Formatif: Jurnal Ilmiah Pendidikan MIPA, March 2025, 15 (1), 1-12
http://dx.doi.org/10.30998/formatif.v15i1.22179
p-ISSN: 2088-351X e-ISSN: 2502-5457
Accredited (S2) by Ministry of Research and Technology of Indonesia No. 148/M/KPT/2020
Available online at https://journal.lppmunindra.ac.id/index.php/Formatif/index

Analysis of Students' Mathematics Learning Outcomes on Matrix Concepts: A Comparative Study

Anderson Leonardo Palinussa *), Jean Limehuwey, Carolina Selfiana Ayal
Universitas Pattimura, Indonesia

Abstract

21st-century education requires students to be skilled and excel in science, technology, and mathematics, but many countries complain about declining student achievement. Therefore, teachers can apply the right learning strategy to improve student learning outcomes. This study aimed to determine the differences in student learning outcomes taught using the TTW (Think Talk Write) type cooperative learning model and the NHT (Numbered Head Together) learning model on matrix material. The type of this research is experimental research. This research uses a research design, namely The posttest group design. The population in this study were all students of class XI Public Senior High School 19 West Seram, a total of 40 students. The sample in this study used saturated sampling, namely class XI MIA1 with a total of 20 students and class MIA2 with a total of 20 students, so the total sample in this study was 40 students. The instrument used in this study is a test instrument consisting of description questions. The results showed that students' math learning outcomes with the TTW model were superior to those taught with the NHT model. Therefore, the TTW model can be recommended for improving students' mathematics learning outcomes on matrix topics.

Keywords: Math learning outcomes, TTW, NHT, matrix

(*) Corresponding Author: palinussaandersonl@gmail.com

How to Cite: Palinussa, A.L., Limehuwey, J., & Ayal, C.S. (2025). Analysis of students' mathematics learning outcomes on matrix concepts: A comparative study. *Formatif: Jurnal Ilmiah Pendidikan MIPA, 15* (1), 1-12. http://dx.doi.org/10.30998/formatif.v15i1.22179

INTRODUCTION

Mathematics is one of the sciences that is essential in developing science, technology, and other sciences (Schoenfeld, 2016). In addition, mathematics is also a fundamental science that is a benchmark for the development and progress of technology (Niess, 2005). Some consider mathematics to be one of the most challenging subjects. However, some consider mathematics easy, enjoyable, and stimulating for students' creativity (Schindler & Lilienthal, 2020). In addition, mathematics provides skills for a person to think logically and systematically when solving problems (Laurens et al., 2018). It is essential to recognise that students in each class have different abilities and show different achievements. Unfortunately, in teacher-led learning, all students are required to learn from the teacher in the same way at the same pace (Yeh et al., 2019). The results of a study in the USA showed that students' low math learning achievement came from students of low economic background (Clarke et al., 2015). It starts with poor numeracy skills at kindergarten entry and continues with low achievement in math until high school (Randel et al., 2016). In addition, students have perceived math to be a complex and dreadful subject in recent decades (Aguilar, 2021). Many students get low scores when taking tests (Li & Schoenfeld, 2019). The factor that results in low student learning outcomes is that mathematics learning in schools is delivered by teachers using a conventional approach. Studies have reported that students with higher literacy skills tend to have better science and mathematics skills (Öztürk et al., 2020). Students must be able

to read and understand texts, understand diagrams and graphs, and use written language to communicate their thinking to solve complex science and mathematics problems. Therefore, students with good literacy skills are better prepared to learn and succeed in science and mathematics (Sarsale et al., 2024). It impacts students' math learning outcomes, who can only achieve scores of 50-60 and cannot achieve 80-100 (Agustyaningrum et al., 2020). The problem is caused by the teacher who needs to deliver material in a fun way (Capinding, 2022).

The goals of teaching mathematics depend on one's conceptualisation of what mathematics is and what it means to understand mathematics. Conceptualisations of mathematics vary widely. At one end of the spectrum, mathematical knowledge is seen as a body of facts and procedures dealing with quantities, magnitudes, and shapes and the relationships among them; mastery of mathematics is seen as mastery of these facts and procedures (Schoenfeld, 2016). Many factors cause students' low mathematics learning achievement, for example, the classic problem of applying conventional learning models, namely questions and answers and giving assignments (Ismail et al., 2015; Mazana et al., 2020). Study results in South Africa show that current mathematics teaching needs more attention to student activity. Teachers dominate learning activities. Teachers are even placed as the primary source of knowledge and function as transferring knowledge. On the other hand, students are more passive, positioned as learning objects, conditioned only to wait for knowledge transformation from the teacher. Therefore, the teacher dominates the class, making students more likely to be passive. As a result, the learning process in the classroom becomes more varied and meaningful, which impacts math learning outcomes (Mutodi & Ngirande, 2014). Changing the trajectory of persistently low math achievement requires instructional support or intervention. To equip early childhood educators to change this habit, teachers should identify educational opportunities that can potentially influence student learning outcomes (Wood et al., 2020).

