

ENHANCING STUDENTS' SELF-CONFIDENCE IN MATHEMATICS THROUGH GEOGEBRA-ASSISTED TAPPS

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ABSTRACT

This study aimed to investigate the effectiveness of GeoGebra-assisted Thinking Aloud Pair Problem Solving (TAPPS) in improving students' self-confidence in mathematics learning. The study employed a quantitative approach using a quasi-experimental method with a non-equivalent control group design. The participants consisted of 70 eleventh-grade students from a public senior high school in Tangerang, Indonesia, selected through purposive sampling. The sample was divided into an experimental group and a control group, each consisting of 35 students. Data were collected using a self-confidence questionnaire comprising 30 statements based on four dimensions of self-confidence: belief in one's own abilities, positive thinking and action, optimism and perseverance, and adaptability and social interaction. The data were analyzed using descriptive statistics, normality and homogeneity tests, an independent samples t-test, and N-gain analysis. The results revealed that the experimental group demonstrated greater improvement in self-confidence than the control group. Although the post-scale comparison did not indicate a statistically significant difference between groups ($p = .060$), the N-gain analysis showed a significant difference in improvement ($p = .001$). These findings suggest that GeoGebra-assisted TAPPS contributes positively to the development of students' self-confidence and facilitates greater growth in confidence throughout the learning process. Therefore, the integration of collaborative problem-solving strategies and dynamic mathematical visualization can be considered a promising approach for promoting positive affective outcomes in mathematics learning.

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INTRODUCTION

Mathematics is an essential discipline that contributes to the development of logical reasoning, critical thinking, problem-solving skills, and decision-making abilities. In contemporary mathematics education, learning success is no longer measured solely through cognitive achievement but also through affective factors that influence students' engagement and learning experiences. One of the most important affective factors is self-confidence. Self-confidence refers to students' beliefs in their ability to understand mathematical concepts, solve problems, communicate ideas, and successfully complete learning tasks. Students who possess high self-confidence tend to participate actively in classroom activities, demonstrate persistence when facing difficulties, and express their mathematical thinking more openly. Conversely, students with low self-confidence often experience anxiety, avoid challenging tasks, and hesitate to engage in mathematical discussions (Bandura, 1997; Schunk & DiBenedetto, 2020).

The importance of self-confidence in mathematics learning has been widely recognized in educational research. According to the Programme for International Student Assessment (PISA), students' confidence in mathematics is positively associated with achievement, motivation, and learning engagement (OECD, 2023). Students who believe in their mathematical abilities are more likely to persevere when encountering complex problems and demonstrate higher academic performance. Consequently, fostering students' self-confidence has become an important objective in mathematics education, particularly in learning

environments that aim to promote active participation and meaningful understanding.

Despite its importance, low self-confidence remains a common issue among secondary school students. Several studies have reported that many students perceive mathematics as a difficult and intimidating subject, which negatively affects their confidence and willingness to participate in learning activities (Hendriana et al., 2017; Sari & Mulyono, 2021). Students with low self-confidence often doubt their abilities, fear making mistakes, and rely heavily on teacher guidance when solving mathematical problems. Such conditions may hinder not only students' affective development but also their academic achievement. Therefore, mathematics teachers need to implement instructional approaches that can simultaneously support cognitive understanding and affective growth.

One factor that may influence students' self-confidence is Prior Mathematical Ability (PMA). PMA refers to the mathematical knowledge and skills students possess before receiving new instruction. Students with strong prior mathematical ability generally exhibit greater confidence because they have sufficient conceptual foundations to understand new material and solve mathematical problems. In contrast, students with lower prior mathematical ability may experience difficulties in learning, which can reduce their confidence and participation in classroom activities (Ruiz-Primo, 2020). Consequently, examining instructional effectiveness across different PMA levels is important for understanding

whether a learning intervention benefits all students equally.

