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# Think-Pair-Share and Mathematical Literacy: A Quasi-Experimental Study in Senior High School Mathematics

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**Abstract**

Improving students' mathematical literacy (ML) remains an important concern in mathematics education, particularly because Indonesian students continue to demonstrate relatively low ML performance. This study examined the effect of the Think–Pair–Share (TPS) learning model on students' ML using a quasi-experimental posttest-only control group design. The participants were 94 Grade 10 students divided equally into experimental and control groups. Data were collected using a mathematical literacy essay test and analyzed through descriptive statistics, the Mann–Whitney U test, and Cohen's $d$ effect size using SPSS version 27. The Mann–Whitney U test was employed because the posttest scores did not fully satisfy the assumption of normality. The results showed no statistically significant difference in overall ML between the experimental and control groups ($p$ = .312). Nevertheless, the effect-size analysis revealed a large positive effect on the understanding indicator ($d$ = 1.256) and a small positive effect on communication ($d$ = 0.190). In contrast, small and moderate negative effects were found for analysis ($d$ = −0.233) and representation ($d$ = −0.520), respectively, indicating slightly better performance in the control group. The overall effect size was small ($d$ = 0.146). These findings indicate that TPS did not significantly improve students' overall ML but may be more effective in supporting conceptual understanding than other dimensions of mathematical literacy.

**Keywords:** Think–pair–share; Mathematical literacy, Probability, Quasi-experimental study

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## INTRODUCTION

Mathematical literacy (ML) refers to the ability to formulate, employ, and interpret mathematics in various contexts. It involves the use of mathematical concepts, procedures, facts, and tools to describe, explain, and predict phenomena, thereby enabling students to understand the role of mathematics and make well-founded decisions in everyday life (Falani 2025; OECD 2018; Sari 2025). Accordingly, ML reflects students' capacity to apply mathematical reasoning and concepts when solving contextual problems and making decisions in real-life situations. It encompasses the application of mathematics to authentic contexts and the ability to recognise functional relationships between mathematical concepts and everyday life (Anggoro et al. 2019; Tabieh 2023; Widyastuti 2020).

Students are expected to develop strong ML skills because these skills enable them to address real-life problems, construct mathematical models of real-world situations, and participate effectively in lifelong learning (Ezaki et al. 2024; Putri and Juandi 2024; Srikoon et al. 2024). Therefore, ML is not limited to performing mathematical calculations. It also involves understanding problems, selecting appropriate mathematical concepts, interpreting results, and making reasoned decisions based on available information.

Despite its importance, Indonesian students' ML performance remains relatively low. The results of recent Programme for International Student Assessment (PISA) cycles show that

Indonesian students' mathematics scores remain below the international average and have declined across recent assessment periods. These findings indicate that students continue to experience difficulties in understanding, applying, and interpreting mathematical concepts in contextual situations. This condition reflects a substantial gap between the expected level of ML and students' actual performance (OECD 2015, 2018, 2022). The comparison between Indonesian students' scores and the PISA average is presented in Figure 1.

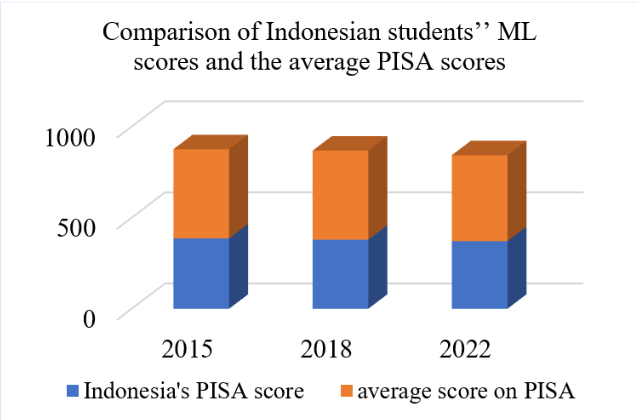


**Figure 1.** Comparison of Indonesian students' mathematical literacy scores and the average PISA scores

Students' low ML performance may be associated with instructional practices that remain dominated by conventional teaching methods and provide limited opportunities to engage with interactive and literacy-oriented mathematical problems (Santos and Santiago 2024; Suprapto and Suryani 2023). Consequently, students may become accustomed to applying routine procedures without adequately interpreting contextual information or explaining their mathematical reasoning. Student achievement is also influenced by internal factors, including self-confidence. Students with higher self-confidence tend to participate more actively and demonstrate stronger problem-solving performance than students with lower self-confidence (Hardianti 2019; Kurniawati 2019; Nakypbek et al. 2025; Purwanti et al. 2020). These conditions indicate the need for an instructional model that actively involves students in thinking, discussing, and communicating mathematical ideas.