Information from several mathematics studies shows that many students still need help understanding matrix material (Pasani & Suryaningsih, 2021). Matrix material is one of the difficult math topics, so many students still need help completing operations on matrices, especially the multiplication operation of two matrices of the same order (Mobrur & Hamed, 2014). Students still make mistakes when completing the multiplication of matrices of the same order. It is due to the need for more student attention in learning, resulting in student interest in learning needs to be more optimal (Inganah, 2018). It is stated that some of the reasons why students have difficulty in the material of the matrix are the first difficulties being that the terms are abstract. The second is that the application field is unfamiliar to students. The third is that most students do not yet know the method of proof. Textbooks are one of the important tools that are easy to use and accessible to all students; information is given directly, can be used continuously, can be referred to at any time and can replace verbal educational interruptions (Aygör & Burhanzade, 2014; Tatira, 2024). Teachers must design learning that makes students active in the learning process (Leasa et al., 2021). A learning model is a plan or pattern used to form a curriculum, design learning materials, and guide learning in the classroom or others. The learning model can be used as a pattern of choice, meaning that teachers can choose an appropriate and efficient learning model to achieve learning objectives (Reyk et al., 2022).

Cooperative learning, in general, requires students to work in small groups or teams to assist each other in understanding the subject matter (Slavin & Cooper, 1999; Johnson et al., 2014). Cooperative learning is a learning strategy that enhances learning by involving students of different knowledge levels in group activities. Cooperative learning has different forms of models, each of which has specific characteristics and advantages. The Johns Hopkins University School of Social Organization Center has

created and analysed a cooperative-based learning paradigm (Slavin & Cooper, 1999). According to Slavin (1980), the differences in cooperative learning are centred on two main components: the reward system and student tasks. The three reward structures are based on group incentives for each learning, group incentives for group output, and individual incentives. However, in other conditions, the application of cooperative learning is also without rewards. Students carry out group-centred and individual task structures. The group-centred task structure describes all members of the group doing the learning. The cooperative learning model is learning that prioritises cooperation among students to achieve learning goals (Slavin, 2015). In other words, cooperative learning is an approach where small groups of students work together and maximise learning conditions to achieve learning goals (Leasa et al., 2019). Therefore, this study extrapolates the problem with a cooperative model in improving students' mathematics learning outcomes.

The *think-talk-write* (TTW) learning model is a learning model that can develop students' understanding and communication skills (Larrosa, 2010; Richgels, 2013). This strategy constructs thinking, reflection, and organising ideas. Furthermore, students have to write based on their ideas. Think-talk-write includes 3 phases consisting of (1) Students learn the material (thinking), (2) Students discuss the results of learning the material (speaking), (3) Students write down the ideas obtained from the speaking stage (writing) (Supandi et al., 2018). The TTW learning model can encourage students to think, talk, and write down a specific topic by familiarising them with solving problems, forming communication, and developing critical and creative skills (Suwarto et al., 2021). The flow of the TTW model starts from student involvement in thinking or dialoguing with themselves after the reading process, talking and sharing ideas with their friends, and then writing the results of the discussion. This model is more effective in heterogeneous groups of 3-5 students. In this group, all students were asked to read, make small notes, explain, listen, share ideas with friends, and then express them through writing (James et al., 2018). In addition, it can be encouraged with another cooperative model, which is NHT (*Numbered Head Together*).

The NHT-type cooperative learning model provides opportunities for students to share ideas and consider the most appropriate answers, increasing the spirit of student cooperation (Maman & Rajab, 2016) NHT is also a cooperative learning model incorporating a unique teacher-questioning strategy that actively engages students while improving their academic scores and behavioural outcomes (W. C. Hunter et al., 2016). The NHT-type cooperative learning model provides opportunities for every student to be involved in learning. *Numbered* means numbering, *and Head Together* means thinking together, so the NHT learning model is thinking together according to the number (Haydon et al., 2010). NHT cooperative learning also encourages students to improve their cooperation. This model can be used for all subjects and all levels of learners (Maheady et al., 2006; Leasa, 2016). NHT is a learning model where each student is given a number, then a group is created, and then the teacher calls the number of the student randomly (Maheady et al., 1991; Leasa et al., 2016). This study aims to determine the differences in student learning outcomes taught with the TTW-type cooperative learning model and the NHT learning model on matrix material.