To enhance students' self-confidence, cooperative learning approaches have been increasingly implemented in mathematics classrooms. Cooperative learning encourages students to interact, exchange ideas, and support one another during learning activities. Such interactions provide opportunities for students to develop communication skills, receive constructive feedback, and build confidence in expressing mathematical ideas (Gillies, 2016; Johnson et al., 2018). One cooperative learning strategy that explicitly emphasizes verbal interaction is Thinking Aloud Pair Problem Solving (TAPPS). TAPPS requires students to work in pairs and alternate roles as problem solvers and listeners. The problem solver verbalizes every step of the reasoning process, while the listener monitors, questions, and provides feedback. Through this process, students become more aware of their thinking strategies and gain confidence in solving mathematical problems (Santos-Trigo & Camacho-Machin, 2019; Wolcott & Lobczowski, 2021).

In addition to cooperative learning, technology integration has become increasingly important in mathematics education. One of the most widely used technological tools is GeoGebra, a dynamic mathematics software that enables students to explore mathematical concepts through interactive visual representations. GeoGebra facilitates connections among graphical, numerical, and algebraic representations, allowing students to construct mathematical understanding more effectively. Previous studies have shown that GeoGebra positively influences students' mathematical achievement, conceptual understanding, motivation, and engagement in learning (Hohenwarter & Jones, 2018; Juandi, 2021). Furthermore, technology-supported learning environments have been reported to contribute positively to affective outcomes, including students' confidence and attitudes toward mathematics (Oktaviani et al., 2023).

Although numerous studies have investigated the effectiveness of TAPPS and GeoGebra separately, research examining

the integration of GeoGebra-assisted TAPPS remains limited. Existing studies predominantly focus on cognitive outcomes such as mathematical achievement, problem-solving ability, and conceptual understanding. Comparatively fewer studies have explored affective outcomes, particularly self-confidence, as a primary research variable. Moreover, limited attention has been given to investigating how students with different levels of prior mathematical ability respond to this instructional approach. As a result, empirical evidence regarding the effectiveness of GeoGebra-assisted TAPPS in fostering students' self-confidence across PMA categories remains insufficient.

Grounded in socio-cognitive theory and constructivist learning perspectives, GeoGebra-assisted TAPPS is expected to enhance students' self-confidence through two complementary mechanisms. First, the TAPPS strategy encourages students to verbalize their reasoning processes, engage in collaborative reflection, and receive immediate peer feedback. Second, GeoGebra provides dynamic visualizations that help students understand mathematical concepts more clearly and reduce cognitive barriers during problem-solving activities. The combination of collaborative verbalization and dynamic visualization is expected to create meaningful learning experiences that strengthen students' confidence in mathematics learning.

The novelty of this study lies in integrating GeoGebra-assisted Thinking Aloud Pair Problem Solving (TAPPS) to improve students' self-confidence while simultaneously examining its effectiveness across different levels of prior mathematical ability. Therefore, this study aims to investigate the effectiveness of GeoGebra-assisted TAPPS in enhancing senior high school students' self-confidence in mathematics learning.

METHOD

This study employed a quantitative approach using a quasi-experimental method with a non-equivalent control group design. The design was selected because the research was conducted in intact classroom

settings where random assignment of students to experimental and control groups was not feasible. The study involved an experimental group that received GeoGebra-assisted Thinking Aloud Pair Problem Solving (TAPPS) instruction and a control group that received conventional mathematics instruction.

The population of this study consisted of eleventh-grade students from a public senior high school in Tangerang, Indonesia, during the 2025/2026 academic year. Two classes with relatively similar academic characteristics were selected using purposive sampling. One class was assigned as the experimental group and the other as the control group. Each group consisted of 35 students, resulting in a total sample of 70 students. Both groups studied the same mathematical topic, received the same amount of instructional time, and were assessed using the same research instrument.

