

The effect of team assisted individualization on students' mathematical problem solving ability

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Abstract

Mathematical problem-solving ability is a critical competency in 21st-century education, yet many students at the junior secondary level continue to struggle with solving non-routine problems and applying systematic strategies. This study aims to examine the effect of the Team Assisted Individualization (TAI) cooperative learning model on students' mathematical problem-solving ability in a madrasah context, which remains underexplored in previous research. A quantitative approach with a quasi-experimental, non-equivalent control-group pretest-posttest design was employed. The sample consisted of 65 eighth-grade students divided into an experimental group ($n=32$) taught using the TAI model and a control group ($n=33$) taught using conventional instruction. Data were collected via a validated essay test based on Polya's four problem-solving indicators and analyzed using an independent-samples t-test, with effect size calculated using Cohen's d . The findings revealed that the TAI model significantly improved students' problem-solving skills ($p < 0.001$), with the experimental group substantially outperforming the control group and a very large effect size (Cohen's $d = 1.94$). These results position TAI as an effective instructional alternative for madrasah contexts, addressing the research gap in the implementation of cooperative learning in such settings. The study contributes practical insights for mathematics teachers seeking to enhance higher-order thinking skills and offers a foundation for further research on TAI's long-term impacts across diverse educational environments.

Keywords: cooperative learning; mathematical problem-solving ability; mathematics learning; madrasah; Team Assisted Individualization (TAI)

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INTRODUCTION

Mathematics plays a fundamental role in education, not only in developing students' ability to perform calculations but also in fostering logical, analytical, and systematic thinking skills (Abdurrahim et al., 2020). Mathematics education, with its focus on logical reasoning and systematic problem-solving, is well-positioned to nurture critical thinking skills (Duma et al., 2024). These competencies are essential for students to respond to increasingly complex challenges in the twenty-first century. Critical thinking skills cultivated through mathematics education are highly relevant for addressing the complex, data-driven challenges of Industry 5.0 (Duma et al., 2024). Through mathematics

learning, students are expected to develop the capacity to analyze situations, make decisions, and solve problems encountered in both academic and real-life contexts. Therefore, mathematical problem-solving ability is considered a key objective of mathematics education.

At the national level, various studies indicate that students' mathematical problem-solving ability at the secondary school level remains relatively low (Azhar et al., 2021). This condition is commonly characterized by students' difficulties in interpreting word problems, determining relevant information, and selecting appropriate solution strategies (Astuti & Syamsuri, 2022). As a result, learning outcomes related to higher-order thinking skills have not been optimally achieved. Meta-analyses have confirmed that cooperative learning methods consistently produce positive effects on mathematics achievement across different educational levels (Slavin, 2015).

Similar conditions were observed at MTs Ma'arif NU 07 Purbolinggo. Based on preliminary observations and interviews with mathematics teachers, students experienced difficulties, particularly in understanding problem situations and planning solution strategies (Rahayu, 2020). In addition, psychological factors such as low self-confidence, anxiety toward word problems, and limited learning motivation further hinder students' ability to engage in logical and analytical thinking processes. Factors like student motivation, teacher competence, and the availability of learning technology can influence the effectiveness of mathematics education in fostering critical thinking (Hattie, 2015). One contributing factor is the predominance of teacher-centered learning practices, which tend to emphasize procedural skills rather than conceptual understanding (Bungin, 2019). Research indicates that teaching methods emphasizing real-world applications and collaborative problem-solving, such as project-based learning, are more effective at developing critical thinking than traditional, lecture-based approaches (Duma et al., 2024). Therefore, it is necessary to implement learning models that actively involve students and accommodate differences in their abilities.

Cooperative learning is considered an effective alternative to address these challenges. Johnson and Johnson (2018) emphasized that cooperative learning provides the foundation for active learning, where students work together to achieve shared goals, promoting higher achievement and more positive relationships. One cooperative learning model that integrates individual learning and group collaboration is Team Assisted

Individualization (Tukan et al., 2023). This model allows students to learn independently at their own pace while also working collaboratively in heterogeneous groups. Through this approach, students who have a better understanding of the material can assist peers who experience difficulties, while individual accountability remains emphasized.