METHODS

The type of research used was quantitative research with *a posttest-only group design,* which was included in the *quasi-experimental design (Pseudo-experimental design).* This *Quasi quasi-experimental design* does not use *random assignment* because,

in reality, it is difficult to get a control group used in research (Landrock, 2017). This pseudo-experiment has a treatment seen from the learning outcomes of students taught with the TTW cooperative learning model and the NHT model with the research design, which can be presented in Table 1.

Table 1. The Posttest-Only Group Design

Group	Treatment	*The post Test*
E1	P1	T
E2	P2	

Description
P1 : Using the TTW Model
P2 : Using the NHT Model
T : Giving posttest for experimental class 1 and experimental class 2

This research was conducted at Public Senior High School 19 West Seram. The population in this study were all students of class XI MIA, consisting of 2 classes, and the total number of samples was 40. The learning tools used in this research were lesson plans, teaching materials, and student worksheets. The instrument in this study was a test of student learning outcomes about matrix material. This study used descriptive analysis to determine the learning outcomes of Public Senior High School 19 West Seram students on mathematics learning using the TTW learning model and the NHT learning model on matrix material. The intended learning outcomes were from scores obtained using assessment techniques.

The research instrument was developed and adapted from NCTM's Catalyzing Change in High School Mathematics (2018). It is used to determine the teaching practices of Mathematics teachers as assessed by students. The instrument consists of 8 constructs, namely: setting learning-focused mathematical goals, carrying out tasks that promote reasoning and problem solving, using and connecting mathematical representations, facilitating meaningful mathematical discourse, asking purposeful questions, building procedural fluency from conceptual understanding, supporting productive struggle in learning mathematics, and obtaining and using evidence of students' thinking. The instrument had a total of twenty-five statements. The instrument used a four-point Likert scale and underwent pilot testing with selected Grade 10 students excluded as respondents for this study due to its reliability. It resulted in a Cronbach's Alpha Coefficient of 0.73, thus rendering it a reliable instrument. In determining teachers' mathematics teaching practices, the following scale was used:

Responses	Continuum	Interpretation
4 - Always (A)	3.25 - 4.0	Very Great Extent (VGE)
3 - Often (O)	2.50 - 3.24	Great Extent (GE)
2 - Sometimes (S)	1.75 - 2.49	Less Extent (LE)
1 - Never (N)	1.0 - 1.74	Least Extent (LtE)

Source: (Bohol & Baluyos, 2023).

To determine the difference in learning outcomes in the two classes, a t-test was conducted by first conducting a prerequisite test, namely the normality and homogeneity tests. The test results were analysed. Then, the findings were applied to the final mathematical representation ability test for both groups. Finally, before testing the hypothesis, the research data were analysed using the Shapiro-Wilk and the homogeneity of variance tests. In addition, two-way analysis of variance (ANOVA) and Scheffe's post hoc test were applied to analyse the differences between the groups. All hypothesis testing was performed using SPSS software with a significance level of 0.05.

RESULTS & DISCUSSION

Results

After making observations, the analysis results of student learning outcomes are presented in Table 3.

Table 3. Categories of Student Learning Outcomes

Qualification	Learning Outcomes	Number of Students	
		TTW	NTH
Very Great Extent (VGE)	3.25 - 4.0	1	1
Great Extent (GE)	2.50 - 3.24	7	3
Less Extent (LE)	1.75 - 2.49	9	12
Least Extent (LtE)	1.0 - 1.74	2	4

Table 3 shows that the class has one student who is included in the VGE qualification in the TTW1, while the NTH class also has one student who is included in the VGE qualification. In addition, there are seven students in the GE category in the TTW class, and the NHT class has three students in the GE category. Furthermore, the LE category is for TTW (9) and NHT (12), and the LtE category is in the TTW (2) and NHT (4) classes. The following Figure 1 presents the average value of learning outcomes of both classes.

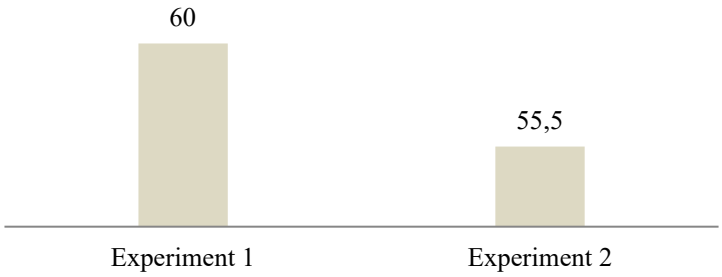

Figure 1. Student Learning Outcomes of Experiment Classes 1 and 2

Giving different treatments to the two classes also resulted in different final results. It can be seen in the significant difference in the average value of student learning outcomes. The class taught with the TTW learning model obtained an average value of 60.0, higher than that of the NHT learning model, which only obtained an average value of 55.5. The results show that the TTW learning model is superior to the NHT model. A normality test was carried out to find out whether the samples used were normally distributed, which can be seen in Table 4.