One cooperative learning model that may address this need is Think–Pair–Share (TPS). This model encourages students to think independently, discuss their ideas with a partner, and share the results of their discussions with the class (Joseph 2021; Nelson et al. 2022; Saraswati 2021). TPS consists of three structured stages: Think, Pair, and Share. These stages are designed to promote active student engagement throughout the learning process (Li and Tu 2024; Rahmy et al. 2021; Sophie et al. 2023). During the Think stage, students independently examine a problem and formulate an initial solution. During the Pair stage, they exchange ideas, compare strategies, and receive feedback from their partners, which may strengthen their conceptual understanding (Astra 2021; Mundelsee and Jurkowski 2021). During the Share stage, students present and justify their solutions before the class. This process provides opportunities to develop ML through the communication of mathematical ideas and the discussion of alternative problem-solving strategies (Boleng and Maasawet 2021; Emerson et al. 2023). Thus, TPS may support active participation, conceptual understanding, and the development of students' ML.

Previous studies have shown that TPS can influence several dimensions of mathematical thinking, including mathematical reasoning (Rahmy et al. 2021), critical thinking (Li and Tu 2024), mathematical communication (Emerson et al. 2023), and mathematical problem-solving skills (Srikoon et al. 2024). Nevertheless, several research gaps remain. Previous studies have generally examined the effects of TPS on specific mathematical abilities rather than on ML as a multidimensional competency. In addition, the implementation of TPS in probability learning has received relatively limited attention. Probability requires students to interpret uncertainty, analyse contextual information, represent possible outcomes, and make mathematically justified decisions. These characteristics make probability a relevant context for investigating the development of ML.

Although TPS has been implemented at different educational levels, previous studies have largely focused on elementary school students (Wuryandani et al. 2021) and junior high school students (Rahmy et al. 2021). Evidence concerning its application among senior high school students, particularly in probability learning, remains limited. Further research is therefore required to determine whether the structured stages of TPS can support students in understanding contextual problems, analysing mathematical information, constructing appropriate representations, and communicating mathematical reasoning.

Based on these research gaps, this study examines the effect of the Think–Pair–Share learning model on the ML of senior high school students in probability learning. The study evaluates both students' overall ML and four specific dimensions: understanding, analysis, representation, and communication. By examining these dimensions separately, the study is expected to provide a more comprehensive account of the practical effects of TPS and identify the dimensions of ML that are most responsive to its implementation.

## METHOD

### Research Design

This study employed a quasi-experimental design with a posttest-only control group. A quasi-experimental design examines the effect of an intervention without randomly assigning participants to experimental and control groups (Amador et al. 2025). The experimental and control groups were selected through purposive sampling, in which participants are chosen according to predetermined criteria relevant to the research objectives (Tabieh 2023). In this study, the mathematics teacher recommended two Grade 10 classes with comparable mathematical abilities based on their performance in previous mathematics examinations. One class was assigned as the experimental group, while the other was assigned as the control group. Intact classes were maintained throughout the study to preserve the natural classroom setting while examining the effect of the Think–Pair–Share (TPS) learning model on students' mathematical literacy (Emerson et al. 2023; Mundelsee and Jurkowski 2021; Tabieh 2023).

The posttest-only control group design was used to compare the mathematical literacy performance of students who received different forms of instruction. This design minimizes the potential testing effect because participants are not exposed to the same or similar test items before the intervention. Consequently, the posttest results more directly reflect differences associated with the instructional treatments.

| Group | Treatment (Implementation) | Post-test |
|---|---|---|
| Experimental | X | $O_1$ |
| Control | – | $O_2$ |

**Figure 2.** Posttest-Only Control Group Design

Note:
X = implementation of the TPS learning model
$O_1$ = posttest observation of the experimental group
$O_2$ = posttest observation of the control group

As illustrated in Figure 2, the TPS learning model was implemented in the experimental group, whereas the control group received conventional instruction. After the intervention, both groups completed the same mathematical literacy posttest. The resulting scores were then compared to determine whether the TPS learning model affected students' mathematical literacy.

