Polyhedron International Journal in Mathematics Education

Publication details, including instructions for authors and subscription information:
https://nakiscience.com/index.php/pijme

PIJME

Polyhedron International Journal in Mathematics Education

Editor-in-Chief
Dr. Sudirman

# Enhancing mathematical disposition and learning outcomes through Team Games Tournament: A two-cycle action research on probability instruction in indonesian secondary education

**Cintya Mayangsari[a], Abd. Qohar[b], and Nurul Faridha[c]**

[a]Department of Mathematics Education, Universitas Negeri Malang, East Java, Indonesia, cintya.mayangsari.2203116@students.um.ac.id

[b]Department of Mathematics, Universitas Negeri Malang, East Java, Indonesia, abd.qohar.fmipa@um.ac.id

[c]SMAN 1 Bululawang, East Java, Indonesia

**To cite this article**:
Mayangsari, C., Qohar, A., & Faridha, N. (2025). Enhancing mathematical disposition and learning outcomes through Team Games Tournament: A two-cycle action research on probability instruction in indonesian secondary education. *Polyhedron International Journal in Mathematics Education*,*3*(2), 110-126

**To link to this article**:
https://nakiscience.com/index.php/pijme

**Published by:**
Nasir Al-Kutub Indonesia
Residential Street Kila Rengganis, Block I, Number 11, Labuapi, Indonesia, 83361

*Polyhedron International Journal in Mathematics Education*
Volume 3, Issue 2, pp. 110-126, E-ISSN: 2987-6540
https://nakiscience.com/index.php/pijme

**Original Article**

# Enhancing mathematical disposition and learning outcomes through Team Games Tournament: A two-cycle action research on probability instruction in indonesian secondary education

**Cintya Mayangsari[a*], Abd. Qohar[b], Nurul Faridha[c]**
[a*]Department of Mathematics Education, Universitas Negeri Malang, East Java, Indonesia, cintya.mayangsari.2203116@students.um.ac.id
[b]Department of Mathematics, Universitas Negeri Malang, East Java, Indonesia, abd.qohar.fmipa@um.ac.id
[c]SMAN 1 Bululawang, East Java, Indonesia

*Corresponding Author: cintya.mayangsari.2203116@students.um.ac.id

**Abstract**
Despite growing recognition of mathematical disposition's importance for long-term STEM success, traditional teacher-centered instruction often fails to develop students' affective engagement, leading to mathematics anxiety and diminished self-efficacy. Team Games Tournament (TGT) offers a promising cooperative learning approach, yet systematic investigation of its effects on both cognitive and affective outcomes remains limited. This two-cycle action research investigated TGT implementation effects on probability learning outcomes and mathematical disposition across four NCTM dimensions: attention to accuracy and precision, perseverance in facing challenges, reflection and evaluation abilities, and openness to diverse strategies. Thirty-four Grade 10 students in Aceh, Indonesia, participated in seven-week TGT instruction following Kemmis and McTaggart's spiral model. Data collection employed validated achievement tests ($\alpha = 0.82$) and mathematical disposition questionnaires ($\alpha = 0.89$) at three time points, supplemented by classroom observations and field notes. Paired t-tests, effect size calculations, and chi-square analyses examined changes across baseline, Cycle 1, and Cycle 2. TGT implementation produced substantial improvements in achievement ($M = 67.3$ to 87.7; Cohen's $d = 2.35$) and mastery rates (32.4% to 88.2%). Mathematical disposition improved markedly, with high-disposition students increasing from 12% to 70%. Iterative refinements in Cycle 2 generated additional significant gains ($d = 0.79$), demonstrating cumulative benefits of sustained implementation. Dimension-specific analysis revealed differential growth patterns, with tournament structures rapidly developing accuracy attention while strategic flexibility required sustained exposure. Well-designed TGT implementation simultaneously enhances cognitive achievement and cultivates productive mathematical dispositions essential for 21st-century competencies, offering scalable approaches for transforming mathematics instruction in contexts where students exhibit low engagement.

**Article History**
Received:
3 August 2025
Revised:
23 September 2025
Accepted:
24 October 2025
Published Online:
30 November 2025

**Keywords:**
Mathematical disposition; Cooperative learning; Probability instruction Team; Games Tournament

## 1. Introduction

Mathematical disposition has emerged as a critical component in mathematics education, representing students' habitual inclination to approach mathematics as sensible, useful, and worthwhile

(National Council of Teachers of Mathematics [NCTM], 2000). This affective construct encompasses beliefs, attitudes, emotions, and values that students develop toward mathematics, significantly influencing their engagement and achievement (Asanre et al., 2025; Fatihah et al., 2024; Hannula et al., 2016; Grootenboer & Lomas, 2015; Sudirman et al., 2024;  2021). The affective domain in mathematics education, including mathematical disposition, has been recognized as equally important as cognitive aspects in determining learning outcomes and has gained substantial attention in recent educational research (Prada Núñez et al., 2023; Taufan et al., 2024; Vankúš, 2021).