Table 4. Normality Test Results

Data Group	Sig	α	Kes
TTW	0,052	0,05	Accept H_0
NHT	0,878	0,05	Accept H_0
Data Group	Sig	α	Kes

In Table 4, it can be seen that in experimental class 1, the *Sig*. value is greater than the value of $\alpha = 0.05$, namely 0.052. The same thing also appears in experimental class 2,

the *Sig*. value is greater than $\alpha = 0.05$, namely 0.876. It means that H_1 is rejected and H_0 is accepted. Thus, it can be concluded that the research taken is a normally distributed sample. An equality test or F test was carried out by comparing the variances of the two classes to determine whether the students' abilities of the two classes are homogeneous. The test results are shown in Table 5.

Table 5. Homogeneity Test Results

Data Group	Sig	α	Conclusion
Experiment 1 and Experiment 2	0,440	0,05	Accept H_0

From Table 6, it can be seen that the *Sig*. value is greater than the value of = 0.05 which is 0.440. This means that H0 is accepted, so the variance between the two classes is homogeneous. It implies that the student's ability in the two classes before being given treatment is homogeneous. Thus, data analysis using the T-test can be seen in Table 6.

Table 6. Hypothesis testing results using t-test

Data Group	Sig (2 tailed)	α	Interpretation
Ex 1 & Ex 2	0,5	0,05	Accept H1

From the results of the mean difference test above, it can be seen that the *Sig. (2-tailed) value* is smaller than the α, which is 0.049 smaller than 0.05. This result shows that H_1 is accepted and H_0 is rejected. This states differences in students' learning outcomes in class Public Senior High School XI MIA 19 West Seram taught using the TTW and NHT types of Cooperative Learning Models on matrix material. Mathematics learning of matrix topics taught with TTW type cooperative learning model is superior to NHT type cooperative learning model.

Discussion

TTW learning begins with thinking through the material (listening), and alternative solutions to the reading results are communicated with presentations; then, a presentation report is made (Evi Widianingrum et al., 2022). The learning process using the TTW learning model lasted four meetings, and in the fifth meeting, the teacher gave a test, which was taught using the TTW-type cooperative learning model on matrix material. The results showed good results because they had a higher average value than the second experiment class taught with the NHT learning model.

The TTW model can affect students' self-confidence. It is in line with Behavioristic theory, a learning theory that prioritises changes in behaviour from a stimulus. The emergence of student self-confidence will strengthen and motivate success because the higher the confidence in their abilities, the stronger the enthusiasm for completing their work (Kwon & Silva, 2020). The first step taken in order to build self-confidence is to understand and believe that every human being has their strengths and weaknesses. Self-confidence is one of the requirements for students to develop their activities and creativity to achieve optimal achievement and learning outcomes. Self-confidence will generate strength in students to create a change and self-improvement; besides that, students are free to direct their attention and self-improvement and achieve learning advantages. The TTW learning model provides students with a sense of confidence in learning mathematics. It explained that students' confidence with the TTW method was significant, so student activity increased. It can be described that TTW learning provides opportunities for students to develop their abilities in terms of thinking

in finding existing problems, writing what is known in the problem, speaking in the form of conveying ideas, and discussing well in solving a problem (Muis & Priawasana, 2022). These learning outcomes are obtained from the application of the TTW-type cooperative learning model, which in its application has learning stages that make students skilled in thinking and better understand the material being taught. This result is supported by Wirda et al. (2019), who stated that one of the advantages of the TTW-type cooperative learning model is that students understand the material taught better, and students' conceptualisation becomes better. TTW is a strategy that reflects and tests the organisation of ideas before students are expected to write them down. The application of the TTW strategy in mathematics learning will provide students with experience in solving contextual problems and improve students' writing skills, especially in organising ideas in mathematics. TTW also supports the idea of teaching students how to think about concepts, discuss their ideas, and share their results in writing (Asvini et al., 2020).