## Participants

The participants were 94 Grade 10 students enrolled at a senior high school in Depok during the 2025–2026 academic year. They were drawn from two intact classes selected through purposive sampling. This sampling technique was used to obtain groups with comparable academic characteristics, thereby reducing the possibility that differences in learning outcomes were caused by pre-existing differences rather than by the instructional intervention (Emerson et al. 2023; Li and Tu 2024). One class was assigned to the experimental group, and the other was assigned to the control group. Each group consisted of 47 students.

**Table 1.** Distribution of Participants by Group and Sex

| Group | Male | Female | Total |
|---|---|---|---|
| Control | 23 | 24 | 47 |
| Experimental | 20 | 27 | 47 |
| Total | 43 | 51 | 94 |

As presented in Table 1, the experimental and control groups contained the same number of students. Female students outnumbered male students in both groups, with 51 female and 43 male students participating in the study.

## Intervention Procedure

Before the intervention, the researchers obtained permission from the selected senior high school to conduct the study. After permission was granted, the instructional materials required for the intervention were prepared. These materials included lesson plans, student worksheets, affective assessment sheets, presentation slides, and learning materials developed in accordance with the TPS model and the probability topic.

The intervention was conducted over six instructional sessions. Students in the experimental group were taught probability using the TPS learning model, whereas students in the control group received conventional instruction. The same learning content and instructional duration were used for both groups to minimize differences unrelated to the instructional model.

After the intervention, both groups completed the mathematical literacy posttest. Follow-up interviews were then conducted with six students from the experimental group to obtain additional information about their learning experiences during the implementation of TPS. The interview sample consisted of two students with high ML scores, two with moderate ML scores, and two with low ML scores, based on their posttest performance. The interview data were used to complement the quantitative findings and provide a more detailed account of how students with different levels of ML experienced the Think, Pair, and Share stages.

## Instrument

The instrument used in this study was a mathematical literacy essay test adapted from Widyaningrum et al. (2024). The adaptation involved modifying the contextual situations and problem statements to correspond with the probability content taught in Grade 10 while retaining the mathematical literacy framework of the original instrument.

The adapted instrument consisted of eight essay questions designed to assess four dimensions of ML: understanding, analysis, representation, and communication. Each dimension was measured using two items. Students' responses were evaluated using an analytical scoring rubric adapted from Widyaningrum et al. (2024). The rubric assessed the extent to which students demonstrated understanding of the problem, analyzed relevant information, represented mathematical ideas appropriately, and communicated their reasoning clearly.

## Scoring

Students' responses were assessed using an analytical scoring rubric adapted from Widyaningrum et al. (2024). The rubric comprised four dimensions of mathematical literacy: understanding, analysis, representation, and communication. Performance in each dimension was rated on a four-point scale ranging from 0 to 3, with higher scores indicating stronger achievement of the relevant mathematical literacy competency. The scoring criteria are presented in Table 2.

**Table 2.** Scoring Rubric for Mathematical Literacy Dimensions

| No. | ML Dimension | Score | Performance Descriptor |
|---|---|---|---|
| 1 | Understanding | 0 | The student does not demonstrate an understanding of the mathematical concepts or information presented in the problem. The student cannot explain the relevant concepts, uses mathematical symbols or notation incorrectly, and does not describe an appropriate problem-solving process. |
| | | 1 | The student demonstrates limited understanding of the mathematical concepts and information presented in the problem. Explanations are incomplete or unclear, mathematical symbols and notation are used inconsistently, and the proposed problem-solving steps are not sufficiently logical or systematic. |
| | | 2 | The student demonstrates an adequate understanding of the mathematical concepts and information presented in the problem. The student explains the relevant concepts using understandable language, generally uses mathematical symbols and notation correctly, and presents a logical problem-solving process with minor omissions. |
| | | 3 | The student demonstrates a comprehensive understanding of the mathematical concepts and information presented in the problem. The student explains the concepts accurately using appropriate mathematical language, uses symbols and notation correctly, and presents a complete, logical, and well-organised problem-solving process. |
| 2 | Analysis | 0 | The student is unable to analyse the information presented in the problem, distinguish relevant information, identify relationships among the given elements, or formulate an appropriate approach to solving the problem. |
| | | 1 | The student demonstrates limited ability to analyse and organise the information presented in the problem. Some relevant elements are identified, but important patterns, relationships, or unnecessary information are not adequately recognised. |
| | | 2 | The student adequately analyses and organises the information presented in the problem. The student identifies most relevant patterns and relationships and formulates an appropriate problem-solving approach, although minor omissions or inaccuracies remain. |
| | | 3 | The student accurately and comprehensively analyses the information presented in the problem. The student distinguishes relevant from irrelevant information, identifies patterns and relationships, and formulates an appropriate and well-reasoned problem-solving approach. |
| 3 | Representation | 0 | The student is unable to transform the information presented in the problem into an appropriate mathematical representation. The representation provided is absent, irrelevant, or fundamentally incorrect. |
| | | 1 | The student attempts to represent the information mathematically, but the representation is incomplete, unclear, or contains substantial errors in the application of mathematical concepts. |
| | | 2 | The student transforms the relevant information into an appropriate mathematical representation, although minor errors or inaccuracies occur during the representation process. |

