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The effect of project-based STAD cooperative learning on students' mathematical literacy viewed from learning independence in linear programming

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Abstract.
This study aims to determine the differences in mathematical literacy abilities between students at SMAN 17 Tebo taught using the Project-Based STAD Cooperative Learning Model and those taught using the conventional learning model, examine whether students with high learning independence taught using the Project-Based STAD Model have better mathematical literacy abilities than students with low learning independence taught using the conventional model, and identify the interaction between the Project-Based STAD Model and learning independence on students' mathematical literacy abilities. This research employs a quasi-experimental design with a population of 112 eleventh-grade students at SMAN 17 Tebo, with the sample randomly selected from two classes. The research instruments include a mathematical literacy test, a learning independence questionnaire, and an observation sheet on the implementation of the learning model. Data were collected through essay tests and analyzed using two-way ANOVA. The results indicate that the Project-Based STAD Cooperative Learning Model significantly improves students' mathematical literacy abilities compared to the conventional learning model, learning independence influences mathematical literacy, with students who have high learning independence performing better, and there is an interaction between the Project-Based STAD Model and learning independence in enhancing students' mathematical literacy abilities.

Keywords:
Project based STAD; mathematical literacy skills; learning independence; linear program

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INTRODUCTION

Mathematics is a fundamental discipline that not only supports the development of science and technology but also cultivates students' critical, logical, and systematic thinking skills (NCTM, 2000; Kilpatrick, Swafford, & Findell, 2001). In the formal education context, the role of teaching is not merely to transmit knowledge but to foster students' understanding of concepts in a meaningful way that promotes independent, creative, and logical thinking. These cognitive processes are crucial for developing students' mathematical literacy, which is increasingly recognized as an essential competency in facing real-world problems (OECD, 2013).

Mathematical literacy, as defined by the Programme for International Student Assessment (PISA), is an individual's capacity to formulate, employ, and interpret mathematics in various contexts. This includes reasoning mathematically and using mathematical concepts, procedures, and tools to describe, explain, and predict phenomena (OECD, 2013). Individuals with strong

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mathematical literacy are able to apply their knowledge and skills effectively in solving contextual problems and making informed decisions (Kusuma, 2012). However, many students still perceive mathematics as a difficult subject, which hinders their ability to engage meaningfully with mathematical content and ultimately leads to low mathematical literacy.

In Indonesia, the importance of developing students' critical thinking skills through mathematics is emphasized in national education policies. According to the Ministry of National Education (2006), one of the core competencies for junior and senior high school graduates is the ability to process and present information using logical, critical, and creative thinking. Furthermore, Law No. 20 of 2003 concerning the National Education System mandates the inclusion of mathematics in the core curriculum, underscoring its role in equipping students with essential life skills.

Empirical evidence also supports the cognitive benefits of learning mathematics. Research by the National Academy of Sciences indicates that mathematical training enhances activity in the prefrontal cortex—an area associated with high-level cognitive functions such as logical reasoning, problem-solving, and decision-making (Ansari, 2008; Runisah et al., 2021). These findings affirm that learning mathematics contributes to a more structured, analytical, and efficient way of thinking, which is vital in an era characterized by complex global challenges.

Despite these recognized benefits, students' performance in mathematical literacy remains suboptimal. Numerous national and international studies consistently reveal that the mathematical literacy skills of Indonesian students remain at a low level. The Programme for International Student Assessment (PISA) 2018 results ranked Indonesia 73rd out of 79 participating countries in mathematics, with over 70% of Indonesian students performing below the basic proficiency level (OECD, 2019). This means most students struggle to interpret and solve even routine problems embedded in real-life contexts. More recent data from PISA 2022 show a persistent trend, where Indonesian students again performed significantly below the OECD average, particularly in tasks requiring reasoning, modeling, and the application of mathematical knowledge in unfamiliar situations (OECD, 2023). This situation is further corroborated by national assessments. For example, the Indonesian National Assessment (Asesmen Nasional) in 2021 indicated that only around 30% of students demonstrated adequate proficiency in numeracy tasks that involve problem-solving and logical reasoning (Kemdikbudristek, 2022). These findings highlight a systemic gap between what is taught in classrooms and the development of higher-order thinking skills that underpin mathematical literacy. Consequently, this raises concerns about the relevance and effectiveness of current pedagogical approaches in fostering students' ability to apply mathematics meaningfully in their daily lives.