The learning process of experimental class 2 used the NHT learning model following the steps. **The First** is numbering. The teacher presented the material in outline and then distributed students into groups of 4 people; because the number of students in the class was 20, there were five groups. After that, all students were given numbering by remembering the number the teacher had called. In each group, there were numbers 1 to 4. At this stage, students followed the directions given by the teacher well. Although it was noisy when dividing groups and numbering, the teacher could direct students to return to calm. **The Second** stage is asking questions; the teacher provides problems to students by distributing materials and student worksheets to think and work together in groups. Then, all students discussed in groups, while the teacher monitored all students in all groups and provided motivation and a brief explanation of whether there were groups that needed help understanding. Students from each group were enthusiastic about seeing the material and student worksheets distributed by the teacher to discuss in their groups. **The third** is the thinking together stage. At this stage, students in each group discussed the problems given by the teacher in the teaching materials and student worksheets. All students were serious in discussing. Some groups needed clarification about the teaching materials and student worksheets provided, but the teacher helped explain related teaching materials and student worksheets distributed. After that, everyone returned to discussing, and the teacher monitored while providing learning motivation. The **fourth** stage is the answering stage. This stage was carried out after all students had finished discussing. Then, students were directed to prepare to solve the problems given. Next, the teacher drew the number that will write the answer first. All students who had gotten their numbers and gotten the same number were required to go to the blackboard and work on the problems given. Initially, students were worried about coming forward to solve the problem, but the teacher convinced them that they would be able to perform, so they dared to come forward and solve the problems given. After all groups finished working on the problems given, the teacher asked students to conclude, and students were given homework. Then, the teacher closed the lesson. In the learning process, students looked passive in completing the student worksheets and asking about material they did not understand. The teacher is only a facilitator ready to help groups or individuals who need help (Leasa et al., 2016).

Cooperative learning is effective because it increases student opportunities to respond, provides faster and more frequent feedback, increases the number of completed learning trials, and allows students to serve as both teachers and learners. In the teacher role, for example, students must outline and explain academic material to peers and provide feedback on their performance. As learners, when they are held accountable for their contributions, they must verbally express what they have learned, and they are given multiple opportunities to participate actively (i.e., answer and ask questions). They hear

various explanations of their peers' problem-solving (W. Hunter & Haydon, 2013). Cooperative learning strategies often improve students' concept understanding and retention. Especially students who are active in collaborating to solve problems in peer groups. This finding is consistent with the observation of Ghaith (2001) that low-achieving learners are more comfortable working in small groups than alone with more able peers. Classroom teachers reported that the NHT strategy was beneficial, easy to implement, and likely to be used in the future. The fact that teachers used NHT in the following year indicates a high degree of social acceptance, which is due to the fact that the longer students interact, the stronger the emotional bond. Finally, future researchers should examine the impact of NHT over a more extended intervention period. Reading comprehension skills tend to develop over extended periods (Haydon et al., 2010).

CONCLUSION

Students learning outcomes in experimental class 1 taught using the TTW-type cooperative learning model are superior to the NHT model. Thus, TTW can be recommended to improve students' mathematics learning outcomes on matrix topics. Therefore, teachers and researchers can improve students' mathematical abilities with other variables that can support students' academic and mathematical literacy. The following conclusions are drawn based on the findings: 1) Teachers have implemented clear and differentiated teaching practices to enhance effective mathematics learning. 2) Students develop a positive dynamic self-concept towards mathematics and are developing a positive self-concept as a learned and organised concept in Mathematics. 3) Students have low performance in Mathematics problem-solving tests. 4) Using mathematical representations that connect students' interests and experiences is an effective strategy and exercise in teaching problem-solving. 5) Students' ability to adapt to new concepts, ideas, and techniques helps them solve math story problems. 6) Students' problem-solving performance in Mathematics is equated to the level of teachers' teaching practice of using and connecting mathematical representations and students' dynamic self-concept in the subject. Based on the research findings and conclusions, the following are the recommendations. 1) Mathematics teachers must attend mathematics teaching training to improve mathematics competence. It will help teachers gain experience, knowledge, and skills from planning learning outcomes to delivering and assessing learning outcomes. 2) Teachers should use varied motivational strategies and techniques in teaching so that students can positively develop concepts in mathematics. It makes learning math fun and enjoyable so students feel comfortable learning. Allowing learners to reflect as they solve story problems helps them achieve concept positivity in Mathematics. 3) Teachers can use different problem-solving strategies tailored to the student's style of solving word problems. Learners should be given remedial instructions to improve their poor performance in solving word problems in Mathematics. 4) Teachers should use a variety of mathematical representations to explore scenarios when solving problems. These include diagrams, illustrations, models, graphs, actual objects, and contextual scenarios. It will make students easily understand the problems and solve them proficiently. 5) Teachers should introduce varied techniques in presenting and solving story problems because learners are adaptive to new ways of solving problems. With the dynamic concept of learners, they explore and learn as they find new concepts and ideas in solving Math story problems. 6) Future researchers should conduct other studies exploring the factors influencing students' problem-solving performance in Mathematics.