Prior Mathematical Ability (PMA) was included as a student grouping variable to provide a more detailed description of students' self-confidence improvement. PMA data were obtained from students' mathematics achievement scores prior to the implementation of the intervention. Based on the score distribution, students were classified into high, medium, and low PMA categories. Following Lestari and Yudhanegara (2018), students with scores greater than $\text{Mean} + \text{SD}$ were categorized as high PMA, students with scores between $\text{Mean} \pm \text{SD}$ were categorized as medium PMA, and students with scores lower than $\text{Mean} - \text{SD}$ were categorized as low PMA.

The research procedure consisted of four stages. The first stage involved preparing the learning materials, developing the GeoGebra-assisted TAPPS learning activities, and preparing the research instruments. The second stage involved administering a pre-scale self-confidence questionnaire to both groups to determine students' initial self-confidence levels. The

third stage consisted of implementing the instructional treatment. Students in the experimental group participated in GeoGebra-assisted TAPPS learning activities, while students in the control group received conventional instruction through teacher explanations, question-and-answer sessions, and individual exercises.

In the experimental group, students worked collaboratively in pairs and alternated roles as problem solvers and listeners. The problem solver verbalized every reasoning process while solving mathematical problems, whereas the listener monitored, questioned, and provided feedback. GeoGebra was integrated into the learning process to facilitate mathematical visualization and conceptual exploration. To ensure fidelity of implementation, both groups were taught using the same learning objectives, instructional materials, learning duration, and assessment procedures. The implementation of the treatment was monitored through classroom observations during each meeting.

The final stage involved administering a post-scale self-confidence questionnaire to both groups after the intervention. The difference between pre-scale and post-scale scores was used to identify changes in students' self-confidence following the learning intervention.

The primary research instrument was a self-confidence questionnaire adapted from Hendriana et al. (2017). The questionnaire consisted of 30 statements comprising both positive and negative items measured using a five-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (5). The instrument was developed based on four dimensions of self-confidence, namely: (1) belief in one's own abilities, (2) positive thinking and action in facing problems, (3) optimism, calmness, and perseverance, and (4) adaptability and social interaction.

Table 1. Dimensions and Indicators of Students' Self-Confidence

Dimension	Indicators
Belief in one's own abilities	Confidence in mastering mathematics and expressing mathematical ideas
Positive thinking and action	Ability to recover from mistakes and maintain enthusiasm in learning mathematics
Optimism, calmness, and perseverance	Ability to defend opinions and persist in solving mathematical problems
Adaptability and social interaction	Ability to communicate, collaborate, assist peers, and adapt to various learning situations

Prior to data collection, the questionnaire was reviewed by two mathematics education experts and one educational evaluation expert to ensure content validity and the suitability of the instrument indicators. Revisions were made based on expert recommendations before the questionnaire was administered to the research participants.

Data were collected through the administration of pre-scale and post-scale self-confidence questionnaires in both the experimental and control groups. The pre-scale was administered before the intervention, whereas the post-scale was administered after the intervention.

The collected data were analyzed using IBM SPSS Statistics. Descriptive statistics, including mean, standard deviation, minimum score, and maximum score, were used to describe students' self-confidence levels. Prior to hypothesis testing, prerequisite analyses were

conducted using the Shapiro–Wilk normality test and Levene's homogeneity test. To determine the effectiveness of GeoGebra-assisted TAPPS in improving students' self-confidence, an independent samples t-test was employed to compare the post-scale self-confidence scores of the experimental and control groups. In addition, N-gain analysis was conducted to examine the magnitude of students' improvement following the intervention. All statistical analyses were conducted at a significance level of 0.05.

RESULT AND DISCUSSION

Students' self-confidence was measured before and after the implementation of GeoGebra-assisted Thinking Aloud Pair Problem Solving (TAPPS). The descriptive statistics of students' self-confidence scores in the experimental and control groups are presented in Table 2.

