



Enhancing Senior High School Students' Creative Thinking, Mathematical Reasoning, and Collaboration Through PBL-STAD in Trigonometry Learning

Peningkatan Berpikir Kreatif, Penalaran Matematis, dan Keterampilan Kolaborasi Siswa SMA melalui PBL-STAD pada Pembelajaran Trigonometri

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Abstract

This study examines the integration of Problem-Based Learning (PBL) and Student Teams Achievement Division (STAD) to improve students' creative thinking, mathematical reasoning, and collaboration skills in trigonometry. Conducted at MA Ali Maksum Yogyakarta, the study involved 26 Grade XI Science 2 students using a one-group pretest-posttest pre-experimental design. Quantitative data were collected through tests and questionnaires, with observations as supporting data, and analyzed using paired-samples t-tests. The results showed significant improvements in creative thinking from 16.5 to 70.5, mathematical reasoning from 19.26 to 75.6, and collaboration skills from 57.1 to 74.7 (all $p < .001$). These findings indicate that integrating PBL and STAD effectively supports trigonometry learning.

Keywords: Collaboration; Creative Thinking; Mathematical Reasoning; PBL; STAD.

Abstrak

Penelitian ini mengkaji integrasi Problem-Based Learning (PBL) dan Student Teams Achievement Division (STAD) untuk meningkatkan kemampuan berpikir kreatif, penalaran matematis, dan keterampilan kolaborasi siswa pada materi trigonometri. Penelitian dilaksanakan di MA Ali Maksum Yogyakarta dengan melibatkan 26 siswa kelas XI IPA 2 menggunakan desain pra-eksperimen tipe one-group pretest-posttest. Data dikumpulkan melalui tes dan angket, dengan observasi sebagai data pendukung, kemudian dianalisis menggunakan uji paired-samples t-test. Hasil penelitian menunjukkan peningkatan signifikan kemampuan berpikir kreatif dari 16,5 menjadi 70,5, penalaran matematis dari 19,26 menjadi 75,6, dan keterampilan kolaborasi dari 57,1 menjadi 74,7 (seluruhnya $p < 0,001$). Temuan ini menunjukkan integrasi PBL dan STAD efektif mendukung pembelajaran trigonometri.

Kata Kunci: Berpikir Kreatif; Keterampilan Kolaborasi; PBL; Penalaran Matematis; STAD.

Introduction

Mathematics education plays a fundamental role in cultivating critical thinking, problem-solving, and reasoning abilities required for learners to function effectively in the twenty-first century ¹. As a universal language, mathematics enables individuals to interpret social realities and construct a deeper understanding of the world ². However, despite its central position in the education curriculum ³, many students still experience difficulties in understanding core mathematical concepts, which in turn negatively affect their motivation and creative engagement in learning ⁴. Teachers likewise encounter challenges in implementing active and student-centered learning due to limitations in classroom conditions and instructional media ⁵. Consequently, teacher-centered approaches remain dominant, restricting opportunities for students to develop higher-order thinking skills, particularly in creativity and reasoning.

In response to these challenges, Regulation No. 5 of 2022 issued by Indonesia's Ministry of Education, Culture, Research, and Technology emphasizes the importance of fostering creativity among learners. Nevertheless, the implementation of this policy in classroom practice remains limited. Creativity in mathematics involves the ability to generate original and effective solutions to complex problems, a competency that is increasingly essential in addressing future challenges ⁶. Prior studies indicate that creative thinking is closely related to mathematical ability and that learning environments which support creativity can significantly improve student outcomes ⁷. However, fostering creativity in mathematics classrooms is not

¹ Yeping Li and Alan H. Schoenfeld, "Problematizing Teaching and Learning Mathematics as 'Given' in STEM Education," *International Journal of STEM Education* 6, no. 1 (2019): 44, s40594-019-0197-99, <https://doi.org/10.1186/s40594-019-0197-9>.

² Ole Skovsmose, *Towards a Philosophy of Critical Mathematics Education* (Springer Netherlands, 1994), <https://doi.org/10.1007/978-94-017-3556-8>.

³ National Council of Teachers of Mathematics, *Principles and Standards for School Mathematics*, with Internet Archive (Reston, VA : National Council of Teachers of Mathematics, 2000), 28, <http://archive.org/details/principlesstanda00nati>.