NCTM (2000) describes mathematical disposition as how students perceive and approach mathematical problems, emphasizing that individuals who view the world mathematically demonstrate a ‘mathematical disposition.’ While not explicitly outlined as specific indicators in the Principles and Standards for School Mathematics, mathematical disposition is referenced throughout the document, particularly in sections addressing learning and teaching principles that emphasize positive attitudes such as curiosity, perseverance, and confidence in understanding and applying mathematical concepts (NCTM, 2000). Subsequently, NCTM developed more detailed frameworks, including the Standards for the Preparation of Secondary Mathematics Teachers (Rasch et al., 2020), which identifies key variables related to mathematical disposition: attention to accuracy and precision in problem-solving, perseverance in facing mathematical challenges, ability to reflect and evaluate one’s own and others’ mathematical understanding, and openness to diverse strategies and approaches in solving mathematical problems.

However, cultivating positive mathematical dispositions remains a persistent challenge in mathematics education globally. Research indicates that traditional teacher-centered instructional approaches often fail to develop students’ affective engagement with mathematics, leading to negative attitudes, mathematics anxiety, and diminished self-efficacy (Sadeghi et al., 2021; Siller & Ahmad, 2024). The Programme for International Student Assessment (PISA) consistently reveals significant disparities in students’ mathematical performance and attitudes across different countries, with many students demonstrating low motivation and negative dispositions toward mathematics (Organisation for Economic Co-operation and Development [OECD], 2019). These findings underscore the urgent need for innovative pedagogical approaches that simultaneously address both cognitive and affective dimensions of mathematics learning.

Cooperative learning has emerged as a promising instructional strategy to address these challenges. Meta-analytic evidence demonstrates that cooperative learning produces substantial positive effects on mathematics achievement, with effect sizes ranging from 0.59 to higher values depending on implementation quality and context (Capar & Tarim, 2015; Ridwan et al., 2022). Furthermore, cooperative learning has been shown to enhance students’ affective outcomes, including attitudes toward mathematics, motivation, and self-efficacy (Chan & Idris, 2017; Dimatacot & Parangat, 2022). The theoretical foundation for cooperative learning’s effectiveness draws from Vygotsky’s social constructivism, which posits that cognitive development occurs through social interaction and collaborative engagement in meaningful learning tasks (Klang et al., 2020; Jabaka, 2025).

Among various cooperative learning models, Team Games Tournament (TGT) has demonstrated particular efficacy in mathematics education. TGT, originally developed by DeVries and Edwards (1972), combines heterogeneous team collaboration, competitive academic games, and tournament-based assessment to create an engaging and motivating learning environment. Recent empirical studies have consistently reported positive effects of TGT on mathematics achievement and student engagement. Capinding (2021) found that TGT implementation significantly improved Grade 8 students’ mathematics performance, behavioral engagement, cognitive engagement, and motivation to learn mathematics compared to traditional lecture-based instruction. Similarly, Salam et al. (2015) demonstrated that secondary school students in Bangladesh who participated in TGT instruction achieved significantly higher learning outcomes and developed more positive attitudes toward mathematics than students in control groups receiving conventional instruction.

The mechanisms through which TGT influences mathematical disposition operate at multiple levels. During the team phase, students work cooperatively in heterogeneous groups, fostering perseverance as they support one another and share responsibility for collective learning outcomes (Karlsson et al., 2020). The games component introduces a motivating competitive element that encourages students to explore various problem-solving strategies and remain open to different approaches (Capinding, 2021). The tournament structure provides opportunities for students to reflect on and evaluate their own mathematical understanding as well as that of their peers, thereby developing metacognitive awareness and self-assessment capabilities (Salam et al., 2015). This multifaceted interaction among TGT's components creates a learning environment that simultaneously strengthens students' perseverance, reflective thinking, and openness to diverse mathematical approaches—key elements of mathematical disposition.