| No. | ML Dimension | Score | Performance Descriptor |
|---|---|---|---|
| | | 3 | The student accurately and precisely transforms the relevant information into appropriate mathematical representations and effectively uses equations, tables, diagrams, charts, or graphs to communicate the information. |
| 4 | Communication | 0 | The student's explanation is unclear, illogical, or incomplete. The solution strategy is inappropriate or ineffective, and the answer is incorrect or unsupported by mathematical reasoning. |
| | | 1 | The student provides a partially understandable explanation, but the reasoning is poorly organised and insufficiently supported. The solution strategy contains substantial weaknesses, resulting in an incomplete or partially incorrect answer. |
| | | 2 | The student explains the solution with sufficient clarity and logical organisation. The reasoning and strategy are generally appropriate, although minor gaps, inefficiencies, or inaccuracies remain. |
| | | 3 | The student communicates the solution clearly, coherently, and systematically. The reasoning is fully justified, the selected strategy is accurate and efficient, and the final answer is complete and correct. |

As shown in Table 2, students' responses were evaluated according to the performance criteria established for each score level. Scores ranged from 0, indicating that the expected competency was not demonstrated, to 3, indicating comprehensive and accurate performance. Higher scores therefore represented stronger achievement in the corresponding dimension of mathematical literacy.

**Validity and Reliability**

The ML test instrument and its scoring rubric were adapted from Widyaningrum et al. (2024) to suit the objectives and context of the present study. Following the adaptation process, the instrument was evaluated by experts to assess the relevance, clarity, and suitability of the test items and the scoring rubric. Based on the experts' suggestions, several revisions were made to improve the wording and the instrument's contextual appropriateness. The validation results indicated that the adapted instrument and scoring rubric were valid and suitable for use in this study. Following the content validation process, the instrument's reliability was also examined prior to data collection. The reliability analysis indicated that the adapted instrument demonstrated acceptable reliability, confirming its consistency and suitability for measuring students' ML in the present study.

**Data Analysis Techniques**

The data were analysed using descriptive and inferential statistics to examine the effect of the TPS learning model on students' mathematical literacy. Descriptive statistics, including the mean, standard deviation, minimum score, and maximum score, were calculated for the experimental and control groups. These statistics were used to describe the distribution of students' posttest performance after the two groups received different forms of instruction (Emerson et al. 2023; Suprapto and Suryani 2023).

Before hypothesis testing, the normality of the posttest scores was examined using the Shapiro–Wilk test in SPSS version 27. The Shapiro–Wilk test was selected because it is appropriate for assessing normality in samples of fewer than 50 participants per group. A significance value greater than .05 indicated that the data did not significantly deviate from a normal distribution, whereas a significance value below .05 indicated a violation of the normality assumption (Astra 2021; Li and Tu 2024).

The normality analysis showed that the experimental-group scores were normally distributed, whereas the control-group scores were not. Because the normality assumption was not satisfied for both groups, the difference in overall mathematical literacy between the experimental and control groups was analysed using the nonparametric Mann–Whitney U test rather than an independent-samples t test. The Mann–Whitney U test is appropriate for comparing two independent groups when the data do not meet the assumptions required for parametric analysis (Srikoon et al. 2024; Tabieh 2023).