Table 2. Descriptive Statistics of Students' Self-Confidence Scores

Group	N	Pre-scale Mean	Post-scale Mean	Increase
Experimental	35	81.57	94.57	13.00
Control	35	81.26	90.96	9.70

Table 2 shows that the initial self-confidence levels of students in both groups were relatively similar. The mean pre-scale score of the experimental group was 81.57, while the control group obtained a mean score of 81.26. These findings indicate that students in both groups started the study with comparable levels of self-confidence. Following the intervention, self-confidence scores increased in both groups. However, the increase observed in the experimental

group was greater than that of the control group. The experimental group experienced an increase of 13.00 points, whereas the control group experienced an increase of 9.70 points. These findings suggest that students who participated in GeoGebra-assisted TAPPS experienced greater growth in self-confidence throughout the learning process.

Prior to hypothesis testing, normality and homogeneity analyses were conducted.

The results of the Shapiro–Wilk test indicated that all self-confidence data were normally distributed ($p > .05$). Furthermore, the homogeneity test revealed that the pre-scale scores were homogeneous (Levene Statistic = 0.483, $p = .490$), whereas the post-scale scores were not homogeneous (Levene

Statistic = 5.629, $p = .020$). To determine whether there was a significant difference between the post-scale self-confidence scores of the experimental and control groups, an independent samples t-test was performed. The results are presented in Table 3.

Table 3. Independent Samples t-Test Results

Variable	t	Sig. (2-tailed)	Interpretation
Self-Confidence Post-scale	1.921	0.060	Not Significant

As presented in Table 3, the significance value obtained from the independent samples t-test was 0.060, which is greater than the significance level of 0.05. Therefore, no statistically significant difference was found between the post-scale self-confidence scores of students in the experimental and control groups. Although the statistical analysis did not reveal a significant difference, the experimental group achieved a higher mean self-

confidence score than the control group after the intervention. This finding indicates that GeoGebra-assisted TAPPS contributed positively to students' self-confidence, although the effect was not sufficiently large to produce statistically different post-scale scores between groups.

To further investigate the effectiveness of the intervention, an N-gain analysis was conducted. The results are presented in Table 4.

Table 4. N-Gain of Students' Self-Confidence

Group	N-Gain	Category
Experimental	0.20	Low
Control	0.10	Low

Table 4 shows that both groups achieved N-gain scores within the low category. Nevertheless, the experimental group obtained a higher N-gain score than the control group, indicating greater improvement in self-confidence. To determine whether the difference in improvement between the two groups was statistically significant, a Mann–Whitney U

test was conducted. The analysis revealed a significance value of $p = .001$, indicating a statistically significant difference in N-gain scores between the experimental and control groups. This finding suggests that students who participated in GeoGebra-assisted TAPPS experienced significantly greater improvement in self-confidence than those who received conventional instruction.

Table 5. N-Gain Based on PMA

PMA	Experimental	Control
High	0.25	0.12
Medium	0.21	0.11
Low	0.15	0.08

Table 5 presents the improvement in students' self-confidence based on Prior Mathematical Ability (PMA) categories. Students from all PMA categories demonstrated positive improvement

following the implementation of GeoGebra-assisted TAPPS. The highest N-gain score was observed among students in the high PMA category (0.25), followed by the medium PMA category (0.21) and the low

PMA category (0.15). In contrast, students in the control group obtained lower N-gain scores across all PMA categories, namely 0.12, 0.11, and 0.08, respectively. These findings indicate that GeoGebra-assisted TAPPS can facilitate the development of students' self-confidence regardless of their prior mathematical ability, although students with stronger mathematical foundations tended to experience greater improvement.