Several previous studies have reported the positive impact of the TAI model on students' mathematical abilities (Tinungki et al., 2022). Research conducted by (Rifa'i et al., 2023) showed that the Problem Based Learning (PBL) model was effective in improving mathematical understanding of MTs students, with the experimental group scoring higher than the control group. Kristiarini et al. (2022) developed learning tools using a scientific approach with the PBL strategy to solve multiplication problems in elementary school, resulting in a valid Learning Implementation Plan. Dari, Aima & Mardiyah (2022) found that the PBL model using online methods had a significant effect on students' mathematics learning outcomes. Lazonder and Harmsen (2016) conducted a meta-analysis confirming that guided inquiry-based learning, which shares characteristics with TAI's structured team study phase, is particularly effective for developing problem-solving skills. However, most existing studies have been conducted in general school settings, and research on the application of the TAI model in madrasah environments remains limited (Widodo et al., 2023). Madrasahs have unique educational characteristics and student backgrounds that may influence the effectiveness of instructional models. This gap underscores the need for empirical investigation into TAI's effectiveness within madrasah contexts.

The novelty of this study lies in its focus on the madrasah context, which has been largely overlooked in previous TAI research. By providing empirical evidence from MTs Ma'arif NU 07 Purbolinggo, this study contributes new insights into how TAI can be adapted to improve mathematical problem-solving skills in an environment with distinct pedagogical and cultural characteristics. Furthermore, this study incorporates effect size analysis using Cohen's d , providing a quantitative measure of practical significance that complements statistical significance testing, a practice recommended by Hattie (2015) for evaluating educational interventions. Based on these considerations, this study aims to examine the effect of the cooperative learning model Team Assisted Individualization on students' mathematical problem-solving ability.

METHODS

This study employed a quantitative research approach using a quasi-experimental method. The research design applied was the Non-Equivalent Control Group Pretest-Posttest Design. The pretest was administered to both groups to control for initial differences in students' mathematical problem-solving abilities. This step ensured that any posttest differences could be attributed to the treatment (TAI model) with greater confidence rather than to pre-existing disparities. The design was selected because the researcher did not randomly assign individual students to groups but used intact classes that already existed at the research site (Hastjarjo, 2019). The use of pretest and posttest, along with a control group, strengthens the internal validity of the findings despite the absence of full randomization.

The research was conducted at MTs Ma'arif NU 07 Purbolinggo during the 2025/2026 academic year. The population consisted of all eighth-grade students. Using purposive sampling based on teacher recommendations and class characteristics, Class VIII.C (N=33) was selected as the control group, and Class VIII.B (N=32) as the experimental group, for a total of 65 students (Asrulla et al., 2023).

The treatment for the experimental group followed the seven phases of the TAI model: (1) Placement Test, (2) Team Formation, (3) Teaching Group, (4) Team Study, (5) Fact Test, (6) Scoring and Team Recognition, and (7) Whole-Class Teaching as adapted from Rifa'i et al. (2023) and Kristiarini et al. (2022). The control group received conventional instruction, primarily through lectures and question-and-answer sessions. To control external variables, the same mathematics teacher taught both classes, used the same learning materials and time allocation, and took the same pretest and posttest under identical conditions.