The statistical significance of the Mann–Whitney U test was interpreted at the 5% significance level, with $\alpha = .05$. When the p value was below .05, the null hypothesis was rejected, indicating a statistically significant difference between the two groups. When the p value was equal to or greater than .05, the null hypothesis was not rejected, indicating insufficient evidence of a statistically significant difference (Li and Tu 2024; Rahmy et al. 2021).

In addition to hypothesis testing, effect-size analysis was conducted to estimate the magnitude and direction of the differences between the experimental and control groups. Cohen's d was calculated for the overall posttest scores and each mathematical literacy dimension. The magnitude of Cohen's d was interpreted using conventional thresholds, with values of approximately 0.20, 0.50, and 0.80 representing small, moderate, and large effects, respectively. Positive values indicated higher mean performance in the experimental group, whereas negative values indicated higher mean performance in the control group. Effect-size analysis was included to complement the significance test by providing information about the practical magnitude of the observed differences (Emerson et al. 2023; Putri and Juandi 2024).

## RESULTS

Before hypothesis testing, the normality of the posttest scores in the experimental and control groups was examined using the Shapiro–Wilk test in SPSS version 27. A significance value greater than .05 indicated that the data did not significantly deviate from a normal distribution, whereas a significance value below .05 indicated that the normality assumption was not satisfied. The results are presented in Table 3.

**Table 3.** Results of the Shapiro–Wilk Normality Test

| Group | Shapiro–Wilk Statistic | *p* | Interpretation |
|---|---|---|---|
| Experimental | 0.983 | .653 | Normally distributed |
| Control | 0.912 | .005 | Not normally distributed |

As shown in Table 3, the experimental group obtained a significance value of .653, which was greater than .05, indicating that its posttest scores were normally distributed. In contrast, the control group obtained a significance value of .005, which was below .05, indicating that its posttest scores were not normally distributed. Because the normality assumption was not satisfied for both groups, the difference in overall mathematical literacy was analysed using the Mann–Whitney U test. The results are presented in Table 4.

**Table 4.** Results of the Mann–Whitney U Test

| Group | *N* | Mean Rank | *p* |
|---|---|---|---|
| Experimental | 47 | 50.320 | .312 |
| Control | 47 | 44.680 | .312 |

Table 4 shows that the experimental group obtained a higher mean rank than the control group, with values of 50.320 and 44.680, respectively. However, the Mann–Whitney U test yielded a significance value of .312, which was greater than the predetermined significance level of .05. Therefore, the null hypothesis was not rejected. This result indicates that there was insufficient statistical evidence of a difference in overall mathematical literacy between students taught using the TPS learning model and those taught using conventional instruction. Accordingly, TPS cannot be concluded to have significantly improved students' overall mathematical literacy within the conditions of this study.

In addition to the hypothesis test, Cohen's *d* was calculated to estimate the magnitude and direction of the differences between the experimental and control groups. Because the primary hypothesis was tested using the Mann–Whitney U test, the following analysis focuses on descriptive mean differences and effect sizes rather than on additional significance tests. The results are presented in Table 5.

**Table 5.** Descriptive Statistics and Cohen's *d* by Mathematical Literacy Dimension

| Dimension | Group | *N* | Mean | SD | SE | Cohen's *d* |
|---|---|---|---|---|---|---|
| Understanding | Experimental | 47 | 92.091 | 15.220 | 2.220 | 1.256 |
| | Control | 47 | 71.978 | 16.777 | 2.447 | |
| Analysis | Experimental | 47 | 51.595 | 34.278 | 5.000 | −0.233 |
| | Control | 47 | 58.361 | 22.743 | 3.317 | |
| Representation | Experimental | 47 | 11.893 | 17.473 | 2.548 | −0.520 |
| | Control | 47 | 21.446 | 19.196 | 2.800 | |
| Communication | Experimental | 47 | 12.319 | 21.169 | 3.087 | 0.190 |
| | Control | 47 | 8.149 | 22.730 | 3.315 | |
| Overall mathematical literacy | Experimental | 47 | 41.959 | 12.548 | 1.830 | 0.146 |
| | Control | 47 | 40.204 | 11.475 | 1.673 | |

As presented in Table 5, the magnitude and direction of the group differences varied across the four dimensions of mathematical literacy. The understanding dimension produced a large positive effect size ($d$ = 1.256), indicating that the experimental group performed substantially better than the control group in conceptual understanding. This was the strongest practical difference observed across the dimensions.