REFERENCES

Aguilar, J. J. (2021). High School students' reasons for disliking mathematics: the intersection between teacher's role and student's emotions, belief and self-efficacy. *International Electronic Journal of Mathematics Education*, *16*(3), em0658. https://doi.org/10.29333/iejme/11294

Agustyaningrum, N., Sari, R. N., Abadi, A. M., & Mahmudi, A. (2020). Dominant Factors that cause students' difficulties in learning abstract algebra: a case study at a university in Indonesia. *International Journal of Instruction*, *14*(1), 847–866. https://doi.org/10.29333/IJI.2021.14151A

Asvini, K. D., Suputra, P. E. D., & Hadisaputra, I. N. P. (2020). The effectiveness of the think-talk-write (ttw) strategy on students' writing skills of the tenth-grade students at SMKN 1 sukasada in the academic year 2019/2020. *Jurnal Pendidikan Bahasa Inggris Undiksha*, *8*(1), 21–27. https://ejournal.undiksha.ac.id/index.php/JPBI

Aygör, N., & Burhanzade, H. (2014). The comparative analyzes of the student's performance about matrix in student selection exam (öss) and the approved lecture books of ministry for the national education (MEB). *Procedia - Social and Behavioral Sciences*, *136*, 360–369. https://doi.org/10.1016/j.sbspro.2014.05.342

Bohol, S. F. T., & Baluyos, G. R. (2023). Teachers' teaching practices and students' self-concept in relation to problem-solving performance. *EduLine: Journal of Education and Learning Innovation*, *3*(2), 175–193. https://doi.org/10.35877/454ri.eduline1674

Capinding, A. T. (2022). Impact of modular distance learning on high school students mathematics motivation, interest/attitude, anxiety and achievement during the COVID-19 pandemic. *European Journal of Educational Research*, *11*(2), 917–934. https://doi.org/10.12973/eu-jer.11.2.917

Clarke, B., Baker, S., Smolkowski, K., Doabler, C., Strand Cary, M., & Fien, H. (2015). Investigating the efficacy of a core kindergarten mathematics curriculum to improve student mathematics learning outcomes. *Journal of Research on Educational Effectiveness*, *8*(3), 303–324. https://doi.org/10.1080/19345747.2014.980021

Evi Widianingrum, Dewi Netta Febrianti, & Wanabuliandari, S. (2022). Literature review using think talk write (ttw) cooperative learning model in students' mathematical reasoning ability. *Mathematics Education Journal*, *6*(2), 130–139. https://doi.org/10.22219/mej.v6i2.22678

Ghaith, G. (2001). Learners' perceptions of their STAD cooperative experience. *System*, *29*(2), 289–301. https://doi.org/10.1016/S0346-251X(01)00016-1

Haydon, T., Maheady, L., & Hunter, W. (2010). Effects of numbered heads together on the daily quiz scores and on-task behavior of students with disabilities. *Journal of Behavioral Education*, *19*(3), 222–238. https://doi.org/10.1007/s10864-010-9108-3

Hunter, W. C., Dieker, L. A., & Whitney, T. (2016). Consultants and co-teachers affecting student outcomes with numbered heads together: keeping all engaged. *Journal of Educational and Psychological Consultation*, *26*(2), 186–199. https://doi.org/10.1080/10474412.2015.1108200

Hunter, W., & Haydon, T. (2013). Examining the effectiveness of numbered heads together for students with emotional and behavioral disorders. *Beyond Behavior*, *22*(3), 40–45. https://doi.org/10.1177/107429561302200306

Inganah, S. (2018). Analysis of students understanding for the concept of matrix rank based on APOS theory. *Advances in Social Science, Education and Humanities Research*, *231*, 563–566. https://doi.org/10.2991/amca-18.2018.156

Ismail, S. F. Z. H., Shahrill, M., & Mundia, L. (2015). Factors contributing to effective mathematics teaching in secondary schools in Brunei Darussalam. *Procedia - Social and Behavioral Sciences*, *186*, 474–481. https://doi.org/10.1016/j.sbspro.2015.04.169

James, C., Drake, J. E., & Winner, E. (2018). Expression versus distraction: an investigation of contrasting emotion regulation strategies when drawing, writing, talking, and thinking. *Empirical Studies of the Arts*, *36*(2), 162–179. https://doi.org/10.1177/0276237417718423