⁴ M. Azhari Panjaitan and Dadang Juandi, "Analysis of Problems in Learning Mathematics Based on Difficulties, Errors, and Misconceptions in the Material of Equations and Inequality Absolute Values of One Variable: Systematic Literature Review," *KnE Social Sciences* 12, no. 13 (2024): 316–24, <https://doi.org/10.18502/kss.v9i13.15932>.

⁵ Aufa Zain and Nina Rahayu, "Systematic Literature Review: Factors Causing Low Students' Interest in Learning Mathematics," *Logaritma : Jurnal Ilmu-Ilmu Pendidikan Dan Sains* 11, no. 1 (2023): 105–18, <https://doi.org/10.24952/logaritma.v11i1.8333>.

⁶ Gemma Carotenuto et al., "Students' Suspension of Sense Making in Problem Solving," *ZDM – Mathematics Education* 53, no. 4 (2021): 817–30, <https://doi.org/10.1007/s11858-020-01215-0>.

⁷ Eveline M. Schoevers et al., "Mathematical Creativity: A Combination of Domain-General Creative and Domain-Specific Mathematical Skills," *The Journal of Creative Behavior* 54, no. 2 (2020): 242–52, <https://doi.org/10.1002/jocb.361>.

straightforward, as it is often hindered by teachers' instructional habits, fixed mindsets, and limited pedagogical support ⁸.

Creative thinking is therefore critical competency in mathematics education, preparing students for complex and technology driven contexts ⁹. Creative thinking in mathematics encompasses several key processes, including identifying problems, formulating hypotheses, testing ideas, and communicating solutions ¹⁰. Key dimensions of creative thinking such as fluency, flexibility, originality, and elaboration, which enable students to move beyond procedural understanding toward innovative problem solving ¹¹. When teachers implement structured creative processes consisting of preparation, incubation, insight, evaluation, and elaboration, students become better able to explore multiple solutions and engage in divergent thinking ¹².

Despite these theoretical perspectives, empirical evidence suggests that students' mathematical creative thinking abilities in Indonesia remain relatively low, partly due to the persistence of conventional teaching approaches ¹³. Local studies confirm that ineffective teaching methods contribute to students' low levels of creative mathematical thinking ¹⁴. Even though there has been a push toward interactive learning, teacher-centered approaches still dominate ¹⁵. This condition was also observed in the

⁸ Ross C. Anderson et al., "How Am I a Creative Teacher? Beliefs, Values, and Affect for Integrating Creativity in the Classroom," *Teaching and Teacher Education* 110 (February 2022): 103583, <https://doi.org/10.1016/j.tate.2021.103583>.

⁹ Ibrahim et al., "Mathematics Learning Orientation: Mathematical Creative Thinking Ability or Creative Disposition?," *Journal on Mathematics Education* 15, no. 1 (2024): 253–76, <https://doi.org/10.22342/jme.v15i1.pp253-276>.

¹⁰ Joy Paul Guilford, *Intelligence, Creativity and Their Educational Implications: Joy Paul Guilford: Free Download, Borrow, and Streaming: Internet Archive* (1968; Robert R. Knapp, 1968), <https://archive.org/details/intelligencecrea0000joyp/page/n9/mode/2up>.

¹¹ E. Paul Torrance, *Creativity. What Research Says to the Teacher* (National Education Association, 1201 Sixteenth Street, N, 1969), <https://eric.ed.gov/?id=ED078435>.

¹² Bilhakil Putra Yulisman and Usmeldi Usmeldi, "Praktikalitas Pengembangan Buku Siswa dengan Model Problem Based Learning Ber-integrasi Kemampuan Berfikir Kreatif untuk Meningkatkan Kreativitas Peserta Didik SMA," *Jurnal Penelitian Pembelajaran Fisika* 7, no. 2 (2021): 163, <https://doi.org/10.24036/jppf.v7i2.113807>.

¹³ Richard Florida et al., *Creativity and Prosperity: The Global Creativity Index* (2015), <http://hdl.handle.net/1807/80125>; Richard Florida and Charlotta Mellander, "The Global Creativity Index: National Creativity Ecosystems and Their Relationship to Economic Development and Inequality," in *Global Creative Ecosystems: A Critical Understanding of Sustainable Creative and Cultural Production*, ed. Tarek E. Virani (Springer International Publishing, 2023), https://doi.org/10.1007/978-3-031-33961-5_10.