Data were collected using a mathematical problem-solving ability test comprising 10 essay questions, developed based on Polya's four indicators: understanding the problem, devising a plan, carrying out the plan, and looking back (Astutiani et al., 2019). The instrument was administered as both a pretest and a posttest to both groups. Before use, the instrument underwent empirical testing. Validity was assessed using the Pearson Product-Moment correlation, and reliability was estimated using Cronbach's Alpha. The results confirmed that all 10 pretest items were valid ($r\text{-count} > r\text{-table} = 0.361$), and the instrument demonstrated very high reliability ($\alpha = 0.996$). For the posttest, 7 out of 10

items met the validity criterion, and the overall reliability was also very high ($\alpha = 0.9999$). Data were analyzed using descriptive statistics (mean, standard deviation) and inferential statistics. After confirming normality (Liliefors test) and homogeneity (Fisher test), the independent sample t-test was used to test the hypothesis at a significance level of 0.05, with effect size calculated using Cohen's d.

RESULTS AND DISCUSSION

This section presents the research results and their interpretation, based on empirical data from the posttest analysis. The discussion is integrated into each result to explain the findings in relation to the research objectives and relevant previous studies.

Result 1: Initial Ability (Pretest)

Before the treatment was implemented, a pretest was administered to both groups to assess their initial mathematical problem-solving abilities. The descriptive statistics for the pretest scores are presented in Table 1.

Table 1. Descriptive Statistics of Pretest Scores

Group	N	Mean	Standard Deviation
Control (Conventional)	33	19.39	7.57
Experimental (TAI)	32	21.25	7.73

As shown in Table 1, the mean pretest score of the experimental group (21.25) was slightly higher than that of the control group (19.39). An independent sample t-test confirmed that this difference was not statistically significant ($t = -0.98, p > 0.05$). This indicates that both groups had relatively equivalent mathematical problem-solving abilities before the intervention, allowing for a fair comparison of the treatment's effect.

Result 2: Normality of Posttest Data

The normality test was conducted to determine whether the posttest data met the assumption of normality, a prerequisite for parametric analysis. The Liliefors test was applied to the posttest scores of the experimental class, and the results are presented in Table 2.

Table 2. Results of Posttest Normality Test

Group	Number of Students (n)	Mean (\bar{x})	Standard Deviation (SD)	$L_{calculated}$	$L_{table} (\alpha = 0.05)$
Control Class	33	21.67	9.24	0.153	0.154
Experimental Class	32	72.97	12.30	0.090	0.156

Based on Table 2, the $L_{calculated}$ values of both the control and experimental classes are lower than their respective L_{table} values. This result indicates that the posttest data from both groups are normally distributed. Therefore, the data fulfill the normality assumption required for further parametric analysis.

Result 3: Homogeneity of Posttest Data

After the normality assumption was satisfied, a homogeneity test was conducted to determine whether the variances of the control and experimental classes were equal. The Fisher test was applied, and the results are shown in Table 3.

Table 3. Results of Posttest Homogeneity Test

Group	Number of Students (n)	Mean (\bar{x})	Variance (S^2)	$F_{calculated}$	$F_{table} (\alpha = 0.05)$
Control Class	33	21.67	86.42	1.773	1.816
Experimental Class	32	72.97	151.39		

Based on Table 3, the $L_{calculated}$ values of both the control and experimental classes are lower than their respective L_{table} values. This result indicates that the posttest data from both groups are normally distributed. Therefore, the data fulfill the normality assumption required for further parametric analysis.

Result 4: Effect of Team Assisted Individualization on Mathematical Problem-Solving Ability

The independent sample t-test was used to compare the posttest scores of the control and experimental groups. The results are presented in Table 4.

Table 4. Results of Independent Sample t-Test and Effect Size

Component	Control Group	Experimental Group
N	33	32
Mean Posttest Score	21.67	66.25
Standard Deviation (SD)	9.24	12.30
t _{value} (t _{count})	16.55	
Degrees of Freedom (df)	63	
Significance (p)	< 0.05	
Cohen's d Effect Size	3.97	

The independent sample t-test revealed a statistically significant difference in posttest scores between the experimental and control groups ($t_{count} = 16.55 > t_{table} = 1.998$, $p < 0.05$). The mean posttest score of the experimental group ($M=66.25$, $SD=12.30$) was substantially higher than that of the control group ($M=21.67$, $SD=9.24$). To determine the magnitude of this effect, Cohen's d effect size was calculated, yielding $d = 3.97$. According to Cohen's conventions, an effect size of 0.2 is considered small, 0.5 medium, and 0.8 large. Therefore, $d = 3.97$ is interpreted as a very large effect. This finding aligns with meta-analytic results reported by Capar and Tarim (2015), who found that cooperative learning methods have a moderate to large effect on mathematics achievement across multiple studies.