The communication dimension showed a negligible positive effect ($d$ = 0.190), with the experimental group obtaining a slightly higher mean score than the control group. In contrast, the analysis dimension produced a small negative effect ($d$ = −0.233), while the representation dimension produced a moderate negative effect ($d$ = −0.520). These negative values indicate that the control group performed better than the experimental group in analysis and representation, particularly in the representation dimension.

For overall mathematical literacy, Cohen's $d$ was 0.146, indicating a negligible positive difference in favour of the experimental group. This result is consistent with the Mann–Whitney U test, which found no statistically significant difference between the groups. Thus, although TPS demonstrated a large practical advantage in conceptual understanding, its effect on students' overall mathematical literacy was limited because the effects on analysis, representation, and communication were small or favoured the control group.

## DISCUSSION

The findings indicate that the Think–Pair–Share (TPS) learning model did not produce a statistically significant difference in students' overall mathematical literacy compared with conventional instruction. The Mann–Whitney U test showed no significant difference between the experimental and control groups, while the overall effect size was negligible ($d$ = 0.146). These results suggest that implementing TPS over six instructional sessions was insufficient to produce a substantial improvement in students' overall mathematical literacy. Nevertheless, the effect-size analysis revealed different patterns across the four dimensions, indicating that TPS may support some dimensions of mathematical literacy more effectively than others.

Among the four dimensions, understanding showed the largest positive effect size ($d$ = 1.256). Students in the experimental group obtained a substantially higher mean score than those in the control group in identifying relevant information, interpreting contextual problems, and recognising the mathematical concepts required to solve the tasks. This result is consistent with the characteristics of TPS, which provide students with opportunities to construct an initial understanding independently before discussing their ideas with peers (Amador et al. 2025; OECD 2022). However, this finding should be interpreted as a large practical difference in conceptual understanding rather than as evidence of a statistically significant improvement in overall mathematical literacy.

The contribution of TPS to conceptual understanding can be explained through its three sequential stages: Think, Pair, and Share. During the Think stage, students independently examine the problem, identify relevant information, and formulate an initial solution strategy before interacting with their peers. Previous research suggests that individual reflection before collaborative discussion can promote deeper conceptual processing and encourage students to organise their reasoning more carefully (Li and Tu 2024; Mundelsee and Jurkowski 2021). During the Pair stage, students compare strategies, exchange explanations, and clarify misunderstandings with a partner. During the Share stage, they communicate and justify their solutions to the class, allowing their understanding to be further refined through feedback from peers and the teacher.

**Figure 3.** Students' activities during the Think stage

Figure 3 documents students' activities during the Think stage. At this stage, students independently identified the contextual problem, selected relevant information, and formulated preliminary solution strategies before participating in paired discussion. The figure therefore provides visual documentation of the individual reasoning process incorporated into the implementation of TPS.

The interview findings provided additional context for interpreting the quantitative results. Students with higher mathematical literacy scores generally reported being able to interpret contextual problems and formulate preliminary solution strategies independently. Students with moderate scores tended to require more time to analyse the available information before selecting an appropriate approach (Anggoro et al. 2019; OECD 2022). Meanwhile, students with lower scores indicated that the Think stage helped them distinguish between known and unknown information, although they still experienced difficulty connecting the information to appropriate mathematical concepts (Chen 2022). These responses suggest that the Think stage supported students at different ability levels by providing time for individual reflection before collaborative learning began (Chen 2022; Nakypbek et al. 2025).

These findings are consistent with the constructivist view that meaningful learning begins with active cognitive processing and is subsequently strengthened through social interaction. Students with stronger prior knowledge appeared to use the Think stage to verify and refine their reasoning, whereas students with weaker mathematical literacy used it primarily to organise information and develop an initial understanding of the problem. Thus, the Think stage may strengthen conceptual understanding by encouraging students to construct their own interpretations before comparing them with those of their peers (Li and Tu 2024; Mundelsee and Jurkowski 2021).