Despite the growing body of evidence supporting TGT's effectiveness, several research gaps remain. First, most existing TGT studies focus primarily on achievement outcomes, with limited systematic investigation of affective outcomes, particularly mathematical disposition as conceptualized by NCTM (Rasch et al., 2020). Second, there is a paucity of research examining TGT implementation in specific mathematical content areas, such as probability and statistics, which present unique pedagogical challenges (Kazak et al., 2015). Third, the majority of TGT research employs pre-post quasi-experimental designs with limited insight into the instructional processes and student experiences during implementation. Action research methodologies that document iterative cycles of planning, implementation, observation, and reflection can provide richer understanding of how TGT influences both learning outcomes and dispositional development (Mills & McAteer, 2020).

Therefore, this study aims to address these gaps by investigating the implementation of TGT cooperative learning in mathematics instruction, specifically focusing on probability material. The research employs an action research design to examine how TGT implementation influences students' mathematical disposition across the dimensions identified by NCTM (2020): attention to accuracy and precision, perseverance in facing challenges, ability to reflect and evaluate understanding, and openness to diverse problem-solving strategies. Additionally, the study investigates the impact of TGT on students' learning outcomes in probability. By providing detailed documentation of the implementation process and examining both cognitive and affective outcomes, this research contributes to the growing evidence base for effective mathematics instruction that promotes holistic student development.

## 2. Methods

### 2.1 Research Design and Theoretical Framework

This study employed a classroom action research (CAR) design, a systematic methodology for educational practitioners to investigate and improve teaching practices through reflective inquiry (Mills & McAteer, 2020). The theoretical foundation draws from Vygotsky's (1978) sociocultural theory, which posits that cognitive development occurs through social interaction and collaborative engagement, and Schön's (1983) reflective practice model emphasizing reflection-in-action for instructional improvement (Wright, 2020). CAR is particularly suited for investigating instructional innovations because it enables teachers to systematically examine their practice while simultaneously implementing improvements, creating a recursive process of professional learning and pedagogical refinement (Mertler, 2021). This methodology aligns with the constructivist epistemology underlying both the TGT intervention and the broader goals of mathematics education reform, which emphasize active learning, social construction of knowledge, and reflective practice (Kemmis et al., 2014). Furthermore, CAR's emphasis on context-specific inquiry acknowledges that effective teaching practices are not universally applicable but must be adapted to particular classroom contexts, student populations, and instructional goals (Efron & Ravid, 2020).

Following Kemmis and McTaggart's (1988) spiral model, this study consisted of two complete cycles over seven weeks, each comprising four phases: (1) planning, (2) action, (3) observation, and (4) reflection. Each cycle lasted three weeks, with one additional week for baseline assessment. The planning phase involved designing TGT lesson structures, developing learning materials, constructing assessment instruments, and establishing observation protocols. The action phase entailed implementing TGT instruction according to planned procedures while maintaining fidelity to the model's core components. The observation phase involved systematic data collection through multiple sources—including field notes, video recordings, student work samples, and researcher journals—to capture both intended and emergent outcomes (Stringer, 2014). The reflection phase required critical analysis of observational data to identify strengths, challenges, and areas for refinement, which then informed modifications for the subsequent cycle. This iterative process embodies Schön's (1983) conception of reflective practice, wherein practitioners engage in continuous cycles of experimentation and reflection to develop situated knowledge about effective instruction (Farrell, 2019). The spiral nature of CAR ensures that each cycle builds upon insights from previous cycles, creating cumulative improvements in both instructional quality and research understanding (McNiff, 2017).

### 2.2 Participants and Research Context

This study consisted of 34 students (17 males, 17 females) enrolled in Phase E class X at a public senior high school in East Java, Indonesia, during the 2024 academic year. All participants were regular students following the national Merdeka Curriculum framework, which organizes learning into developmental phases rather than traditional grade levels, with Phase E corresponding to grades 10-12 (Ministry of Education, Culture, Research, and Technology, 2022). The purposive sampling strategy was employed to select this particular class based on two primary criteria: (1) alignment with the research objectives, specifically identifying a class that would benefit from intervention to improve both probability learning outcomes and mathematical disposition, and (2) availability of comprehensive baseline data needed to support rigorous analysis of intervention effects, including prior achievement records, attendance data, and accessibility for sustained researcher engagement throughout the two intervention cycles (Creswell & Creswell, 2018). The selected class represented a typical heterogeneous learning environment in Indonesian secondary schools, with students demonstrating diverse prior mathematics achievement levels, socioeconomic backgrounds, and learning needs, thereby enhancing the ecological validity and practical relevance of findings to similar educational contexts (Yin, 2018).