At the local level, observations and formative assessments conducted in class X of SMA Negeri 17 Tebo during the 2020/2021 academic year revealed that a significant portion of students encountered difficulties in interpreting contextual problems, applying mathematical concepts to solve open-ended problems, and communicating the logical and systematic reasons for their solutions. This indicates that students' mathematical literacy is still inadequate and has not been adequately developed.

This low level of mathematical literacy is closely associated with the predominance of conventional learning approaches, which emphasize teacher-centered instruction and minimize student involvement in collaborative and contextual activities. Such an approach is less effective in fostering critical thinking skills, reflective abilities, and the ability to relate mathematics to real-life situations that are pertinent to students' daily lives. Consequently, it is imperative to introduce innovative learning models that effectively integrate collaborative activities, contextual problem-solving, and active student engagement.

One promising approach to address the gap in students' mathematical literacy is the implementation of cooperative learning models, particularly the Student Teams Achievement Division (STAD) model. STAD, developed by Robert E. Slavin at Johns Hopkins University, is designed to foster collaboration and mutual responsibility among students in mastering academic content (Slavin, 1995; Anggraeni et al., 2020). The model involves structured stages, including team formation, group work, individual assessments, and group recognition, all aimed at encouraging active participation and peer support.

Empirical studies have shown that STAD can significantly enhance students' learning outcomes, motivation, and interpersonal skills. For instance, a quasi-experimental study by Arifah et al. (2025) and Luthfi and Murtiyasa (2024) found that students taught using the STAD model demonstrated higher mathematical problem-solving abilities and increased engagement compared to those in conventional classrooms. Similarly, research conducted by Roka and Khatri (2024) and Wibowo et al. (2021) revealed that the implementation of STAD improved students' mathematical reasoning and communication skills by promoting peer interaction and reflective thinking. These findings are aligned with Slavin's (1995) assertion that STAD encourages students to take ownership of both individual and group success, which fosters a supportive learning environment and enhances conceptual understanding. Moreover, the model has proven to be adaptable across different academic levels and subject areas, making it a versatile strategy in promoting both academic achievement and collaborative competencies.

To further enhance students' critical thinking and problem-solving abilities, STAD can be effectively integrated with Project-Based Learning (PjBL). This combination leverages the strengths of cooperative learning and contextualized problem solving, encouraging students to engage in meaningful, real-world tasks that require analysis, reflection, and collaborative decision-making (Bell, 2010; Thomas, 2000). In this integrated model, students not only work together to understand mathematical concepts but also apply them in designing and presenting real-life projects, thus deepening their mathematical understanding and literacy.

Empirical evidence supports the effectiveness of integrating cooperative learning with project-based approaches. A study by Sulistiyani and Pratama (2024) demonstrated that students who participated in learning using a hybrid STAD–PBL model showed significant improvement in mathematical communication and conceptual understanding compared to those in traditional learning environments. Furthermore, research by Amidi et al. (2024) and Holmes and Hwang (2016) found that the integration of PjBL not only increased students' mathematical literacy scores but also fostered greater student engagement and confidence in expressing ideas. The contextual nature of PjBL provides authentic learning experiences, while the structured cooperation in STAD ensures that all students are actively involved and accountable for both their own learning and their group's success.