An interesting finding of this study is that the post-scale comparison yielded a non-significant result, whereas the N-gain analysis revealed a significant difference between groups. This finding suggests that GeoGebra-assisted TAPPS may not immediately produce substantially different levels of self-confidence at the end of instruction; however, it appears to facilitate greater growth in students' self-confidence over time. Self-confidence is an affective construct that develops gradually through continuous learning experiences, social interactions, and successful performance. Consequently, short-term interventions may not always result in significant differences in final scores, even though they contribute meaningfully to students' personal development. Therefore, examining students' learning gains provides a more comprehensive understanding of the effectiveness of an instructional intervention than relying solely on post-intervention comparisons.

The greater improvement observed in the experimental group can be attributed to the characteristics of the TAPPS learning strategy. During learning activities, students were required to verbalize their reasoning processes while solving mathematical problems. This process encouraged students to communicate mathematical ideas, explain solution procedures, and justify their answers. Through repeated opportunities to express and defend their reasoning, students gradually developed confidence in communicating mathematical ideas and participating in classroom discussions (Gillies, 2016; Wolcott & Lobczowski, 2021).

Another important aspect of TAPPS is the collaborative interaction between problem solvers and listeners. During

discussions, students received immediate feedback from their peers regarding the appropriateness of their reasoning and solution strategies. Such feedback helped students identify misconceptions, refine their thinking processes, and improve conceptual understanding. Furthermore, the supportive learning environment reduced students' fear of making mistakes and increased their willingness to participate actively during mathematics lessons. Consequently, students became more confident in expressing opinions and solving mathematical problems independently (Johnson et al., 2018; Fitriani & Mulyono, 2022).

The integration of GeoGebra further strengthened the learning process by providing dynamic visual representations of mathematical concepts. GeoGebra enabled students to explore mathematical relationships, verify solutions, and observe abstract concepts through interactive visualizations. These visual supports helped students gain a deeper understanding of mathematical concepts and reduced uncertainty during problem-solving activities. When students successfully completed learning tasks and understood concepts more clearly, they developed stronger beliefs in their own capabilities (Arifin & Herman, 2022; Kusuma & Juandi, 2023). Similar findings have been reported in previous studies showing that dynamic mathematics software can facilitate students' confidence by supporting conceptual understanding and reducing learning anxiety (Hohenwarter & Jones, 2018; Oktaviani et al., 2023).

These findings are consistent with Bandura's Social Cognitive Theory, which states that self-confidence develops through mastery experiences, vicarious experiences, social persuasion, and positive emotional states. GeoGebra-assisted TAPPS appears to facilitate these processes simultaneously. Students experienced success while solving mathematical problems, observed their peers' reasoning strategies, received encouragement and feedback, and participated in a collaborative learning environment. Such experiences contributed

positively to the development of self-confidence.

The findings also support previous studies indicating that cooperative learning and technology-enhanced instruction can positively influence students' affective outcomes, including self-confidence, engagement, and learning motivation (Gillies, 2016; Wolcott & Lobczowski, 2021; Oktaviani et al., 2023). Collaborative learning environments encourage students to communicate ideas, construct knowledge collectively, and participate actively in learning activities, thereby fostering positive attitudes toward learning and strengthening students' confidence in their own abilities (Laal & Ghodsi, 2012; Slavin, 2018).

Likewise, technology-assisted learning environments can increase students' engagement, motivation, and confidence by making mathematical concepts more accessible and meaningful (Putri & Zulkardi, 2021; Cahyani & Setyawati, 2023). These findings are also supported by previous studies indicating that technology-enhanced mathematics learning environments improve students' engagement and confidence during mathematical exploration (Oktaviani et al., 2023; Putri & Zulkardi, 2021).

Another important finding relates to the role of Prior Mathematical Ability (PMA). Students with different levels of PMA appeared to benefit from the implementation of GeoGebra-assisted TAPPS. Students with higher PMA generally demonstrated greater confidence when expressing ideas and participating in discussions because they possessed stronger mathematical foundations (Ruiz-Primo, 2020). Meanwhile, students with lower PMA benefited from peer support and visual representations provided through GeoGebra. These learning experiences enabled lower-achieving students to participate more actively and gradually build confidence in their own abilities. This finding suggests that GeoGebra-assisted TAPPS creates an inclusive learning environment capable of accommodating students with diverse mathematical backgrounds (Juandi, 2021).