These findings demonstrate that the Team Assisted Individualization (TAI) learning model has a significant positive effect on students' mathematical problem-solving ability. The very large effect size ($d = 3.97$) indicates that the TAI model not only produces a statistically significant improvement but also a practically meaningful one, far exceeding the threshold for a large effect. Slavin (2015) emphasized that cooperative learning methods like TAI are particularly effective because they combine individual accountability with group rewards, creating positive interdependence among students.

Discussion

The results of this study confirm that the TAI model is significantly more effective than conventional instruction in enhancing students' mathematical problem-solving skills. The superiority of the TAI model can be explained through the lens of constructivist learning theories, particularly those of Vygotsky and Piaget.

From Vygotsky's perspective, the TAI model effectively utilizes the Zone of Proximal Development (ZPD). In heterogeneous TAI groups, students with higher abilities act as "more knowledgeable others," providing scaffolding and assistance to peers who are struggling within their ZPD. Through collaborative discussion and peer tutoring, students can solve problems they could not solve independently, leading to cognitive growth. This social interaction is a core component of the TAI model, as students are required to explain concepts, justify strategies, and critique solutions within their teams. Johnson and Johnson (2018) argued that such positive interdependence is the heart of cooperative learning, distinguishing it from simple group work.

From Piaget's perspective, TAI supports cognitive constructivism. The individual fact test phase requires students to independently apply their knowledge, promoting accommodation and assimilation of new information. The team study phase creates cognitive conflict when students encounter different solution strategies or misconceptions, forcing them to re-evaluate and restructure their understanding. This active, hands-on engagement with problems aligns with Piaget's view that learning is an active process of constructing knowledge rather than a passive reception of it. Zakaria and Iksan (2017) found that cooperative learning approaches significantly improved students' mathematics achievement compared to traditional instruction, supporting the constructivist foundation of TAI.

The TAI model's effectiveness in this study aligns with broader findings in mathematics education research. Teaching methods that emphasize real-world applications and collaborative problem-solving have been shown to be more effective at developing critical thinking than traditional, lecture-based approaches (Lazonder & Harmsen, 2016). Furthermore, critical thinking skills cultivated through mathematics education are highly relevant for addressing the complex, data-driven challenges of Industry 5.0 (Duma et al., 2024).

The findings of this study are consistent with and extend previous research on the TAI model. Rifa'i et al. (2023) found that the PBL model effectively improved mathematical understanding in MTs students, while Kristiarini et al. (2022) developed PBL-based learning tools for elementary mathematics. Dari, Aima & Mardiyah (2022) demonstrated that PBL using online methods positively affected learning outcomes. First, a comparison with Rifa'i et al. (2023) found that the PBL model significantly improved students' understanding of mathematical concepts. The present study similarly found that TAI was significantly more effective than conventional instruction. However, the current study yields a much larger effect size ($d=3.97$) and focuses specifically on problem-solving ability rather than general concept understanding. This difference may be attributed to the madrasah context, where the strong emphasis on collaboration and mutual assistance (gotong royong) may foster a more conducive environment for cooperative learning models such as TAI. Additionally, the present study used a more comprehensive measurement based on Polya's four indicators, potentially capturing a broader range of problem-solving skills.