Although understanding showed a large positive effect, similar results were not observed for analysis and representation. The effect sizes for these dimensions were negative, with $d = -0.233$ for analysis and $d = -0.520$ for representation. These values indicate that the control group obtained higher mean scores than the experimental group, with a small difference in analysis and a moderate difference in representation. Therefore, TPS did not appear to provide the same practical advantage for competencies requiring students to analyse relationships, construct mathematical models, and transform contextual information into formal representations.

Mathematical analysis requires students to distinguish relevant information, identify relationships among concepts, and select appropriate strategies for solving contextual problems. Mathematical representation involves translating real-world situations into mathematical expressions, diagrams, tables, graphs, or equations that accurately reflect the given information (OECD, 2022). These competencies generally require repeated modelling activities, explicit guidance, and sustained practice in transforming contextual information into formal mathematical forms.

One possible explanation for the lower performance in analysis and representation is the distribution of instructional time during TPS implementation. Students spent considerable time thinking independently, discussing ideas with partners, and presenting solutions. Although these activities promoted participation and conceptual clarification, they may have reduced the time available for intensive modelling exercises and repeated procedural practice. Consequently, students may have developed stronger conceptual understanding without receiving sufficient structured practice to improve analytical and representational competencies.

Previous research indicates that cooperative learning is particularly useful for conceptual development and peer interaction, whereas mathematical modelling and representation may require more explicit demonstrations and guided practice (Amador et al. 2025; OECD, 2022). Conventional instruction often involves direct teacher explanation followed by repeated exercises. Such instruction may have provided the control group with more opportunities to practise formal procedures and transform contextual problems into mathematical representations. This difference in instructional emphasis may partly explain the control group's higher mean scores in analysis and representation.

**Figure 4.** Students' activities during the Pair stage

Figure 4 illustrates the implementation of the Pair stage, during which students compared solution strategies, exchanged ideas, and clarified their understanding through discussion. The figure documents how peer interaction was incorporated into the intervention before students presented their solutions to the wider class.

The interview findings further clarified students' participation during the Pair stage. Students with higher mathematical literacy scores were generally able to justify their reasoning, evaluate alternative strategies, and assist their partners in understanding mathematical concepts. Students with moderate scores used paired discussions primarily to verify their initial answers and identify errors in their reasoning. In contrast, students with lower scores tended to rely more heavily on their partners' explanations and focused on obtaining the correct answer rather than independently constructing a mathematical model. These patterns suggest that the Pair stage functioned more effectively as a means of conceptual clarification than as a mechanism for developing independent analytical reasoning and representation.

These results reinforce the view that mathematical literacy consists of several interconnected but distinct competencies. Although TPS promotes interaction and conceptual exchange, additional instructional activities may be required to develop analysis and representation. These activities may include explicit mathematical modelling, guided problem-solving, comparison of multiple representations, and repeated analytical exercises (Chen 2022; Rahmy et al. 2021). Combining TPS with such activities may support a more balanced development of mathematical literacy across its different dimensions (OECD 2022; Tabieh 2023).

The communication dimension showed a negligible positive effect size ($d = 0.190$). The experimental group obtained a slightly higher mean score than the control group, but the magnitude of the difference was limited. This result suggests that TPS provided some opportunities for students to communicate mathematical ideas, although the six-session intervention was not sufficient to produce a substantial practical improvement in this dimension.

Mathematical communication involves explaining reasoning clearly, describing solution procedures, interpreting mathematical information, and responding to alternative arguments during problem-solving (Emerson et al. 2023; Rahmy et al. 2021). TPS provides opportunities for students to express their thinking during paired discussion and classroom presentation. However, effective mathematical communication also requires explicit guidance in organising arguments, using appropriate mathematical language, and presenting evidence systematically (Tabieh 2023).

**Figure 5.** Students' activities during the Share stage

Figure 5 documents the implementation of the Share stage, during which students presented the results of their paired discussions, explained their solution strategies, and responded to questions from classmates and the teacher. The figure illustrates the communicative interaction incorporated into the final stage of TPS.

The interview findings indicated that students with higher mathematical literacy scores were generally more confident when explaining their reasoning and responding to questions. Students with moderate scores viewed classroom presentations as opportunities to verify their understanding and learn alternative solution strategies. Several students with lower scores reported that presenting their ideas increased their confidence, although they continued to experience difficulty expressing mathematical reasoning systematically. These findings indicate that the Share stage created meaningful opportunities for mathematical communication, but students' ability to benefit from these opportunities differed according to their initial level of mathematical literacy.