¹⁴ Hayatun Nufus et al., "Analyzing the Students' Mathematical Creative Thinking Ability in Terms of Self-Regulated Learning: How Do We Find What We Are Looking For?," *Heliyon* 10, no. 3 (2024), <https://doi.org/10.1016/j.heliyon.2024.e24871>; Diki Laksono and Kiki Nia Sania Effendi, "Kemampuan Berpikir Kreatif Matematis Siswa SMP Di Kabupaten Karawang Pada Materi Bangun Datar," *JPMI (Jurnal Pembelajaran Matematika Inovatif)* 4, no. 3 (2021): 507–16, <https://doi.org/10.22460/jpmi.v4i3.p%25p>.

¹⁵ S. Aziz and Suparman, "Design Of Mathematical E-Module Based On Inquiry Learning Model To Stimulate The Creative Skills," 9, no. 3 (2020): 1–7,

experimental class. Preliminary observations showed that learning was still dominated by teacher explanations, with limited opportunities for students to explore alternative solution strategies or engage in collaborative problem-solving. Students tended to rely on procedural methods and had difficulty generating multiple ideas in solving trigonometric problems, as reflected in their low initial creative thinking pretest scores. Therefore, it can be hypothesized that limited student-centered and collaborative learning activities contributed to the low development of students' creative thinking skills, indicating the need for an instructional approach that integrates inquiry-based learning and structured collaboration.

In addition to creativity, collaboration has become an essential competency in modern education. Collaborative learning environments allow students to exchange ideas, negotiate meaning, and construct knowledge collectively, thereby enhancing both conceptual understanding and creative performance ¹⁶. Cooperative learning models, such as Student Teams Achievement Division (STAD), have been shown to promote active participation, teamwork, and individual accountability within group settings ¹⁷. Through structured interaction, students not only develop academic understanding but also strengthen communication skills and social responsibility, which are crucial for future professional contexts.

Furthermore, mathematical reasoning remains a central component of meaningful mathematics learning ¹⁸. Mathematical reasoning is another crucial aspect of mathematics education. It requires logical thinking, drawing conclusions, and solving problems through reasoning and proof ¹⁹. Effective instruction in reasoning helps students construct logical conclusions and prepares them for real-world challenges. The National Council of Teachers of Mathematics identifies reasoning and proof as core elements, which include forming conjectures, constructing arguments, and providing justifications ²⁰.

<https://www.semanticscholar.org/paper/Design-Of-Mathematical-E-Module-Based-On-Inquiry-To-Aziz-Suparman/ef3c6a5ef2c80dc458c84a5e6bb53a107cd4da36>.

¹⁶ Mark Vincent B. Yu et al., "Working Together as a Team Really Gets Them Fired up': Afterschool Program Mentoring Strategies to Promote Collaborative Learning Among Adolescent Participants," *Applied Developmental Science* 26, no. 2 (2022): 350, <https://doi.org/10.1080/10888691.2020.1800467>.

¹⁷ Robert E. Slavin, *Cooperative Learning* (Nusa Media, 2015), 42.

¹⁸ Rohati Rohati et al., "Exploring Students' Mathematical Reasoning Behavior in Junior High Schools: A Grounded Theory," *Education Sciences* 13, no. 3 (2023): 5, <https://doi.org/10.3390/educsci13030252>.

¹⁹ John A. Van de Walle et al., *Elementary and Middle School Mathematics: Teaching Developmentally*, 7th ed. (Allyn & Bacon, 2010), 45; Etienne Wenger, *Communities of Practice: Learning, Meaning, and Identity* (Cambridge University Press, 1998), 12, <https://doi.org/10.1017/CBO9780511803932>.

²⁰ NCTM, "Principles and Standards - National Council of Teachers of Mathematics," National Council of Teachers of Mathematics, 2025, 25, <https://www.nctm.org/standards-and-positions/principles-and-standards/>.

Similarly, Indonesia's Directorate General of Secondary Education defines reasoning indicators such as presenting statements, formulating conjectures, performing manipulations, and drawing conclusions skills that cultivate critical and logical thought essential to problem solving.