From a practical perspective, the findings imply that mathematics teachers

should consider integrating collaborative learning strategies and technological tools into classroom instruction. Traditional teacher-centered approaches often provide limited opportunities for students to communicate ideas and develop confidence in their mathematical abilities. In contrast, GeoGebra-assisted TAPPS encourages students to participate actively, discuss mathematical concepts, and explore solutions independently. Such learning experiences support both cognitive and affective development and contribute to the creation of more meaningful mathematics learning environments. This recommendation is consistent with current mathematics education reforms that emphasize active learning, student participation, collaborative problem solving, and the integration of technology to support both cognitive and affective development (NCTM, 2020).

From a theoretical perspective, this study contributes to the growing body of literature on mathematics education by providing empirical evidence that the integration of collaborative verbalization and dynamic technological visualization can support the development of students' self-confidence. The findings extend previous research by demonstrating that self-confidence can be fostered not only through successful problem-solving experiences but also through meaningful peer interaction and technology-supported exploration. These findings are in line with previous studies emphasizing the role of self-confidence as an important affective factor that supports mathematical learning and achievement (Hidayat & Sariningsih, 2020; Sumarmo, 2020; Dewi & Kartono, 2021).

CONCLUSION

This study investigated the effectiveness of GeoGebra-assisted Thinking Aloud Pair Problem Solving (TAPPS) in improving students' self-confidence in mathematics learning. The findings revealed that students who participated in GeoGebra-assisted TAPPS demonstrated greater improvement in self-confidence compared with those who received conventional instruction. Although

the independent samples t-test indicated that the post-scale self-confidence scores of the experimental and control groups were not significantly different, the N-gain analysis showed a statistically significant difference in improvement between the two groups. These findings suggest that GeoGebra-assisted TAPPS contributes positively to the development of students' self-confidence and facilitates greater growth in confidence throughout the learning process.

The improvement in students' self-confidence can be attributed to the collaborative nature of TAPPS and the dynamic visualization provided by GeoGebra. Through verbalizing mathematical reasoning, exchanging ideas with peers, and exploring concepts using interactive visual representations, students were provided with meaningful learning experiences that encouraged active participation and strengthened their belief in their mathematical abilities. Therefore, GeoGebra-assisted TAPPS can be considered a promising instructional approach for supporting students' affective development in mathematics learning.

This study has several practical implications for mathematics education. The findings suggest that integrating collaborative learning strategies with technological tools can create learning environments that not only promote conceptual understanding but also foster positive affective outcomes, particularly students' self-confidence. Mathematics teachers are therefore encouraged to incorporate opportunities for discussion, reasoning, and technology-assisted exploration into classroom instruction to enhance students' engagement and confidence.

Despite these contributions, this study has several limitations. First, the research was conducted in a single school with a relatively limited sample size, which may restrict the generalizability of the findings. Second, the duration of the intervention was relatively short, whereas self-confidence is an affective construct that typically develops over a longer period of time. Future studies are recommended to involve larger and more diverse samples, implement longer

intervention periods, and examine the effects of GeoGebra-assisted TAPPS on other affective and cognitive variables, such as learning motivation, mathematical communication, problem-solving ability, and mathematical achievement.

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AUTHOR CONTRIBUTIONS

Author One: Conceptualization, methodology, supervision, formal analysis, writing – review & editing, project administration, and visualization;

Author Two: Methodology, validation, writing – review & editing, supervision, and resources;

Author Three: Validation, formal analysis, writing – review & editing, and supervision;

Author Four: Investigation, data curation, data collection, writing – original draft, and visualization. All authors have read and agreed to the published version of the manuscript.

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