This integrative approach supports the development of higher-order thinking skills by placing students in situations where they must apply mathematical reasoning, evaluate alternatives, and justify their choices—skills that are essential for mathematical literacy. Consequently, the integration of STAD and PjBL creates a dynamic, student-centered learning environment that bridges the gap between conceptual mathematics and real-world application, aligning well with the goals of modern mathematics education.

Although previous studies have demonstrated the efficacy of the STAD cooperative learning model in enhancing student learning outcomes and engagement (Slavin, 1995; Anggraeni et al., 2020), the majority of these studies have concentrated solely on cognitive aspects, such as concept mastery and academic achievement, without explicitly examining its contribution to the development of mathematical literacy in the context of meaningful learning. Conversely, the Project-Based Learning (PjBL) approach has garnered significant attention for its ability to enhance critical thinking and problem-solving skills (Thomas, 2000; Bell, 2010). However, its integrated application with the STAD model in mathematics subjects remains relatively limited, particularly in the context of secondary school education in Indonesia.

Furthermore, studies pertaining to the combined implementation of STAD and PjBL in strengthening mathematical literacy among high school students are scarce, especially in schools with diverse academic backgrounds, such as SMA Negeri 17 Tebo. Consequently, there is a dearth of empirical evidence that elucidates the substantial positive impact of the collaboration between these two approaches on the enhancement of students' mathematical literacy skills within the framework of collaborative and contextual mathematics learning. Given these identified gaps, this study seeks to investigate the impact of implementing the STAD type project-based cooperative learning model on the mathematical literacy skills of students enrolled at SMA Negeri 17 Tebo.

METHOD

This study employed a quasi-experimental design with the Randomized Posttest-Only Control Group Design type, which is considered one of the most robust designs in experimental educational research (Creswell, 2012). This design allows researchers to assess the effect of an intervention by comparing outcomes between an experimental group and a control group, both of which are formed through random assignment. Unlike pretest-posttest designs, this model omits the pretest to eliminate testing effects that might influence the posttest results, thereby enhancing the internal validity of the study.

In the context of this research, students were randomly assigned to two groups. The experimental group received instruction using the Project-Based STAD Cooperative Learning model, while the control group received instruction through conventional teaching methods. After the instructional period, both groups were given the same posttest to assess differences in students' mathematical literacy outcomes. The structure of this experimental design is illustrated in Table 1, which outlines the treatment and posttest procedures for each group.

Table 1. Research design

Class	Treatment	Posttest
E_1	X_1	T_{E1}
C_2	X_2	T_{C2}

E_1 = experimental group given STAD type project-based cooperative learning treatment
C_2 = control group given conventional learning treatment
T_{E1} = posttest of experimental group
T_{E2} = posttest of control group
X_1 = cooperative learning process of STAD type based on project
X_2 = conventional learning process

The population used was 43 students of class XI IPS SMA Negeri 17 Tebo in the 2021/2022 academic year. The class was taken by sampling with the Simple Random Sampling technique, namely that each member of the population has an equal opportunity to be selected as a sample member. The simple random sampling technique is said to be simple because the sampling of sample members from the population is carried out randomly without considering the strata in the population, with the condition that the population members must be homogeneous (Elfil & Negida, 2017).

In the study, the influencing variable or independent variable is the STAD-type project-based cooperative learning model, while the influenced variable or dependent variable is students' mathematical literacy skills. In this study, one class was given treatment with the STAD-type project-based cooperative learning model called the experimental class and one other class received conventional learning treatment which is often used by researchers in this case called the control class.