To address the interconnected demands of creativity, collaboration, and reasoning, mathematics education has increasingly adopted constructivist and cooperative learning approaches, particularly Problem-Based Learning (PBL) and STAD. PBL engages students in authentic problem-solving situations that encourage inquiry, reflection, and self-directed learning ²¹, while STAD facilitates structured group work through heterogeneous teams and individual accountability ²². Previous studies have shown that PBL contributes positively to higher-order thinking in mathematics. For example, PBL has been reported to improve students' mathematical reasoning ability ²³ and support the development of creative mathematical thinking through inquiry-oriented problem-solving activities ²⁴. In addition, PBL also promotes collaboration and communication because students are required to discuss ideas, negotiate meaning, and solve problems collectively ²⁵. Meanwhile, STAD has been shown to strengthen student participation, teamwork, and responsibility in group learning settings ²⁶. These findings indicate that PBL and STAD have strong potential to support cognitive and social dimensions of mathematics learning.

However, existing studies have generally examined PBL and STAD separately or have focused on limited learning outcomes, such as creativity or reasoning. Research that integrates both models simultaneously while examining multiple competencies remains limited, particularly in trigonometry learning. Trigonometry is often perceived as an abstract and challenging topic that requires conceptual understanding, flexible reasoning, exploration of multiple solution strategies, and effective peer interaction. This condition indicates a clear research gap in the integration of PBL and STAD to address these multidimensional learning needs. Therefore, this study aims to

²¹ David Jonassen and Woei Hung, "All Problems Are Not Equal: Implications for Problem-Based Learning," *Interdisciplinary Journal of Problem-Based Learning* 2, no. 2 (2008): 10, <https://doi.org/10.7771/1541-5015.1080>.

²² Slavin, *Cooperative Learning*, 42.

²³ Ihda Mutimmatul Fitriyah et al., "Meta Analysis Study: Effectiveness of Problem Based Learning on Indonesian Students' Mathematical Reasoning Ability," *Jurnal Riset Pendidikan Matematika* 9, no. 1 (2022): 40, <https://doi.org/10.21831/jrpm.v9i1.46447>.

²⁴ Ibrahim et al., "Mathematics Learning Orientation," 258.

²⁵ Cynthia Putri et al., "Students' Collaboration and Communication Skills with Problem-Based Learning Model," *Jurnal Inovasi Dan Teknologi Pembelajaran* 10 (January 2025): 225, <https://doi.org/10.17977/um031v10i32023p225>.

²⁶ Desy Fitriani and Jailani Jailani, "Pengaruh Pembelajaran Kooperatif Tipe STAD Dengan Pendekatan Saintifik Terhadap Berpikir Kritis, Kecerdasan Emosional Dan Kolaborasi," *AKSIOMA: Jurnal Program Studi Pendidikan Matematika* 12, no. 2 (2023): 2499, <https://doi.org/10.24127/ajpm.v12i2.7280>.

investigate the effectiveness of integrating Problem-Based Learning (PBL) and Student Teams Achievement Division (STAD) models in enhancing senior high school students' creative thinking, mathematical reasoning, and collaboration skills in trigonometry learning.

Method

This study employed a quantitative pre-experimental design using a one-group pretest–posttest approach. The purpose of the study was to examine the effectiveness of integrating Problem-Based Learning (PBL) and Student Teams Achievement Division (STAD) models in enhancing students' creative thinking, mathematical reasoning, and collaboration skills in trigonometry learning. The study was conducted at a MA Ali Maksum in Yogyakarta during the 2024/2025 academic year. The population consisted of all Grade XI Science students, distributed across four classes. The sample was one class, Grade XI Science 2, consisting of 26 students, selected through purposive sampling based on class characteristics, schedule feasibility, and teacher recommendations.

