treatment by Level (2 × 2 factorial design), following the approach described by Arikunto (2014), to examine both the main effects and interaction effects between the independent variable (learning model) and the moderator variable (critical thinking ability) on the dependent variable (learning achievement). Two learning models were used as treatments: the Think Talk Write (TTW) model as the experimental treatment and Direct Instruction (DI) as the control condition. Meanwhile, the moderator variable—students' critical thinking ability—was categorized into two levels, high and low. This factorial structure made it possible to test three aspects simultaneously: the effect of the learning model, the effect of critical thinking ability, and the interaction between both variables on students' mathematics achievement.

The research was conducted at SMA Negeri 6 Gorontalo Utara, located in Tolango Village, Anggrek District, Gorontalo Utara Regency, Indonesia. The school comprises seventeen study groups: six classes at grade X, six at grade XI, and five at grade XII. The study took place during the second semester of the 2022–2023 academic year. The population of the study consisted of all grade X students, totaling 151 students distributed across six classes.

According to Arikunto (2014), the population refers to the entire group of subjects to which the results of the research are expected to apply. From this population, a simple random sampling technique was employed to ensure that every class had an equal opportunity to be selected. Four classes were chosen randomly: two were assigned to the experimental group receiving the TTW model and two to the control group receiving direct instruction. Specifically, X IPA 1 (24 students) and X IPA 3 (24 students) were designated as experimental classes, while X IPA 2 (25 students) and X IPS 3 (25 students) were assigned as control classes, bringing the total sample to 98 students.

To explore the moderating role of critical thinking, participants in each instructional model group were further classified into high and low critical thinking categories, determined by their test results. Students whose scores were within the top 33.3% were categorized as having high critical thinking skills, while those in the bottom 33.3% were categorized as having low critical thinking skills. This classification resulted in 16 students with high critical thinking ability and 16 students with low critical thinking ability in each learning model, leading to a total of 64 students used for factorial analysis. The research therefore involved three variables: (1) the independent variable, which was the learning model (TTW and direct instruction); (2) the moderator variable, which was critical thinking ability (high and low); and (3) the dependent variable, which was students' learning achievement in mathematics, specifically in the topic of trigonometry, focusing on the sine and cosine rules.

Two main instruments were developed and validated for data collection: a learning achievement test and a critical thinking ability test. Both instruments underwent content validation by experts, empirical testing for validity, and reliability analysis to ensure they were both valid and consistent. The learning achievement test aimed to measure students' mastery of trigonometric concepts, following Bloom's taxonomy of cognitive domains, which includes knowledge, comprehension, application, analysis, synthesis, and evaluation. Conceptually, learning achievement in mathematics refers to students' ability to apply mathematical concepts to solve problems after experiencing a learning process. Operationally, it was defined as the total score obtained by students on a 23-item multiple-choice test related to trigonometric problem-solving.

Initially, the instrument consisted of 30 items, which were assessed through expert validation by two university mathematics lecturers and one high school mathematics teacher. The experts examined the items for their relevance, clarity, and consistency with the intended learning objectives. The empirical validity of the instrument was tested using the Point Biserial Correlation (Djaali & Muljono, 2008), with the criterion that items were valid if the correlation coefficient $r_{hitung} \geq r_{tabel}$. The results showed that 23 items were valid and 7 items were invalid, which were subsequently removed. The reliability of the instrument, measured using Cronbach's Alpha, was $r_{11} = 0.90$, indicating very high internal consistency.

The critical thinking ability test was designed in the form of essay questions to assess cognitive skills such as analysis, synthesis, problem identification, reasoning, and evaluation (Facione, 2013; Irdayanti, 2018). Conceptually, critical thinking is defined as the mental process that allows individuals to make reasoned judgments, solve problems logically, and evaluate evidence critically (Rasiman & Kartinah, 2018). Operationally, the test measured students' ability to apply logical reasoning and problem-solving skills to trigonometric problems. The test items were constructed based on specific indicators of critical thinking, including the ability to analyze problems, synthesize information, identify relationships, and make evaluative judgments. The validity of the items was determined using the Pearson Product-Moment Correlation (Djaali & Muljono, 2008), where items with $r_{hitung} \geq r_{tabel}$. were considered valid. The reliability coefficient, calculated using Cronbach's Alpha, also demonstrated a high level of reliability, indicating that the instrument was consistent and suitable for use in the study.

