

Comparative Effectiveness of Rotating Trio Exchange and Numbered Heads Together Cooperative Learning Models on Elementary Students' Mathematics Learning Outcomes

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Abstract

Mathematics learning outcomes among elementary school students remain relatively low, as indicated by the large proportion of students who have not achieved the minimum mastery criterion (MMC) and their limited active participation in the learning process. Therefore, this study aimed to: (1) examine the effect of the Rotating Trio Exchange (RTE) cooperative learning model on students' mathematics learning outcomes; (2) investigate the effect of the Numbered Heads Together (NHT) cooperative learning model on students' mathematics learning outcomes; and (3) compare the improvement in mathematics learning outcomes between students taught using the RTE and NHT cooperative learning models in Grade V of Elementary School X. The data were analyzed using simple linear regression, the normalized gain (N-Gain) test, and the Mann-Whitney U test. The results revealed that both the Rotating Trio Exchange and Numbered Heads Together cooperative learning models had a significant positive effect on students' mathematics learning outcomes. Furthermore, the improvement in mathematics learning outcomes achieved through the RTE model was higher than that obtained through the NHT model. Based on the N-Gain analysis, the RTE class achieved a medium gain category, whereas the NHT class fell into the low gain category. These findings indicate that the Rotating Trio Exchange cooperative learning model is more effective than the Numbered Heads Together cooperative learning model in improving elementary school students' mathematics learning outcomes.

Keywords: cooperative learning model, mathematics learning outcomes, Numbered Heads Together, Rotating Trio Exchange

A. Introduction

Education plays a fundamental role in developing human resources capable of adapting to the rapid advancement of science and technology. One of the primary indicators of educational quality is students' learning outcomes, which reflect the achievement of

cognitive, affective, and psychomotor competencies. Among various school subjects, mathematics is recognized as a fundamental discipline that develops logical reasoning, problem-solving ability, and critical thinking skills. Consequently, improving students' mathematics learning outcomes has become a major concern for educators and policymakers worldwide.

Despite continuous efforts to improve mathematics education, students' mathematics achievement in Indonesia remains relatively low. Evidence from the Trends in International Mathematics and Science Study (TIMSS) 2007 showed that Indonesia ranked 36th out of 49 participating countries, with an average mathematics score of 397, substantially below the international average score of 500. These findings indicate persistent challenges in mathematics education and suggest the need for more effective instructional approaches to improve students' learning outcomes.

The same problem is evident at the school level. A preliminary survey conducted among fifth-grade students at SD Negeri 11 Metro Pusat during the 2022/2023 academic year revealed that fewer than 50% of students achieved the Minimum Mastery Criterion (MMC) in the Mathematics Final Semester Assessment. Specifically, 54.84% of students in Class VA and 58.62% in Class VB failed to reach the required level of achievement. Classroom observations further indicated that mathematics instruction was predominantly teacher-centered, relying mainly on lectures and question-and-answer sessions. As a result, students participated passively in classroom activities and perceived mathematics as difficult, monotonous, and uninteresting. This situation suggests that the instructional strategies currently employed have not effectively promoted active learning or meaningful conceptual understanding.

One instructional approach that has been widely recommended to enhance students' engagement and academic achievement is cooperative learning. Cooperative learning encourages students to work collaboratively, exchange ideas, and take shared responsibility for learning, thereby promoting both academic achievement and social interaction. Several cooperative learning models have demonstrated positive effects on mathematics learning outcomes, including Rotating Trio Exchange (RTE), Numbered Heads Together (NHT), and Student Teams Achievement Division (STAD).

Among these models, the Rotating Trio Exchange (RTE) model has received considerable attention because it combines structured small-group discussions with systematic member rotation, allowing students to interact with different peers and exchange diverse perspectives. Previous studies have consistently reported its effectiveness. Utami et al. (2019) and Hadiyaturido et al. (2020) found that the RTE model significantly improved mathematics achievement and increased students' learning mastery at both elementary and junior high school levels. Likewise, Dipayana et al. (2014) demonstrated that students taught using the RTE model achieved significantly higher learning outcomes than those receiving conventional instruction. Other studies have also reported that RTE improves

students' conceptual understanding and mathematical reasoning (Pratama, 2015; Nuraeni et al., 2016). These findings indicate that RTE provides a learning environment that encourages active participation, collaborative problem solving, and deeper conceptual understanding.