The learning material focused on trigonometry, particularly trigonometric ratios, angle relationships, and the application of trigonometric concepts in contextual problems such as angles of elevation and depression. The research procedure consisted of three stages: pretest, treatment, and posttest. The pretest was administered to measure students' initial abilities in creative thinking and mathematical reasoning. The treatment was conducted through classroom instruction using the integrated PBL–STAD model. After the intervention, a posttest was administered to determine changes in students' abilities. The research design can be represented as follows:

Pre-test (O_1) → Treatment (X) → Post-test (O_2)

The instruments used in this study consisted of: (1) a creative thinking test, (2) a mathematical reasoning test, (3) an observation sheet, and (4) a collaboration skills questionnaire. The creative thinking test consisted of five open-ended trigonometry problems. The items were developed based on four indicators of creative thinking: fluency, flexibility, originality, and elaboration²⁷. Fluency refers to the ability to generate multiple relevant ideas, flexibility refers to the ability to use different solution strategies, originality refers to the uniqueness of responses, and elaboration refers to the ability to provide detailed and systematic solutions. Each item was scored using an analytic rubric with a maximum score of 20, resulting in a total maximum score of 100.

²⁷ Torrance, *Creativity. What Research Says to the Teacher*, 15.

The mathematical reasoning test also consisted of five open-ended trigonometry problems. The assessment was based on six indicators: presenting mathematical statements, proposing conjectures, performing mathematical manipulation, constructing proof or justification, checking the validity of arguments, and drawing conclusions²⁸. Each item was scored using an analytic rubric (maximum 20 points), with a total maximum score of 100.

The collaboration skills questionnaire was administered using a self-assessment technique. The instrument consisted of 20 items adapted and modified from the collaboration rubric developed by Ofstedal and Dahlberg²⁹. The questionnaire covered six aspects: contribution, time management, team support, problem-solving, group interaction, and reflection. The items included both positive and negative statements. Students responded using a four-point Likert scale, with reverse scoring applied to negative items. The total score was converted into a percentage to represent students' collaboration skills. The observation sheet was used to monitor the implementation of the PBL-STAD learning process, particularly teacher-student interaction and student participation.

The validity of the research instruments was established through expert judgment. The creative thinking test, mathematical reasoning test, and collaboration questionnaire were reviewed by two mathematics education experts based on relevance to constructs, clarity, appropriateness to students' cognitive level, and alignment with learning objectives. Revisions were made accordingly, and the instruments were considered valid in terms of content. Instrument reliability was supported using analytic scoring rubrics and consistent scoring procedures. Each indicator was accompanied by clear criteria to minimize subjectivity. Due to the limited sample size, statistical reliability testing such as Cronbach's Alpha was not conducted.

Students' responses to the creative thinking and mathematical reasoning tests, which were qualitative in nature, were converted into quantitative data using analytic scoring rubrics. Responses were evaluated based on completeness, correctness, originality, logical coherence, and procedural accuracy, then summed and converted into a 0-100 scale. For the collaboration questionnaire, responses were scored using a Likert scale and converted into percentage values.

Data analysis employed both descriptive and inferential statistics. Descriptive analysis included mean, standard deviation, minimum, and maximum scores, while inferential analysis used paired-samples t-tests in

²⁸ NCTM, "Principles and Standards - National Council of Teachers of Mathematics," 25.

²⁹ Kathleen Ofstedal and Kathryn Dahlberg, "Collaboration in Student Teaching: Introducing the Collaboration Self-Assessment Tool," *Journal of Early Childhood Teacher Education* 30, no. 1 (2009): 37-48, <https://doi.org/10.1080/10901020802668043>.

SPSS to examine differences between pretest and posttest scores in creative thinking, mathematical reasoning, and collaboration skills.

Results and Discussion

This study was conducted at a private senior high school in Yogyakarta and examined the implementation of the Student Teams-Achievement Divisions (STAD) model integrated with the Problem-Based Learning (PBL) approach in Grade XI Science 2. The study aimed to evaluate the impact of this integrated model on students' creative thinking, mathematical reasoning, and collaboration skills in trigonometry learning.

Prior to conducting the paired-samples t-test, a normality test using the Shapiro-Wilk method was performed because normality is an essential assumption for parametric tests, including the t-test. The results indicated that the difference scores between the pretest and posttest for all variables were normally distributed ($p > 0.05$). Therefore, the use of parametric statistical analysis through the paired-samples t-test was considered appropriate³⁰.

The analysis results revealed statistically significant improvements in students' creative thinking, mathematical reasoning, and collaboration skills, as indicated by the paired-samples t-test results ($p < .001$). These findings suggest that the integration of PBL and STAD contributes positively to the development of students' cognitive and collaborative competencies.