The data collection procedure consisted of three stages: preparation, implementation, and testing. In the preparation stage, the researcher obtained permission from the school administration, coordinated with teachers, and finalized the research schedule. The instruments were reviewed by experts and revised according to their feedback. In the implementation stage, the experimental classes were taught using the TTW model, while the control classes received direct instruction. Both groups studied the same trigonometric material under similar time allocations. The TTW model followed three sequential stages as proposed by Siswanto and Ariani (2016): the *think* stage, where students individually analyzed problems and developed preliminary ideas; the *talk* stage, where they engaged in group discussions to share and refine their reasoning; and the *write* stage, where they synthesized their understanding in written form. In the testing stage, after completing the learning sessions, all students were administered the learning achievement and critical thinking tests under standardized conditions.

The data analysis process was conducted using quantitative methods. A Two-Way Analysis of Variance (ANOVA) was employed to determine both the main and interaction effects of the learning model and critical thinking ability on learning achievement. Prior to conducting the ANOVA, assumption tests for normality and homogeneity were performed. The Kolmogorov–Smirnov test was used to check data normality, while Levene's Test of Equality of Variances was used to assess the homogeneity of variance across groups. The significance level for hypothesis testing was set at 0.05. Post-hoc tests were conducted when significant effects were found to identify specific group differences. The hypotheses tested were: (1) there is a significant difference in learning achievement between students taught using TTW and those taught using direct instruction; (2) there is a significant interaction between the learning model and students' critical thinking ability on learning achievement; (3) students with high critical thinking ability perform better under the TTW model than under direct instruction; and (4) students with low critical thinking ability perform better under direct instruction than under TTW.

## Results and Discussion

### *Overview of Data Analysis*

The analysis in this study aimed to determine the effect of the Think Talk Write (TTW) learning model on students' mathematics achievement when viewed from their critical thinking ability. Data were obtained from two primary sources: the results of the mathematics achievement test and the critical thinking test. The mathematics achievement data were used to measure students' mastery of trigonometric concepts—specifically the sine and cosine

rules—after learning through either TTW or direct instruction, while the critical thinking scores were used to categorize students into high and low levels of critical thinking.

Before hypothesis testing, the researcher conducted assumption tests for normality and homogeneity. The results of the Kolmogorov–Smirnov test indicated that the data for all groups were normally distributed ($p > 0.05$), and the Levene's test confirmed that the variances between groups were homogeneous ($p > 0.05$). These findings met the basic assumptions required for the application of Two-Way Analysis of Variance (ANOVA).

The subsequent two-way ANOVA was conducted to determine (1) whether there were significant differences in learning achievement between students taught using the TTW model and those taught using direct instruction, (2) whether there was an interaction between the learning model and critical thinking ability, and (3) whether students' critical thinking levels influenced the effectiveness of each learning model.

***Descriptive Results***

The descriptive statistics revealed that the mean score of students in the TTW group was higher than that of students in the direct instruction group. Students with high critical thinking ability also demonstrated higher scores in both learning conditions compared to those with low critical thinking ability. Specifically, students in the TTW–high critical thinking group ($A_1B_1$) achieved the highest mean score among all groups, while students in the TTW–low critical thinking group ($A_1B_2$) obtained the lowest mean score.

This preliminary result suggested that the TTW model benefited students with strong critical thinking skills but was less effective for students with limited cognitive engagement. In contrast, the direct instruction model yielded relatively consistent outcomes across both levels of critical thinking, suggesting its stability for learners requiring structured guidance.

***Hypothesis Testing***

The results of the Two-Way ANOVA demonstrated several key findings. First, there was a significant main effect of the learning model on mathematics achievement ($F_{1,60} > F_{table}$, $p < 0.05$). This means that students who were taught using the TTW model performed significantly better than those who were taught using the direct instruction model. Second, the interaction effect between learning model and critical thinking ability was statistically significant ($F_{1,60} > F_{table}$, $p < 0.05$). This finding indicates that the effect of the learning model on student achievement depended on students' level of critical thinking ability. Third, the simple effects analysis revealed that students with high critical thinking ability performed significantly better under the TTW model than under direct instruction, whereas students with low critical thinking ability achieved better results under the direct instruction model than under TTW.