Another cooperative learning model that has been extensively implemented is Numbered Heads Together (NHT). In this model, students work collaboratively in small groups, and each member is assigned a number to ensure individual accountability during group discussions. The NHT model promotes equal participation, strengthens communication among students, and encourages every learner to contribute actively because each student has an equal opportunity to represent the group. Previous research has reported that NHT positively affects students' academic achievement, learning motivation, and classroom participation, making it one of the most widely adopted cooperative learning strategies in mathematics education.

Although numerous studies have confirmed the effectiveness of cooperative learning models, most have focused on comparing a single cooperative learning model with conventional teaching methods. Consequently, little empirical evidence is available regarding the relative effectiveness of different cooperative learning models implemented under similar classroom conditions. In particular, direct comparisons between Rotating Trio Exchange (RTE) and Numbered Heads Together (NHT) remain scarce, despite the fact that both models share similar cooperative learning principles and implementation complexity. As a result, teachers still have limited evidence for determining which model is more effective in improving mathematics learning outcomes.

This limitation represents an important research gap. From an empirical perspective, the low mathematics achievement observed among fifth-grade students at SD Negeri 11 Metro Pusat indicates that conventional teaching approaches have not effectively supported students' learning. From a theoretical perspective, while previous studies have demonstrated the individual effectiveness of both RTE and NHT, few studies have directly compared these two cooperative learning models within the same educational context. Such a comparison is necessary to identify the instructional model that provides greater benefits for improving elementary students' mathematics learning outcomes.

Therefore, this study aims to compare the effectiveness of the Rotating Trio Exchange (RTE) and Numbered Heads Together (NHT) cooperative learning models in improving mathematics learning outcomes among fifth-grade students at SD Negeri 11 Metro Pusat. Specifically, this study examines the effect of each learning model on students' mathematics achievement and compares the magnitude of learning improvement between the two instructional approaches.

The novelty of this study lies in its direct comparison of two cooperative learning models with comparable implementation complexity within the same learning environment. Unlike previous studies that mainly compared cooperative learning with conventional instruction, this research provides empirical evidence regarding the relative effectiveness of RTE and NHT in elementary mathematics education. The findings are expected to enrich the literature on cooperative learning and provide practical guidance for teachers in selecting the most appropriate instructional model to improve mathematics learning outcomes.

B. Methods

This study employed a quasi-experimental design using a two-group pretest-posttest design to compare the effectiveness of two cooperative learning models in improving students' mathematics learning outcomes. This design allowed the researchers to implement two different instructional treatments in existing classroom settings without random assignment. The study was conducted at SD Negeri 11 Metro Pusat during the second semester of the 2022/2023 academic year. The population consisted of all fifth-grade students enrolled at the school. Because the population comprised only 60 students, total sampling was employed, whereby all students participated in the study. Class VB, consisting of 29 students, was assigned to the Rotating Trio Exchange (RTE) group, while Class VA, consisting of 31 students, was assigned to the Numbered Heads Together (NHT) group.

The research instrument consisted of a mathematics achievement test and an observation checklist. The achievement test, administered as both a pretest and a posttest, comprised multiple-choice items designed to measure students' mathematics learning outcomes. The observation checklist was used to monitor students' learning activities throughout the implementation of the instructional models. Prior to data collection, the test instrument underwent validity and reliability testing. The final instrument consisted of 20 valid items and demonstrated excellent reliability, with a reliability coefficient of 0.84. The research procedure began with the administration of a pretest to both groups to determine students' initial mathematics achievement. Subsequently, the RTE group received instruction using the Rotating Trio Exchange cooperative learning model, whereas the NHT group was taught using the Numbered Heads Together cooperative learning model. Following the instructional intervention, a posttest was administered to measure students' mathematics learning outcomes.

C. Results and Discussion

Results

This study was conducted at SD Negeri 11 Metro Pusat from 28 August to 2 September 2023 to examine the effects of the Rotating Trio Exchange (RTE) and Numbered Heads

Together (NHT) cooperative learning models on fifth-grade students' mathematics learning outcomes in the topic of fractions. Data were collected using a mathematics achievement test consisting of 20 multiple-choice questions administered as a pretest and posttest, as well as classroom observations conducted during three instructional sessions. The school established a Minimum Mastery Criterion (MMC) of 77.

Table 1 summarizes the students' mathematics learning outcomes before and after the implementation of the two cooperative learning models.