Johnson, D. W., Johnson, R. T., & Smith, K. A. (2014). Cooperative learning: Improving university instruction by basing practice on validated theory. *Journal of Excellence in College Teaching*, *25*, 85–118. http://www.ncbi.nlm.nih.gov/pubmed/10180297

Kwon, H. R., & Silva, E. A. (2020). Mapping the landscape of behavioral theories: systematic literature review. *Journal of Planning Literature*, *35*(2), 161–179. https://doi.org/10.1177/0885412219881135

Landrock, U. (2017). Enquête sur les falsifications d'intervieweurs - Un projet quasi-expérimentale. *BMS Bulletin of Sociological Methodology/ Bulletin de Methodologie Sociologique*, *136*(1), 5–20. https://doi.org/10.1177/0759106317725640

Larrosa, J. (2010). Endgame: reading, writing, talking (and perhaps thinking) in a faculty of education. *Educational Philosophy and Theory*, *42*(5–6), 683–703. https://doi.org/10.1111/j.1469-5812.2010.00693.x

Laurens, T., Batlolona, F. A., Batlolona, J. R., & Leasa, M. (2018). How does realistic mathematics education (RME) improve students' mathematics cognitive achievement? *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(2), 569–578. https://doi.org/10.12973/ejmste/76959

Leasa, M. (2016). The effect of numbered heads together (NHT) cooperative learning model on the cognitive achievement of students with different academic ability. *Journal of Physics: Conference Series*, *755*(1), 1–10. https://doi.org/10.1088/1742-6596/755/1/011001

Leasa, M., Fenanlampir, A., Batlolona, J. R., & Saimima, A. S. (2021). Problem-solving and creative thinking skills with the PBL model : The concept of the human circulatory system. *Biosfer : Jurnal Pendidikan Biologi*, *14*(2), 154–166.

Leasa, M., Sanabuky, Y. L., Batlolona, J. R., & Enriquez, J. J. (2019). Jigsaw in teaching circulatory system: a learning activity on elementary science classroom. *Biosfer*, *12*(2), 122–134. https://doi.org/10.21009/biosferjpb.v12n2.122-134

Leasa, M., Talakua, M., & Batlolona, J. R. (2016). The development of a thematic module based on Numbered Heads Together (NHT) cooperative learning model for elementary students in Ambon, Moluccas-Indonesia. *New Educational Review*, *46*(4), 174–185. https://doi.org/10.15804/tner.2016.46.4.15

Li, Y., & Schoenfeld, A. H. (2019). Problematizing teaching and learning mathematics as "given" in STEM education. *International Journal of STEM Education*, *6*(1), 1–13. https://doi.org/10.1186/s40594-019-0197-9

Maheady, L., Mallette, B., Harper, G. F., & Sacca, K. (1991). Heads together: A peer-mediated option for improving the academic achievement of heterogeneous learning groups. *Remedial and Special Education*, *12*(2), 25–33. https://doi.org/10.1177/074193259101200206

Maheady, L., Michielli-Pendl, J., Harper, G. F., & Mallette, B. (2006). The effects of Numbered Heads Together with and without an incentive package on the science test performance of a diverse group of sixth graders. *Journal of Behavioral Education*, *15*(1), 25–39. https://doi.org/10.1007/s10864-005-9002-6

Maman, M., & Rajab, A. A. (2016). The implementation of cooperative learning model 'number heads together (NHT)' in improving the students' ability in reading comprehension. *International Journal of Evaluation and Research in Education (IJERE)*, *5*(2), 174. https://doi.org/10.11591/ijere.v5i2.4536

Mazana, M. Y., Montero, C. S., & Casmir, R. O. (2020). Assessing students' performance in mathematics in Tanzania: the teacher's perspective. *International Electronic Journal of Mathematics Education*, *15*(3), em0589. https://doi.org/10.29333/iejme/7994

Mobrur, A., & Hamed, M. (2014). European Journal of Educational Sciences. *Journal of Educational Sciences*, *1*(4), 190–204.