The instruments used were the final test and the student learning independence questionnaire. The main instrument in this study was a mathematical literacy test, which was used to measure the increase in students' mathematical literacy skills after the implementation of the learning model. Mathematical literacy in this study refers to the definition of the Program for International Student Assessment (PISA), namely the ability of individuals to formulate, use, and interpret mathematics in various real-life contexts. The mathematical literacy test used was in the form of contextual essay questions, which were arranged based on three main aspects, namely:

(1) mathematical content (quantity, change and relationships, space and shape, uncertainty and data), (2) mathematical processes (formulating, employing, and interpreting mathematics), and (3) question context (personal, societal, occupational, and scientific). The questions were developed by adjusting the applicable curriculum and considering the cognitive level according to the PISA taxonomy. To ensure the validity of the content, this instrument was validated by material experts and educational evaluation experts. The validation process was carried out by assessing the suitability between the mathematical literacy indicators and the questions developed. Suggestions and input from the validator were used as a basis for revising and refining the questions. Furthermore, a trial of the instrument was conducted on students outside the research sample. The trial results were analyzed to measure reliability, level of question difficulty, and discriminatory power.

The data analysis in this study employed the Two-Way Analysis of Variance (ANOVA) technique, with the assistance of the SPSS statistical software. This method was selected to examine the effects of two independent variables—namely, the type of learning model and students' learning independence—on the dependent variable, which is students' mathematical literacy skills. Two-Way ANOVA is particularly appropriate for this research design as it enables simultaneous testing of the main effects of both independent variables as well as their interaction effect. In other words, this analysis not only determines whether the learning model and learning independence individually influence mathematical literacy, but also whether there is a significant interaction between the two factors in shaping students' outcomes.

RESULTS AND DISCUSSION

Mathematical Literacy Ability Test

In the second phase of the research, both the experimental and control groups were administered a posttest to assess their mathematical literacy skills. The purpose of this posttest was to evaluate the impact of the treatment (i.e., the teaching methods applied to each group) on students' mathematical literacy. The posttest results were then analyzed to compare the mathematical literacy outcomes between the two groups. The details of the posttest implementation and the respective scores for both groups are presented in Table 2.

Table 2. Results of the sample class' mathematical literacy assessment

Class	N	Mean	X_{max}	X_{min}
Experiment	22	78.21	93.75	56.25
Control	21	68.65	87.50	50.00

Based on the data presented in Table 2, it is evident that the experimental class outperformed the control class in the mathematical literacy posttest. The average score for the experimental class was 78.21, while the control class had a lower average score of 68.65. This difference indicates a significant disparity in mathematical literacy between the two groups, with the experimental class demonstrating superior performance. Furthermore, the highest score achieved in the experimental class was 93.75, which exceeds the highest score in the control class (87.50). This suggests that some students in the experimental class exhibited exceptional mathematical literacy skills, outperforming their peers in the control class.

However, it is important to note that, despite the experimental class achieving the highest score, the lowest score in the experimental class (56.25) was also higher than the lowest score in the control class (50.00). This variation indicates that, while there is a general trend of higher performance in the experimental class, both classes exhibit a range of outcomes, suggesting that individual differences in learning achievements persist within each group.

The following presents the average scores of students' mathematical literacy abilities based on the specific indicators of mathematical literacy, as detailed in Table 3. These indicators provide a comprehensive measure of students' proficiency in various aspects of mathematical literacy, which are crucial for understanding their overall performance.

Table 3. Presents the average scores of students' mathematical literacy abilities

Mathematical Literacy Indicator	Experimental Class	Control Class
Formulating problems from real-life situations	78.50	69.25
Using mathematical concepts and procedures	80.10	70.60
Interpreting and evaluating results in real-life contexts	77.35	66.85
Communicating thoughts and arguments logically	76.90	68.90
Average Total	78.21	68.65

A more detailed examination of the mathematical literacy indicators reveals a consistent trend: the experimental class outperformed the control class across all indicators. As presented in Table 3, the highest score in the experimental class was observed in the indicator *Using mathematical concepts and procedures* (M = 80.10), while the corresponding score in the control class was notably lower (M = 70.60). Similarly, for the indicator *Formulating problems from real-life situations*, students in the experimental class achieved an average score of 78.50, compared to 69.25 in the control class. Other indicators, such as *Interpreting and evaluating results in real-life contexts* and *Communicating thoughts and arguments logically*, also showed substantial differences in favor of the experimental class. These consistent gaps suggest that the project-based STAD cooperative learning model implemented in the experimental class contributed positively to enhancing students' mathematical literacy skills. Overall, the data indicates that students exposed to this learning model demonstrated higher levels of understanding and application of mathematical concepts, which can be attributed to the collaborative and contextual learning environment fostered by the intervention.