Table 1. Students' Mathematics Learning Outcomes

Class	Learning Model	Mean Pretest	Mean Posttest	Pretest Mastery (%)	Posttest Mastery (%)	N-Gain	Category
VB	Rotating Trio Exchange (RTE)	59.31	75.93	21	55	0.367	Moderate
VA	Numbered Heads Together (NHT)	56.31	65.93	10	19	0.184	Low

As presented in Table 1, both cooperative learning models improved students' mathematics learning outcomes. However, the improvement achieved by students taught using the Rotating Trio Exchange (RTE) model was substantially greater than that of students taught using the Numbered Heads Together (NHT) model.

Students in the RTE group achieved an increase in the mean score from 59.31 on the pretest to 75.93 on the posttest. The percentage of students achieving the Minimum Mastery Criterion also increased markedly from 21% to 55%. Furthermore, the normalized gain analysis produced an N-Gain score of 0.367, which falls within the moderate improvement category.

In comparison, students in the NHT group showed a smaller improvement. The mean score increased from 56.31 to 65.93, while the percentage of students achieving mastery increased from 10% to 19%. The N-Gain score of 0.184 was classified as low, indicating that the improvement in mathematics learning outcomes was less substantial than that observed in the RTE group.

Inferential statistical analysis further confirmed these findings. The simple linear regression analysis demonstrated that both cooperative learning models had a significant positive effect on students' mathematics learning outcomes. The coefficient of determination indicated that the RTE model contributed 82.5% to the variance in students' mathematics learning outcomes, whereas the NHT model contributed 50.7%. In addition, the Mann-Whitney U test revealed a statistically significant difference in learning improvement between the two instructional models ($p = 0.012 < 0.05$). These findings indicate that students taught using the Rotating Trio Exchange (RTE) model

achieved significantly greater improvements in mathematics learning outcomes than those taught using the Numbered Heads Together (NHT) model.

Students' classroom learning activities observed during the intervention are presented in Table 2.

Table 2. Students' Learning Activities

Class	Learning Model	Very Active (%)	Active (%)	Moderately/Less Active (%)
VB	Rotating Trio Exchange (RTE)	48	52	0
VA	Numbered Heads Together (NHT)	19	74	7

The observation results indicate that both instructional models successfully encouraged students to participate actively in classroom learning. Nevertheless, students taught using the Rotating Trio Exchange (RTE) model demonstrated higher levels of classroom engagement than those taught using the Numbered Heads Together (NHT) model. In the RTE class, 48% of students were categorized as very active, while the remaining 52% were classified as active, with no students categorized as moderately or less active. In contrast, only 19% of students in the NHT class were categorized as very active, whereas 74% were categorized as active, and 7% were classified as moderately or less active. These findings suggest that the RTE model created a more interactive learning environment, leading to higher student participation throughout the instructional process.

Discussion

The findings of this study demonstrate that both the Rotating Trio Exchange (RTE) and Numbered Heads Together (NHT) cooperative learning models significantly improved students' mathematics learning outcomes. This result indicates that cooperative learning provides a more effective learning environment than traditional teacher-centered instruction by encouraging students to actively participate in constructing knowledge through discussion, collaboration, and shared problem-solving. These findings support the principles of social constructivism, which emphasize that knowledge is developed through social interaction and collaborative learning experiences.

Although both instructional models positively influenced students' mathematics achievement, the Rotating Trio Exchange (RTE) model produced greater improvements than the Numbered Heads Together (NHT) model. Students who learned through the RTE model achieved higher posttest scores, a greater percentage of learning mastery, and a higher normalized gain than those who learned through the NHT model. Furthermore, the Mann-Whitney U test confirmed that the difference in learning improvement between the two groups was statistically significant. These findings suggest that the

instructional characteristics of the RTE model provide a more effective learning environment for enhancing mathematics achievement.

One possible explanation for the superior performance of the RTE model is its structured group rotation mechanism. Unlike conventional cooperative learning, RTE requires students to rotate among different discussion groups, enabling them to exchange ideas with a greater number of peers and encounter multiple perspectives in solving mathematical problems. This continuous interaction encourages students to explain concepts repeatedly, evaluate alternative solutions, and reconstruct their understanding through peer discussion. According to Silberman (2013), learning becomes more meaningful when students actively communicate and exchange ideas with different learning partners, as such interactions promote deeper cognitive processing and conceptual understanding.