Muis, A., & Priawasana, E. (2022). The effect of learning the Think Talk Write model with PowerPoint assistance on students' mathematics learning outcomes. *International Journal of Trends in Mathematics Education Research*, *5*(3), 236–243. https://doi.org/10.33122/ijtmer.v5i3.122

Mutodi, P., & Ngirande, H. (2014). The influence of students' perceptions on mathematics performance. A case of a selected high school in South Africa. *Mediterranean Journal of Social Sciences*, *5*(3), 431–445. https://doi.org/10.5901/mjss.2014.v5n3p431

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education*, *21*(5), 509–523. https://doi.org/10.1016/j.tate.2005.03.006

Öztürk, M., Akkan, Y., & Kaplan, A. (2020). Reading comprehension, Mathematics self-efficacy perception, and Mathematics attitude as correlates of students' non-routine Mathematics problem-solving skills in Turkey. *International Journal of Mathematical Education in Science and Technology*, *51*(7), 1042–1058. https://doi.org/10.1080/0020739X.2019.1648893

Pasani, C. F., & Suryaningsih, Y. (2021). Analysis of students' Higher Order Thinking Skills (HOTS) ability in matrix subjects. *Journal of Physics: Conference Series*, *1760*(1), 1–9. https://doi.org/10.1088/1742-6596/1760/1/012039

Randel, B., Apthorp, H., Beesley, A. D., Clark, T. F., & Wang, X. (2016). Impacts of professional development in classroom assessment on teacher and student outcomes. *Journal of Educational Research*, *109*(5), 491–502. https://doi.org/10.1080/00220671.2014.992581

Reyk, J. V., Leasa, M., Talakua, M., & Batlolona, J. R. (2022). Research-based learning: added value in students' science critical thinking skills. *Jurnal Penelitian Pendidikan IPA*, *8*(1), 230–238. https://doi.org/10.29303/jppipa.v8i1.1121

Richgels, D. J. (2013). TALK, W R I T E, AND RE AD. *The Reading Teacher*, *66*(5), 380–389. https://doi.org/10.1002/TRTR.1139

Sarsale, J., Alonzo, D., Caseñas, A., Oo, C. Z., Sy, F. A., & Yepes, P. I. (2024). Assessing literacy practices and futures in science and mathematics classrooms: A systematic review. *Issues in Educational Research*, *34*(2), 719–742.

Schindler, M., & Lilienthal, A. J. (2020). Students' creative process in mathematics: insights from eye-tracking-stimulated recall interview on students' work on multiple solution tasks. *International Journal of Science and Mathematics Education*, *18*(8), 1565–1586. https://doi.org/10.1007/s10763-019-10033-0

Schoenfeld, A. H. (2016). Learning to Think Mathematically: Problem Solving, Metacognition, and Sense Making in Mathematics (Reprint). *Journal of Education*, *196*(2), 1–38. https://doi.org/10.1177/002205741619600202

Slavin, R. E. (1980). Cooperative Learning in Teams: State of the Art. *Educational Psychologist*, *15*(2), 93–111. https://doi.org/10.1080/00461528009529219

Slavin, R. E. (2015). Cooperative learning in elementary schools. *Education 3-13*, *43*(1), 5–14. https://doi.org/10.1080/03004279.2015.963370

Slavin, R. E., & Cooper, R. (1999). Improving intergroup relations: Lessons learned from cooperative learning programs. *Journal of Social Issues*, *55*(4), 647–663. https://doi.org/10.1111/0022-4537.00140

Supandi, S., Waluya, S. B., Rochmad, R., Suyitno, H., & Dewi, K. (2018). Think-talk-write model for improving students' abilities in mathematical representation. *International Journal of Instruction*, *11*(3), 77–90. https://doi.org/10.12973/iji.2018.1136a

Suwarto, M., Yatimah, D., & Komalasari, G. (2021). The effectiveness of think talk write learning model to the students' writing skills in Indonesian Elementary School. *International Journal of Multicultural and Multireligious Understanding*, *8*(6), 115–132. http://dx.doi.org/10.18415/ijmmu.v8i6.2724

Tatira, B. (2024). Schema development in solving systems of linear equations using the triad framework. *Mathematics Teaching-Research Journal*, *16*(1), 167–189.

Wirda, Setiawan, D., & Hidayat. (2019). The effect of think talk write (ttw) learning method on the creative thinking ability of the students at primary school (Sd) No. 060856 Medan, Indonesia. *British Journal of Education*, *5*(11), 12–28.

Wood, T., Mazzocco, M. M. M., Calhoon, M. B., Crowe, E. C., & Connor, C. M. D. (2020). The effect of peer-assisted mathematics learning opportunities in first-grade classrooms: What works for whom? *Journal of Research on Educational Effectiveness*, *13*(4), 601–624. https://doi.org/10.1080/19345747.2020.1772422

Yeh, C. Y. C., Cheng, H. N. H., Chen, Z. H., Liao, C. C. Y., & Chan, T. W. (2019). Enhancing achievement and interest in mathematics learning through Math-Island. *Research and Practice in Technology Enhanced Learning*, *14*(1), 1–19. https://doi.org/10.1186/s41039-019-0100-9