Student Learning Independence Questionnaire

The results of the student learning independence questionnaire for both the experimental and control classes are presented in Table 4.

Table 4. Descriptive statistics of students' learning independence scores in the sample classes

Class	N	Mean	X_{max}	X_{min}
Exsperiment	22	120.2	136	107
Control	21	115	131	101

Based on the data presented in Table 4, it is evident that students in the experimental class demonstrated a higher level of learning independence compared to their peers in the control class. The average score of the experimental group was 120.2, while the control group recorded a lower mean of 115.0. This difference suggests that the learning model implemented in the experimental class had a positive influence on fostering students' autonomy in the learning process.

Furthermore, the experimental class also achieved a higher maximum score of 136, compared to 131 in the control class. This finding indicates that some students in the experimental group attained a particularly high level of learning independence. Such outcomes are likely attributable to the learning approach applied—namely, the project-based STAD cooperative learning model—which emphasizes student engagement, active participation, critical thinking, and individual accountability in group-based tasks.

In addition, the lowest score in the experimental class was 107, which exceeded the minimum score in the control class (101). This difference implies that students in the experimental class not only achieved higher top scores but also exhibited greater consistency in learning independence, with fewer students falling into the low-independence category. This consistency reflects the supportive and collaborative nature of the instructional approach, which appears to have provided all students with opportunities to enhance their self-directed learning capabilities.

Overall, these results suggest that the intervention implemented in the experimental class was effective in enhancing various aspects of students' learning independence, including the highest achievements, overall average performance, and the minimum levels observed. Learning independence is a critical competency in the context of 21st-century education, as students who exhibit strong independent learning behaviors tend to be more self-disciplined, proactive, and capable of managing their own learning processes—attributes essential for academic success and lifelong learning.

Hypothesis Test Results

Table 5 presents the results of the hypothesis testing using the two-way Analysis of Variance (ANOVA) technique, specifically a univariate ANOVA, conducted with the aid of SPSS version 10 for Windows. This analysis was performed to examine the main effects of the learning model and student learning independence, as well as their interaction, on students' mathematical literacy skills.

Table 5. Test of between-subjects effects on the dependent variable: Mathematical literacy

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6405.904	3	2135.301	18.749	.000
Intercept	120530.114	1	120530.114	1058.288	.000
Learning Model	537.771	1	537.771	4.722	.036
Learning Independence	5646.780	1	5646.780	49.580	.000
Model × Independence Interaction	1.285	1	1.285	0.011	.916
Error	4441.771	39	113.892	–	–
Total	191225.000	43	–	–	–
Corrected Total	10847.674	42	–	–	–

The results indicate that the learning model significantly influences students' mathematical literacy, as shown by an F-value of 4.722 with a p-value of .036, which is less than the standard significance level of 0.05. This suggests that the learning strategy used (project-based STAD vs. conventional methods) contributes meaningfully to differences in mathematical literacy outcomes. Similarly, learning independence shows a strong and statistically significant effect, with an F-value of 49.580 and a p-value of .000. This result highlights that students with higher learning independence tend to perform better in mathematical literacy, regardless of the instructional model applied.

However, the interaction effect between the learning model and learning independence is not significant, with an F-value of 0.011 and a p-value of .916. This indicates that the influence of the learning model on mathematical literacy does not depend on students' level of learning independence, and vice versa. In summary, both the learning model and students' learning independence independently contribute to enhancing mathematical literacy skills. Yet, their interaction does not produce a synergistic effect, suggesting that these factors operate independently in affecting student outcomes.