The observation data further support this interpretation. Students in the RTE class demonstrated higher levels of classroom participation, with nearly half of the students categorized as very active and the remaining students classified as active. Frequent rotation among discussion groups created opportunities for every student to contribute, ask questions, and express opinions. Consequently, students became more engaged throughout the learning process and developed stronger collaborative learning skills. Active participation is widely recognized as an important factor contributing to improved academic achievement because students who actively participate in classroom discussions are more likely to process information deeply and retain newly acquired knowledge.

These findings are consistent with previous studies reporting the effectiveness of the RTE model in mathematics learning. Utami et al. (2019) found that the implementation of RTE significantly improved students' mathematics achievement and increased learning mastery. Similarly, Hadiyaturido et al. (2020) reported that the RTE model enhanced students' learning outcomes by promoting active discussion and collaborative problem-solving. In addition, Dipayana et al. (2014) demonstrated that students taught using the RTE model achieved significantly higher learning outcomes than those taught through conventional instruction. Collectively, these studies support the present findings that RTE facilitates meaningful interaction among students and promotes deeper mathematical understanding.

Although the Numbered Heads Together (NHT) model also improved students' mathematics learning outcomes, its effectiveness was lower than that of the RTE model. The NHT model encourages students to discuss problems collaboratively and promotes individual accountability by randomly selecting group members to present answers. However, classroom observations indicated that some students were still hesitant to explain mathematical concepts because they had not fully mastered the learning materials. Consequently, more capable students often repeated explanations to other group members, extending discussion time and reducing instructional efficiency. These findings are consistent with Humaira (2019), who reported that unequal individual

readiness may limit the effectiveness of the NHT strategy, particularly when students have different levels of prior knowledge.

From a theoretical perspective, the findings suggest that the greater effectiveness of the RTE model may be explained by its ability to maximize both positive interdependence and individual interaction, two essential components of cooperative learning proposed by Johnson and Johnson (2009). Through systematic rotation, students engage with a wider range of peers, receive more diverse feedback, and repeatedly articulate mathematical ideas. These learning experiences strengthen conceptual understanding and encourage higher-order thinking, which are particularly important in mathematics education.

The findings of this study also have important practical implications. Elementary school teachers may consider adopting the RTE model as an alternative instructional strategy to improve mathematics learning outcomes and classroom engagement. The structured interaction and collaborative learning environment created through RTE can help students develop not only mathematical competence but also communication, teamwork, and problem-solving skills, which are essential competencies in twenty-first-century education.

Despite these contributions, this study has several limitations. First, the research focused solely on the cognitive domain of learning outcomes without examining affective variables such as learning motivation, self-efficacy, or attitudes toward mathematics. Second, the intervention was limited to the topic of fraction operations, which may restrict the generalizability of the findings to other mathematics topics. Third, the study involved only fifth-grade students from a single elementary school with a relatively small sample size. Therefore, future research should investigate the effectiveness of RTE across different mathematics topics, educational levels, and larger populations. Further studies are also encouraged to examine the influence of cooperative learning models on higher-order thinking skills, mathematical reasoning, learning motivation, and collaborative competence to provide a more comprehensive understanding of their educational impact.

D. Conclusions

This study concludes that both the Rotating Trio Exchange (RTE) and Numbered Heads Together (NHT) cooperative learning models have a significant positive effect on fifth-grade students' mathematics learning outcomes. However, the Rotating Trio Exchange (RTE) model demonstrated greater effectiveness than the Numbered Heads Together (NHT) model in improving students' mathematics achievement. Students who learned through the RTE model obtained higher posttest scores, achieved a greater percentage of learning mastery, and recorded a moderate level of learning improvement ($N\text{-Gain} = 0.367$), whereas students taught using the NHT model achieved a low level of improvement ($N\text{-Gain} = 0.184$). The Mann-Whitney U test further confirmed that the

difference in learning improvement between the two instructional models was statistically significant.

These findings suggest that the structured interaction and systematic group rotation implemented in the RTE model provide a more effective learning environment for promoting active participation, collaborative learning, and conceptual understanding in mathematics. Therefore, the RTE model can be recommended as an effective instructional strategy for improving mathematics learning outcomes at the elementary school level.

This study contributes to the growing body of evidence on cooperative learning by providing a direct comparison between two cooperative learning models implemented within the same educational context. Future studies are recommended to examine the effectiveness of these models across different mathematics topics, educational levels, and larger populations, as well as to investigate their impact on other learning outcomes, such as mathematical reasoning, critical thinking, learning motivation, and collaborative skills.

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