Table 1. Combined Achievement Results of Creative Thinking, Mathematical Reasoning, and Collaboration Skills

Variation	Learning Model	Test Type	Number of Students	Average Score	Standard Deviation	Maximum Observed Score	Minimum Observed Score
Achievement Results of Creative Thinking Ability	STAD with	Pre-test	26	16.5	5.24	25	10
	PBL	Post-test	26	70.5	10.1	84	55
Achievement Results of Mathematical Reasoning	STAD with	Pre-test	26	19.26	7.5	30	8
	PBL	Post-test	26	75.6	9.4	92	62
Achievement Results of Collaboration Skills	STAD with	Pre-test	26	57.1	5.8	72.5	45
	PBL	Post-test	26	74.7	6.2	88.75	65

Source: Authors processed data.

³⁰ Tae Kyun Kim and Jae Hong Park, "More About the Basic Assumptions of T-Test: Normality and Sample Size," *Korean Journal of Anesthesiology* 72, no. 4 (2019): 331–35, <https://doi.org/10.4097/kja.d.18.00292>.

Table 2. Paired Samples *t*-test Results for Creative Thinking Ability, Mathematical Reasoning, and Collaboration Skills

Ability	Mean	Std. Deviation	Std. Error Mean	95% Confidende Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	Upper			
Creative Thinking Ability	-54	11.2	2.2	-58.59	-49.46	-	25	.000
Mathematical Reasoning	-56.4	10.6	2.0	-60.75	-52.17	-	25	.000
Collaboration Skills	-17.5	2.7	0.53	-18.69	-16.49	-	25	.000

Source: Authors processed data.

The findings of this study indicate substantial improvements in students' creative thinking, mathematical reasoning, and collaboration skills following the implementation of the integrated PBL-STAD model. Creative thinking scores increased from 16.5 in the pre-test to 70.5 in the post-test, while mathematical reasoning scores improved from 19.26 to 75.6. In addition, collaboration skills showed a marked increase from 57.1 to 74.7. These results suggest that the integration of Problem-Based Learning (PBL) and Student Teams Achievement Division (STAD) enhances students' performance and changes how they approach problem-solving in trigonometry.

These improvemets can be explained through the interaction of two key instructional mechanisms. First, the PBL approach exposes students to open-ended and contextual problems that require the generation of multiple solution strategies. This process stimulates fluency and flexibility, as students are encouraged to explore alternative pathways rather than rely on single procedural solutions. PBL also promotes reasoning by requiring students to formulate hypotheses, test their ideas, and justify their conclusions, thereby supporting the development of logical and structured thinking.

Second, the STAD model reinforces these cognitive processes through structured collaboration. By working in groups, students are required to articulate their ideas, compare them with those of their peers, and refine their reasoning. This interaction enhances originality in creative thinking and strengthens mathematical reasoning, as students must explain, defend, and evaluate different solution strategies. In parallel, the structured nature of STAD promotes positive interdependence and individual accountability, which are critical for developing collaboration skills. Students are encouraged to contribute actively, support one another, and take responsibility for group outcomes, resulting in more effective teamwork and interaction.

The integration of PBL further amplifies collaborative processes by presenting complex problems that cannot be solved individually. Such tasks require students to negotiate meaning, coordinate strategies, and construct shared understanding. Consequently, collaboration becomes a necessary

component of learning rather than a supplementary activity. This explains the observed improvement across multiple collaboration indicators, including contribution, team support, problem-solving, and group interaction.

The synergy between inquiry-based problem-solving and structured collaboration explains the overall improvement across cognitive and social competencies. PBL provides the cognitive demand necessary to stimulate idea generation and reasoning, while STAD offers the social structure for refining and validating those ideas. In addition, the shift from teacher-centered to student-centered learning increases student autonomy and engagement, leading to deeper cognitive processing.

The results of the paired-samples t-test further confirm that these improvements are statistically significant ($p < .001$), indicating that the instructional intervention contributed meaningfully to the development of creative thinking, mathematical reasoning, and collaboration skills. These findings are consistent with previous studies showing that Problem-Based Learning (PBL) improves students' mathematical reasoning through structured problem-solving activities ³¹. PBL has also been reported to produce higher mathematical reasoning outcomes than conventional instruction, particularly when students are actively involved in contextual mathematical tasks ³². In addition, cooperative learning models such as STAD have been found to significantly enhance students' mathematical reasoning through structured group interaction and peer discussion ³³. Previous research also shows that PBL supports the development of creative thinking by engaging students in real-world problem-solving scenarios that require critical and creative responses ³⁴. The combination of inquiry-driven tasks and collaborative learning environments further strengthens students' ability to generate, refine, and evaluate ideas ³⁵. Empirical evidence also indicates that PBL can improve students' collaboration and communication skills because students are required to discuss ideas, negotiate solutions, and solve problems

³¹ Fitriyah et al., "Meta Analysis Study," 40.