These results collectively confirm the study's hypotheses: (1) TTW significantly improves learning outcomes compared to direct instruction, (2) critical thinking moderates the relationship between learning model and achievement, and (3) the interaction pattern shows a crossover effect—meaning that the most suitable learning model depends on the learner's critical thinking ability.

## Discussion of Findings

*1. The Effect of the Think Talk Write Model on Learning Achievement*

The finding that students taught using the TTW model achieved higher mathematics scores than those taught using direct instruction aligns with prior studies (Amardi, Aprinawati, & Mufarizuddin, 2023; Damayanti, 2023; Wa Ode Oni, 2020). The TTW model facilitates deeper learning by integrating cognitive, social, and metacognitive processes. During the *think* phase, students independently analyze information, which stimulates cognitive activation and encourages self-reflection. The *talk* phase allows students to articulate and negotiate their ideas in group discussions, thereby reinforcing understanding through social interaction. Finally, the *write* phase consolidates learning by transforming verbal reasoning into written articulation, enabling students to construct coherent mathematical arguments.

This sequence mirrors the constructivist learning paradigm, which views knowledge as actively built through interaction and reflection rather than passively received from teachers. According to Hamdayama (2015), TTW not only encourages student participation but also enhances conceptual understanding by engaging learners in verbal and written communication. As students express their thoughts through writing, they refine their comprehension, develop logical consistency, and internalize the learned material. Consequently, the TTW model supports higher levels of cognitive engagement and results in superior achievement compared to the teacher-centered direct instruction model, where students often remain passive recipients of information.

Moreover, TTW provides an inclusive environment for peer-assisted learning, fostering cooperative dialogue that allows students to clarify misconceptions and learn from diverse perspectives. This interactional process resonates with Vygotsky's theory of social constructivism, which emphasizes the role of collaborative dialogue in the development of higher mental functions. Therefore, it is not surprising that students in the TTW group exhibited higher performance, as they were actively involved in interpreting and articulating mathematical concepts, rather than merely memorizing procedural formulas.

*2. The Effect of Critical Thinking Ability on Learning Achievement*

The results also revealed that students with high critical thinking ability outperformed those with low critical thinking ability, regardless of the learning model applied. This finding supports the argument that critical thinking serves as a foundational skill in mathematical reasoning and problem-solving (Facione, 2013; Irdayanti, 2018). Students with well-developed critical thinking skills can analyze mathematical relationships, evaluate alternative strategies, and justify their solutions based on evidence. Conversely, students with low critical thinking ability tend to rely on rote learning, leading to difficulties in applying knowledge to new or complex problems.

According to Rasiman and Kartinah (2018), critical thinking allows learners to connect prior knowledge with new information, enabling them to reason abstractly and formulate logical conclusions. In the context of trigonometry, students with high critical thinking are better equipped to interpret the meaning of trigonometric ratios, identify relevant formulas, and adapt their problem-solving strategies. In contrast, students with limited critical thinking often struggle to recognize patterns or relationships, leading to lower accuracy and confidence in mathematical reasoning.

Thus, the data corroborate the theoretical framework that learning achievement is not only influenced by instructional design but also by the cognitive capacities that students bring into the classroom. Critical thinking acts as a cognitive catalyst that enhances the internalization of mathematical concepts and promotes flexible thinking.

*3. The Interaction between Learning Model and Critical Thinking Ability*

The significant interaction between the learning model and critical thinking ability highlights an important pedagogical insight: the effectiveness of a learning model is contingent upon students' cognitive readiness. The analysis indicated that the TTW model was particularly effective for students with high critical thinking ability, whereas direct instruction produced better outcomes for students with low critical thinking ability.

