



The Effect of the Peer Tutoring Learning Model on Student Learning Outcomes Regarding Matrices in Senior High School

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Abstract. This study aims to analyze the impact of the Peer Tutoring learning model on students' mathematics learning outcomes regarding the topic of matrices at SMA Negeri 1 Tapa. The primary issue underlying this research is the low level of active student engagement in conventional instruction and the failure of learning outcomes to meet the minimum mastery criteria. The study employed a quasi-experimental design, specifically a pre-test and post-test control group design involving 38 Grade XI students selected via simple random sampling. The research instrument consisted of an essay test with established validity and reliability. Data were analyzed using the Independent Sample t-test and an effect size test. The results indicate a significant difference in learning outcomes between the experimental and control groups; the experimental class achieved an average score of 90.00, far surpassing the control class. Hypothesis testing yielded a t-value of 5.300 (exceeding the critical value of 1.688), with an effect size of 4.884, indicating a very high impact of the Peer Tutoring model. These findings confirm that the Peer Tutoring model is effective in enhancing students' conceptual understanding through mechanisms of learning-by-teaching and metacognitive dialogue. The study highlights the importance of adopting peer-tutoring-based cooperative learning models as an adaptive instructional solution to optimize student academic achievement in high schools.

Keywords: High School; Learning Model; Learning Outcomes; Matrices; Peer Tutoring.

1. INTRODUCTION

The peer tutoring model is widely recognized in mathematics education and offers significant potential to foster collaboration, motivation, and conceptual understanding among students (Roberts & Spangenberg, 2020). Empirical evidence consistently demonstrates that peer tutoring significantly impacts cognitive outcomes in high school mathematics, with meta-analyses reporting academic benefits ranging from moderate to substantial (Moliner and Alegre 2020; Wills, Kamps, and Greenwood 2025). Furthermore, 88% of mathematics peer tutoring programs show positive effects on academic performance, with reciprocal models emphasizing metacognitive strategies yielding more significant achievement gains (Alegre-Ansuategui et al. 2018; Thurston et al. 2020). Despite cognitive success, research remains limited regarding the impact on affective development—such as student motivation and social-emotional learning (SEL)—as well as the influence on psychomotor skills at the high school level (Ryan and Bowman 2022). In Indonesia, high school mathematics instruction often faces challenges related to student ability heterogeneity and low active engagement during classroom learning; consequently, student-centered learning models like peer tutoring are highly relevant for implementation. Instructional innovations that integrate technological and pedagogical aspects are crucial for maximizing student engagement and critical thinking skills (Setyo et al. 2023).

However, the transition from theory to practice in high school mathematics education reveals several critical gaps. Although peer tutoring is conceptually well established, there remains a lack of comprehensive meta-analyses examining the specific academic benefits for tutors themselves; this limits our understanding of how to optimize tutor training for mutual benefit (Leung 2019). In practice, many implementation approaches remain unstructured, leading to inefficiencies such as wasted time or unbalanced group dynamics (Leke Pepkolaj, Shkelqim Duraj and Gerbeti 2020). Furthermore, current assessment instruments are often limited to superficial academic outcomes, failing to capture deeper conceptual understanding or metacognitive skills (Demak et al. 2021; Kitabayashi, Takagi, and Shintani 2025). Moreover, while peer tutoring is an effective strategy for managing mathematical abstraction, its integration with modern digital tools, AI, and inclusive Social-Emotional Learning (SEL) frameworks remains underdeveloped—particularly for diverse student populations with varying socioeconomic backgrounds or academic abilities (Kassanew et al. 2026; Lin 2025). The gap between competency targets and actual learning outcomes poses a distinct challenge, as students' understanding of fundamental mathematical concepts often remains at a level that requires improvement (Abdullah, Achmad, and Fahrudin 2020).