Second, the comparison with Kristiarini et al. (2022) found that developing learning tools with a scientific approach using the PBL strategy produced a valid Learning Implementation Plan for elementary students. The present study confirms this finding at the junior secondary level. The similarity is the use of a developmental research approach. The key difference lies in the educational level and the addition of effect size analysis. While Kristiarini's study demonstrated the validity of the learning tools, the present study quantifies the magnitude of the effect ($d=3.97$), providing stronger evidence of TAI's practical significance, especially in a madrasah context.

Third, the comparison with Dari, Aima & Mardiyah (2022) found that PBL using online methods had a significant effect on mathematics learning outcomes, with the experimental group outperforming the control group. The present study confirms this finding at the junior secondary level. The similarity is the use of a quasi-experimental design and the focus on mathematics achievement. The difference is the educational level and the addition of effect size analysis. While Dari's study demonstrated effectiveness, the present study quantifies the magnitude of the effect ($d=3.97$), providing stronger evidence of TAI's practical significance, especially in a madrasah context.

Fourth, comparison with Tukan et al. (2023) on elementary school students showed that TAI significantly improved problem-solving skills. The present study confirms this finding at the junior secondary level. The similarity lies in the focus on problem-solving using Polya's indicators. The difference is the educational level and the addition of effect size analysis.

Fifth, the very large effect size found in this study ($d=3.97$) is consistent with meta-analytic findings. Capar and Tarim (2015) reported an overall effect size of $d=0.59$ for cooperative learning on mathematics achievement, while the present study's effect size is substantially larger, suggesting that TAI may be particularly effective in madrasah contexts. Hattie (2015) reported a cooperative learning effect size of $d=0.59$ which is considered above average, further supporting the effectiveness of cooperative approaches.

Overall, the very large effect size found in this study ($d = 3.97$) suggests that the TAI model is exceptionally effective in the madrasah environment, possibly more so than in general school settings reported in previous studies. This highlights the importance of considering contextual factors, such as school culture and student characteristics, when implementing instructional models. Several factors can influence the effectiveness of mathematics education in fostering critical thinking, including student motivation, teacher competence, and the availability of learning technology (Duma et al., 2024). In this study, these factors were partially controlled: the same teacher instructed both groups to ensure consistency in teacher competence, and both classes had access to the same basic learning technology.

In contrast, the conventional instruction in the control group emphasized teacher-centered lectures and routine individual exercises. This approach did not provide structured opportunities for peer scaffolding or collaborative problem-solving, limiting students' exposure to diverse strategies and critical dialogue. Consequently, their problem-solving skills remained low, as reflected in their posttest scores. Lazonder and Harmsen (2016) found that unguided instruction is less effective than guided approaches, which explains why the conventional group's performance remained low.

The practical implication is that teachers in madrasah settings can confidently adopt the TAI model to improve students' higher-order thinking skills. The structured phases of TAI, from team formation to individual fact tests, provide a clear framework for

implementation. Nevertheless, this study has limitations, including its relatively short intervention period and focus on a single school. Future research should explore the long-term effects of TAI and its application across different mathematical topics and grade levels, and investigate the specific factors within madrasah culture that may moderate its effectiveness. Overall, the results confirm that TAI is an effective instructional alternative for improving students' mathematical problem-solving ability in diverse educational contexts, particularly in *madrasah*.

CONCLUSION

This study concludes that the Team Assisted Individualization cooperative learning model has a significant positive effect on students' mathematical problem-solving ability in the *madrasah* context. The experimental group taught using TAI substantially outperformed the control group, with a very large effect size (Cohen's $d = 3.97$). These findings position TAI as a highly effective instructional alternative to conventional methods, addressing the research gap in the implementation of cooperative learning in madrasah settings.

Despite its limitations, including the relatively short intervention period (limited to one academic semester), the focus on a single madrasah institution (MTs Ma'arif NU 07 Purbolinggo), and the specific mathematical topic (linear equations), this study provides practical insights for mathematics teachers seeking to enhance higher-order thinking skills. Future research should explore the long-term effects of TAI across different mathematical topics, grade levels, and broader educational contexts to determine the generalizability of these findings.

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