The results of the study showed that students in the experimental class had higher mathematical literacy skills compared to students in the control class. This can be seen from the average score, the highest score, and the lowest score which were all superior in the experimental class. This finding shows that the learning model applied in the experimental class, such as the STAD type cooperative learning approach collaborated with project-based learning, provides a positive contribution to improving students' mathematical literacy.

Project-based learning encourages students to be actively involved in solving contextual problems independently or in groups, thus training critical thinking skills, reasoning, and presenting solutions systematically—skills that are included in the mathematical literacy indicators according to the OECD (2019). In addition, group work in the STAD model allows for meaningful social interaction and discussion, which contributes to a deeper understanding of concepts.

In addition to improving literacy skills, the results of the questionnaire showed that students' learning independence also increased significantly in the experimental class. The learning model that emphasizes students' active involvement in planning, implementing, and evaluating projects allows them to develop a sense of responsibility for their own learning process. This finding is in line with Zimmerman's (2002) view, which states that learning independence includes students' ability to motivate themselves, manage time, and evaluate learning outcomes independently.

The relationship between improving mathematical literacy skills and learning independence shows that the two variables support each other. Independent students tend to be more skilled in managing problem-solving strategies, understanding mathematical concepts in real contexts, and being able to make logical decisions based on data analysis. This reinforces the importance of implementing a learning approach that is not only oriented towards cognitive outcomes, but also towards developing students' character and learning attitudes.

Overall, the results of this study support the findings of several previous studies (for example by NCTM, 2000; Suryadi, 2012) which state that contextual, collaborative, and project-based learning can improve students' mathematical literacy and 21st century skills, including learning independence.

Based on the results of data analysis using Two-Way ANOVA, it was obtained that there was a significant difference in students' mathematical literacy skills between the experimental class and the control class. This shows that the learning model applied in the experimental class, namely a combination of Student Teams Achievement Division (STAD) and Project-Based Learning, has a significant influence on improving students' mathematical literacy skills.

This significance can be seen from the p-value < 0.05, which means that the null hypothesis (H_0), namely "there is no significant difference between the experimental and control classes", is rejected. Thus, the learning approach involving teamwork, exploration of real problems, and final products in the form of projects has been proven to be able to train students' critical thinking and reasoning skills, in accordance with the mathematical literacy indicators of the PISA framework (OECD, 2019).

In addition, the test results also show an interaction between the learning model and learning independence on mathematical literacy skills. This indicates that the influence of the learning model does not apply generally to all students, but is also influenced by the level of learning independence of each student. Students with a high level of independence tend to be better able to utilize innovative learning approaches, because they have greater initiative, responsibility, and motivation to learn.

This finding strengthens Zimmerman's (2002) theory that learning independence is an important factor in learning success, especially in the context of active learning. The STAD model allows students to help each other understand the material, while the project approach requires an active role and strong self-regulation-two things that are only optimal if students have good learning independence.

Thus, collaborative and project-based learning models that are applied appropriately not only have a direct impact on mathematics learning outcomes but also provide space for strengthening character, such as independence and cooperation. These results are also in line with the findings of previous studies (Putri et al., 2024; Suryadi, 2012) which state that project-based learning models are effective in improving both cognitive and non-cognitive abilities of students.

CONCLUSIONS

Based on the research data, it can be concluded that the use of the project-based STAD learning model has a significant impact on students' mathematical literacy skills compared to the conventional learning model. Students who were taught using the project-based STAD model demonstrated better mathematical literacy skills than those who followed traditional learning methods. Additionally, differences in learning independence also influenced students' mathematical literacy abilities. Students with high learning independence showed better mathematical literacy skills than those with low learning independence. However, the study found no significant interaction between the application of the project-based STAD learning model and students' level of learning independence in determining mathematical literacy skills. This indicates that while both factors independently contribute to students' mathematical literacy, their combined effect does not result in a significant interaction.

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