This pattern can be explained by examining the cognitive demands of each instructional approach. The TTW model requires students to engage in abstract reasoning, interpret information, and express complex ideas both orally and in writing. Students with high critical thinking ability are capable of meeting these cognitive demands; they can evaluate peer arguments, formulate coherent explanations, and synthesize information effectively. Consequently, the TTW model maximizes their learning potential by providing autonomy and opportunities for intellectual exploration.

In contrast, students with low critical thinking ability may find the TTW process cognitively overwhelming. The need to independently analyze, discuss, and write about complex mathematical ideas may exceed their current cognitive capacity. For such students, the direct instruction model—which provides clear explanations, guided examples, and repetitive practice—serves as a more structured and supportive learning environment. As suggested by Suhartono (2021), direct instruction ensures the transmission of core knowledge through systematic teaching, reducing the cognitive load for learners who struggle with abstract reasoning.

Therefore, the interaction effect demonstrates that instructional differentiation is essential in mathematics education. Teachers should align instructional models with students' cognitive profiles to achieve optimal learning outcomes. For advanced learners, constructivist-based models like TTW encourage independence and critical engagement. Meanwhile, for students needing additional support, more explicit and structured instruction may be appropriate.

*4. The Implications of the Findings*

The findings of this study contribute to the growing body of evidence supporting learner-centered pedagogies in mathematics education. The superior performance of students in the TTW group underscores the importance of engaging learners in collaborative and reflective activities that go beyond mere procedural practice. It also affirms the argument by Shadiq (2017) and Purwanto (2014) that mathematics learning should focus on developing reasoning and conceptual understanding, not just memorization.

At the same time, the observed interaction between learning model and critical thinking ability carries significant pedagogical implications. Teachers should recognize that no single instructional model fits all learners. Instead, effective teaching requires flexibility, combining collaborative strategies like TTW with more structured approaches depending on students' readiness levels. This differentiation aligns with the principles of adaptive instruction, which emphasize tailoring teaching methods to accommodate learners' cognitive diversity.

Furthermore, this study highlights the critical role of teacher facilitation in implementing TTW. Teachers must not only design group activities and guide discussions but also scaffold students' reasoning processes. When properly facilitated, TTW can nurture a classroom culture that values inquiry, dialogue, and evidence-based reasoning—key components of critical thinking development.

*5. Comparison with Previous Studies*

The results of this study are consistent with the findings of Amardi et al. (2023), who reported that TTW enhanced critical thinking skills in elementary school students, and Damayanti (2023), who demonstrated its positive impact on high school mathematics achievement. Similarly, Wa Ode Oni (2020) found a significant effect of TTW on student learning outcomes in trigonometry. The present study extends these findings by demonstrating that the effectiveness of TTW is moderated by critical thinking ability, providing a more nuanced understanding of how cognitive factors influence learning outcomes in cooperative learning environments.

This study's contribution lies in integrating pedagogical and cognitive dimensions within a single experimental framework. By showing that TTW's effectiveness varies according to students' cognitive profiles, the study provides empirical evidence for differentiated instruction and underscores the importance of cognitive diagnosis before implementing innovative teaching models.

## Conclusion

This study demonstrated that the Think Talk Write (TTW) learning model significantly enhances students' mathematics achievement compared to the traditional direct instruction approach. The findings revealed a strong interaction between learning model and critical thinking ability, indicating that the effectiveness of TTW depends on students' cognitive characteristics. Students with high critical thinking ability performed better when taught through TTW, as the model promotes independent reasoning, collaboration, and reflective writing. Conversely, students with low critical thinking ability benefited more from direct instruction, which provides structured guidance and reduces cognitive load.

These results underscore the importance of adaptive instruction, suggesting that teaching strategies should be aligned with students' cognitive profiles. The study contributes to the existing body of knowledge by integrating pedagogical and cognitive dimensions in mathematics education, demonstrating that learning outcomes are shaped by the interaction between instructional design and thinking skills. Theoretically, the findings support constructivist and social learning perspectives, emphasizing that active engagement enhances conceptual understanding. Practically, teachers should combine interactive and structured models to accommodate diverse learners. Future research may explore longitudinal applications of TTW, its impact on different mathematical topics, and its integration with digital learning environments to further enrich critical thinking and problem-solving development in mathematics education.

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