The challenges of student engagement and the abstract nature of high-level mathematics necessitate more adaptive, structured interventions. Peer tutoring addresses this by fostering metacognitive dialogue and providing personalized support, thereby making learning less intimidating for struggling students (Leke Pepkolaj, Shkelqim Duraj and Gerbeti 2020). However, the model's effectiveness relies heavily on moderating variables, including program design, tutor-tutee dynamics, and the specific focus on cognitive versus metacognitive tasks (Alegre-Ansuategui et al. 2018; Ryan and Bowman 2022). Without clear guidelines regarding fairness, reliability, and structured training, the potential for peer tutoring to thrive effectively in high school mathematics remains limited (Biton 2025).

Therefore, this study aims to analyze the effect of the peer tutoring learning model on high school students' mathematics learning outcomes. By addressing this need, the study is expected to provide empirical evidence regarding the contribution of the peer tutoring model to enhancing students' academic achievement in the high school setting.

2. THEORETICAL REVIEW

The peer tutoring learning model is fundamentally rooted in social constructivism theory, which views learning as a participatory process mediated by social interaction. In contrast to traditional teacher-centered models, peer tutoring fosters a student-centered

environment in which academic knowledge is co-constructed through dialogue among students with varying levels of subject mastery (Ahyar et al. 2021). This model shifts classroom dynamics from passive reception to active negotiation, wherein tutors—often students with higher academic proficiency—leverage socio-emotional connections to facilitate peer support (Nurhasanah and Gumindari 2021). Such interactions reduce the affective barriers often present in formal teacher-student communication, enabling students to overcome difficulties within a supportive atmosphere that fosters both academic and socio-emotional growth (Hidayat et al. 2023). By delegating instructional authority to peers, the model cultivates a sense of responsibility and collaborative problem-solving—qualities essential to modern learning environments (Putri, Hidayat, and Ardiansyah 2024). Furthermore, the use of structured learning materials has proven effective in fostering student independence, initiative, and responsibility in achieving a deeper mastery of mathematical concepts (Takaendengan 2018).

Mathematics learning outcomes span a complex cognitive domain, requiring not only procedural accuracy but also deep conceptual understanding—particularly for abstract topics such as matrix algebra. The inherent abstraction of mathematics often acts as a major cognitive barrier, leading to 'learning poverty' or persistent gaps in conceptual understanding (Fitriati, Totuk, and Kusmaryono, Iwan Dwidayati 2026). When students encounter complex algebraic structures, a lack of adaptation of instructional strategies often leads to rote memorization rather than meaningful learning, ultimately resulting in suboptimal academic performance (Ulfa 2021). Consequently, success in mathematics does not merely depend on curriculum coverage; rather, it is fundamentally linked to how effectively a model reduces cognitive load and enhances students' ability to articulate mathematical reasoning independently (Sardin and Sukrillah 2022).

The cognitive efficacy of peer tutoring is primarily driven by the 'learning-by-teaching' mechanism. Research consistently demonstrates that tutors derive significant cognitive benefits from teaching itself, as they are compelled to restructure, elaborate, and refine their internal knowledge frameworks (Hidayat et al. 2023). This process triggers metacognitive awareness; as tutors explain concepts, they must monitor their own understanding and anticipate their peers' misconceptions, thereby effectively consolidating their own knowledge retention (Putri et al. 2024). Furthermore, this pedagogical cycle—in which learners must translate abstract mathematical information into accessible peer-to-peer discourse—reinforces procedural fluency for the tutee and conceptual depth for the tutor (Sardin and Sukrillah 2022). Thus, the peer tutoring model serves as a bidirectional cognitive

enhancer, bridging the gap between abstract mathematical concepts and tangible student understanding through systematic, collaborative scaffolding (Hidayat et al. 2023; Nurhasanah and Gumiandari 2021).

3. RESEARCH METHODOLOGY

This study employed a quasi-experimental design, specifically a pre-test and post-test control group design to analyze the impact of the Peer Tutoring learning model on the mathematics learning outcomes of students at SMA Negeri 1 Tapa. The sample consisted of 38 Grade XI students selected via simple random sampling; they were divided into an experimental group ($n = 20$) that implemented the Peer Tutoring model and a control group ($n = 18$) that utilized the Expository model. The Peer Tutoring intervention was conducted through four structured phases: selecting tutors based on initial cognitive performance, providing intensive tutor training, facilitating cooperative group discussions using student worksheets (LKPD), and implementing rotating supervision by the researcher and the teacher to ensure optimal peer-to-peer knowledge transfer.