The limited duration of the intervention may explain the negligible effect observed in communication. Developing mathematical communication requires repeated opportunities to explain ideas, justify reasoning, respond to criticism, and participate in sustained mathematical discourse. Therefore, although TPS facilitated classroom interaction, a longer and more intensive implementation may be required to produce stronger improvements in students' mathematical communication skills (Emerson et al. 2023; Rahmy et al. 2021).

The findings demonstrate that TPS did not affect all dimensions of mathematical literacy equally. Its strongest practical advantage was observed in conceptual understanding, whereas its effects on analysis, representation, and communication were limited or favoured the control group. These results indicate that conceptual understanding, mathematical analysis, representation, and communication require different forms of instructional support. TPS may therefore be more appropriate as one component of a broader instructional approach rather than as a stand-alone strategy for developing all dimensions of mathematical literacy (Amador et al. 2025; Anggoro et al. 2019; Chen 2022; Nakypbek et al. 2025; OECD, 2022).

## CONCLUSION

The results showed no statistically significant difference in overall mathematical literacy between the experimental and control groups ($p = .312$). This finding indicates that, within the six-session intervention, the Think–Pair–Share (TPS) learning model did not produce a significant improvement in students' overall mathematical literacy compared with conventional instruction.

The effect-size analysis, however, revealed different patterns across the four dimensions of mathematical literacy. Understanding showed a large positive effect ($d = 1.256$), indicating a substantial practical advantage for the experimental group in conceptual understanding. Communication showed a negligible positive effect ($d = 0.190$), whereas analysis ($d = -0.233$) and representation ($d = -0.520$) showed small and moderate effects, respectively, in favour of the control group. These results indicate that TPS provided stronger support for conceptual understanding than for analysis, representation, and communication.

The stronger effect on understanding may be associated with the structured stages of TPS. During the Think stage, students independently examined problems and developed an initial understanding of the relevant mathematical concepts. During the Pair stage, they exchanged ideas and clarified misunderstandings through peer discussion. During the Share stage, they communicated and justified their solutions while receiving feedback from classmates and the teacher. Nevertheless, these activities appeared to provide less intensive support for mathematical modelling, symbolic representation, analytical reasoning, and sustained mathematical communication. Therefore, TPS may be more effective as part of a broader instructional approach than as a stand-alone model for developing all dimensions of mathematical literacy.

## RECOMMENDATION

Future studies should examine the implementation of TPS at different educational levels, including junior high school and university, to determine whether its effects vary according to students' cognitive development and prior mathematical knowledge. Further research should also use longer intervention periods and, where possible, include pretest and posttest measurements to provide stronger evidence of changes in students' mathematical literacy.

TPS may also be combined with instructional approaches that place greater emphasis on mathematical modelling, guided problem-solving, multiple representations, and extended mathematical discourse. Approaches such as Problem-Based Learning, Realistic Mathematics Education, or Discovery Learning may complement TPS by providing more structured opportunities to develop analysis, representation, and communication.

Further studies should also investigate the use of TPS across other areas of mathematics, such as algebra, geometry, statistics, and calculus. Such research would help determine whether the effectiveness of TPS depends on the characteristics, level of abstraction, and cognitive demands of the mathematical content.

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### AUTHOR CONTRIBUTION STATEMENT

| Name of Author | C | M | So | Va | Fo | I | R | D | O | E | Vi | Su | P | Fu |
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| Andrea Putri Sabbina | ✓ | ✓ | | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | | ✓ | |
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**CONFLICT OF INTEREST STATEMENT**
Authors state no conflict of interest.

**INFORMED CONSENT**
Permission to conduct this study, including interviews with selected students, was obtained from SMAN 6 Depok and the homeroom teachers prior to data collection. The students interviewed were informed of the purpose of this study, and their participation was voluntary.

**ETHICAL APPROVAL**
This study was conducted in accordance with educational research ethics standards. Permission to conduct this study was obtained from SMAN 6 Depok prior to data collection. The confidentiality and anonymity of all participants were maintained throughout the study.

**DATA AVAILABILITY**
Data supporting the findings of this study are available from the corresponding author, AF, upon reasonable request. The data are not publicly available because they contain information that could compromise the privacy of the study participants.

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