³² Asmara Desi et al., "Pengaruh Model Pembelajaran Problem Based Learning (PBL) Berbantuan Media Wordwall Terhadap Kemampuan Penalaran Matematis Peserta Didik Kelas IV," *Arus Jurnal Sosial Dan Humaniora*, ahead of print, December 21, 2024, <https://doi.org/10.57250/ajsh.v4i3.742>.

³³ Lailatuz Zahra et al., "Pengaruh Model Pembelajaran Kooperatif Tipe STAD (Student Team Achievement Division) Terhadap Kemampuan Penalaran Matematis Siswa Kelas XI MIPA SMAN 3 Mukomuko," *Jurnal Pendidikan Tambusai* 7, no. 2 (2023): 14428-36, <https://doi.org/10.31004/jptam.v7i2.8682>.

³⁴ Kardoyo et al., "Problem-Based Learning Strategy: Its Impact on Students' Critical and Creative Thinking Skills," *European Journal of Educational Research* 9, no. 3 (2020): 1145, <https://doi.org/10.12973/eu-jer.9.3.1141>.

³⁵ Yulisman and Usmeldi, "Praktikalitas Pengembangan Buku Siswa dengan Model Problem Based Learning Ber-integrasi Kemampuan Berfikir Kreatif untuk Meningkatkan Kreativitas Peserta Didik SMA," 168.

collectively³⁶. Similarly, STAD support collaboration through group accountability, cooperative problem-solving, and structured peer interaction³⁷.

However, this study extends previous research in several important ways. Prior studies tend to examine PBL or STAD separately or focus on a single competency. In contrast, this study integrates both models within a single instructional framework and examines creative thinking, mathematical reasoning, and collaboration skills simultaneously. Furthermore, the study is conducted in the context of trigonometry learning at the senior high school level, providing a more comprehensive perspective on the multidimensional impact of integrated learning models.

Despite these contributions, several limitations should be acknowledged. The use of a pre-experimental design without a control group limits the ability to establish strong causal relationships. The relatively small sample size and focus on a single class may affect the generalizability of the findings. In addition, the short duration of the intervention may not fully capture the long-term impact of the PBL-STAD approach.

Future research is recommended to employ experimental or quasi-experimental designs with larger samples and comparison groups to validate these findings. Further studies may also explore the long-term effects of the PBL-STAD integration and its applicability across different mathematical topics and educational levels. Nevertheless, the findings provide important implications for mathematics education. The integration of PBL and STAD creates a learning environment that simultaneously promotes cognitive development and collaborative engagement. This approach not only enhances students' ability to generate ideas and construct logical arguments but also strengthens essential 21st-century skills. Therefore, the PBL-STAD model can be considered an effective alternative for teaching complex and abstract topics such as trigonometry.

Conclusion

The results of this study show that combining the STAD model with PBL strongly influences students' creative thinking, mathematical reasoning, and collaboration skills in trigonometry. The notable gains in posttest scores in these three domains indicate that this instructional design effectively promotes both cognitive and interpersonal competencies. By integration structured cooperative learning and problem-solving activities, the approach strengthened students' grasp of trigonometric concepts and nurtured their

³⁶ Putri et al., "Students' Collaboration and Communication Skills with Problem-Based Learning Model," 225.

³⁷ Fitriani and Jailani, "Pengaruh Pembelajaran Kooperatif Tipe STAD Dengan Pendekatan Saintifik Terhadap Berpikir Kritis, Kecerdasan Emosional Dan Kolaborasi," 2499.

capacity to generate ideas and work productively with others. These findings underscore the need for innovative, learner-centered teaching that equips students with critical skills for academic achievement and real-world problem-solving, and offer implications for teachers designing more engaging and effective mathematics learning environments.

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