The research instrument consisted of a 10-item essay test covering matrix topics, which was validated by subject matter experts and demonstrated a Cronbach's Alpha reliability coefficient of 0.816, indicating a high level of reliability. The quantitative data obtained were analyzed using descriptive and inferential statistics; the prerequisites for parametric analysis (normality and homogeneity) were assessed using the Shapiro-Wilk and Hartley's tests at a significance level of $\alpha = 0.05$. Hypothesis testing was conducted using an independent-samples t-test to determine the significance of the learning model's effect, while the magnitude of the model's contribution to learning outcomes was calculated using Cohen's effect size formula.

4. RESULTS AND DISCUSSION

Results

This study was conducted at SMA Negeri 1 Tapa during the odd semester of the 2025/2026 academic year, involving 38 Grade XI students. Empirical analysis revealed a significant difference in cognitive learning outcomes between the experimental group (Peer Tutoring) and the control group (Expository).

To provide a comprehensive overview of the students' academic progression, the descriptive statistics detailing the pre-test and post-test scores of both the experimental group (utilizing the Peer Tutoring model) and the control group (utilizing the Expository model) are systematically presented in the table below:

Table 1. Descriptive Statistics of Student Learning Outcomes

Group	N	Mean (Pre-test)	Mean (Post-test)	Standard Deviation
Experiment	20	36,75	90,00	1,26
Control	18	33,50	68,25	2,43

As presented in Table 1, the experimental class achieved a post-test average of 90.00, exceeding the school's Minimum Mastery Criterion (KKM), whereas the control class achieved only 68.25. The significance of this difference was subsequently confirmed through hypothesis testing.

Following the descriptive evaluation, inferential statistical analyses were conducted to rigorously test the research hypothesis and measure the magnitude of the instructional model's impact. The comprehensive outcomes of the Independent Sample t-test and Cohen's effect size calculations are explicitly detailed in the following table:

Table 2. Hypothesis Testing and Effect Size

Statistical Test	Value	Critical Value	Result
Independent Sample T-test	$t_{\text{calculated}} = 5,300$	$t_{\text{table}} = 1,688$	H_1 Accepted
Effect Size (Cohen's)	4,884	$> 1,00$	Very High Effect

Based on Table 2, the calculated t-value of 5.300 far exceeds the t-table value of 1.688; therefore, H_1 is accepted. The effect size of 4.884 confirms that the Peer Tutoring model has a very high and significant impact on students' academic achievement in matrices.

Discussion

The advantage of the Peer Tutoring model over the Expository model lies in the "learning-by-teaching" effect, which transforms the student's role from a passive recipient of information into an active constructor of knowledge. In this model, tutors facilitate the understanding of abstract matrix concepts using peer-friendly language that is easier to grasp, thereby mitigating cognitive barriers—such as errors involving negative signs—that students frequently encounter. These findings support Abidin's (2021) research on the effectiveness of the Peer Tutoring model in mathematics education. The results also align with the study by Suma et al. (2025), which confirms that selecting an appropriate instructional model can create a conducive learning environment while significantly improving students' mathematics learning outcomes. The novelty of this study lies in its demonstrated effectiveness regarding matrix-related material, which demands procedural precision and a high level of abstraction. The model's success was further bolstered by the teacher's implementation of "rolling

supervision," which effectively addressed student distraction and ensured that every group remained productive. Theoretically, the study demonstrates that the model's success depends not merely on group formation, but on how metacognitive dialogue is managed to enable tutors and tutees to collectively strengthen their cognitive structures. In this context, the peer tutoring model provides students with the opportunity to explore diverse problem-solving approaches; the variety of strategies emerging from these student interactions reflects individual characteristics and the specific cognitive abilities of each student in absorbing the material (Setyo et al. 2023).

To substantiate these theoretical mechanisms with empirical evidence, a deeper analysis of the quantitative outcomes reveals the trajectory of students' cognitive development throughout the intervention. Initially, the pre-test results indicated that the baseline capabilities of both groups were relatively equivalent, with a mean raw score of 14.7 for the experimental group and 13.4 for the control group (equivalent to converted scores of 36.75 and 33.50 on a 100-point scale, respectively). This initial parity confirms that both groups started from a similar cognitive baseline prior to the treatments.

However, following the implementation of the learning models, the post-test results demonstrated a striking divergence. The experimental class achieved a mean raw score of 36.00 (converting to a final mean score of 90.00), successfully surpassing the school's Minimum Mastery Criterion (KKM of 75). In contrast, the control class under the expository model attained a mean raw score of 27.30 (converting to 68.25), which falls below the institutional mastery threshold. This substantial difference is further substantiated by the inferential statistical analysis using the Independent Sample T-Test, which yielded a calculated t-value of 5.300, significantly exceeding the critical t-table value of (1.688 $t_{\text{calculated}} = 5.300 > t_{\text{ctable}} = 1.688$) at a significance level of $\alpha = 0.05$. Consequently, the null hypothesis (H_0) was rejected and the alternative hypothesis (H_1) was accepted, providing robust empirical evidence that the Peer Tutoring learning model exerts a statistically significant positive effect on students' mathematics learning outcomes regarding matrices.

To measure the magnitude of this impact, the effect size was calculated using Cohen's formula, resulting in an effect size value of 4.884. According to Cohen's interpretation criteria, this value far exceeds the threshold for a "high effect" (> 1.00), indicating that the Peer Tutoring model provides an extraordinarily strong and massive contribution to enhancing student academic achievement.

Methodologically, the success of the Peer Tutoring model in this study relied heavily on a systematic tutor selection process based on initial cognitive performance combined with

qualitative assessments of communication skills and social readiness. A key procedural decision in this study was maintaining consistent tutor assignments across all sessions rather than rotating them. This consistency fostered emotional rapport (chemistry) and psychological safety, gradually dissolving non-tutor students' math anxiety and reluctance to ask questions.

Despite these overwhelming advantages, practical challenges emerged during classroom implementation—notably, a tendency toward focus dispersion or passive behavior among some non-tutor students during peer discussions. To mitigate this limitation, the researcher applied an active "rolling supervision" strategy, circulating intensively among groups to ensure that peer tutors facilitated knowledge transfer effectively without acting condescendingly, while guiding off-task students back to productive engagement with the Student Worksheets (LKPD). The integration of supportive classroom conditioning, rigorous tutor preparation, and active teacher scaffolding successfully neutralized the latent weaknesses of the peer tutoring framework, establishing a highly conducive learning environment for mastering abstract matrix concepts. Ultimately, these empirical insights suggest that adopting structured peer-assisted frameworks can serve as a viable, low-cost, yet highly effective pedagogical intervention for mathematics classrooms facing student heterogeneity and low engagement.

5. CONCLUSION AND RECOMMENDATIONS

This study demonstrates that the peer tutoring learning model has a significant positive impact on students' mathematics learning outcomes regarding the topic of matrices at SMA Negeri 1 Tapa. Hypothesis testing—yielding a calculated t-value of 5.300 (exceeding the critical t-value of 1.688) and an effect size of 4.884—provides empirical evidence that the peer tutoring model is far more effective than the expository learning model. Furthermore, the converted final mean score of the experimental class reaching 90.00 confirms that this collaborative strategy successfully elevates student achievement far beyond the institutional Minimum Mastery Criterion (KKM). These results confirm that a collaborative approach facilitates better conceptual understanding by mitigating the psychological barriers students face when learning abstract mathematical topics. From a practical standpoint, the findings suggest that educators adopt the peer tutoring model as an alternative strategy to enhance student engagement and mastery of the material. Given that this study was limited to the topic of matrices in Grade XI, it is recommended that future research explore the application of this model across a broader range of mathematical topics and educational levels to test the generalizability of the findings. Future researchers are also advised to develop more varied

guidance instruments and systematic monitoring strategies to ensure students maintain focus, particularly when addressing subtopics that require a high degree of arithmetic precision.

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