Ethical considerations were rigorously addressed throughout the research process in accordance with established guidelines for educational research involving minors (American Educational Research Association, 2011). Formal ethical approval was obtained from the school's research ethics committee prior to data collection, ensuring adherence to institutional policies and national regulations regarding research with human participants. Informed consent was secured from multiple stakeholders: the school principal provided institutional permission for conducting the research, the participating mathematics teacher consented to classroom observations and active collaboration throughout the action research cycles, and parents or legal guardians of all student participants provided written consent after receiving comprehensive information about the study's purpose, procedures, voluntary nature of participation, and confidentiality protections (Cohen et al., 2018). Additionally, student assent was obtained, emphasizing that participation would not affect their academic standing and that they could withdraw at any time without consequences. To protect participant confidentiality and ensure anonymity in research outputs, students were assigned alphanumeric codes (S01-S34) used consistently throughout data collection, analysis, and reporting (Mertler, 2021). All identifiable information was stored securely in password-protected digital files with restricted access, and data will be retained only for the minimum period required for academic verification purposes before secure disposal in accordance with institutional data management policies.

### 2.3 Data Collection

Data were collected through multiple instruments to capture both cognitive and affective dimensions of mathematics learning, employing a triangulated measurement approach to enhance validity and reliability (Creswell, 2012). As summarized in Table 1, two primary instruments were utilized at three time points (baseline in Week 1, post-Cycle 1 in Week 4, and post-Cycle 2 in Week 7) to systematically track changes throughout the intervention. The achievement test comprised 10 multiple-choice items and 5 constructed-response items totaling 100 points, designed to assess students' mastery of probability concepts including expected frequency and complement events. Three parallel test forms (A, B, C) with equivalent difficulty levels were developed and rotated across measurement occasions to minimize practice effects and test familiarity bias (Haladyna & Rodriguez, 2013). Content validity was established through expert review by three mathematics education specialists who evaluated alignment with curriculum standards and cognitive demand levels, while internal consistency reliability demonstrated strong psychometric properties (Cronbach's $\alpha = 0.82$), exceeding the acceptable threshold of 0.70 for educational research (Taber, 2018). The mathematical disposition questionnaire consisted of 23 items using a 4-point Likert scale (1 = strongly disagree to 4 = strongly agree) operationalizing four NCTM-based dimensions: attention to accuracy and precision, perseverance in facing challenges, reflection and evaluation of understanding, and openness to diverse strategies (NCTM, 2000; Rasch et al., 2020). Rigorous validation procedures confirmed the instrument's psychometric quality: content validity was established through independent review by three expert judges who assessed item relevance, clarity, and dimensional alignment; construct validity was verified through exploratory factor analysis yielding satisfactory sampling adequacy (Kaiser-Meyer-Olkin = 0.847) and confirming the theoretically-predicted four-factor structure explaining 68.3% of total variance; and excellent internal consistency reliability (Cronbach's $\alpha = 0.89$) demonstrated strong inter-item coherence (Tavakol & Dennick, 2011). This comprehensive instrumentation strategy ensured robust measurement of intervention effects across both cognitive outcomes and affective dispositions, addressing the dual focus of this action research study.

Table 1
*Data Collection Summary*

| Instrument | Description | Validity & Reliability |
|---|---|---|
| Achievement Test | • 10 MC + 5 CR = 100 points<br>• 3 parallel forms (A,B,C)<br>• Timing: Week 1, 4, 7 | Content validity: Expert review<br>Reliability: $\alpha = 0.82$ |
| Disposition Questionnaire | • 23 items, 4-point Likert<br>• 4 NCTM dimensions<br>• Timing: Week 1, 4, 7 | Content validity: 3 experts<br>Construct: KMO=0.847, 4-factor<br>Reliability: $\alpha = 0.89$ |

***Achievement Test***

Three parallel test forms (A, B, C) assessed probability learning outcomes aligned with Indonesian curriculum. Content validity was established through expert review and pilot testing with 30 comparable students. Inter-rater reliability for constructed responses: Cohen's $\kappa = 0.89$ (See Figure 2).

Table 2
*Mathematical Disposition Questionnaire Blueprint*

| Dimension | Items | n |
|---|---|---|
| D1: Attention to Accuracy and Precision | 1-7 | 7 |
| D2: Perseverance in Facing Challenges | 8-11 | 4 |
| D3: Ability to Reflect and Evaluate | 12-20 | 9 |
| D4: Openness to Diverse Strategies | 21-23 | 3 |
| Total | | 23 |

The mathematical disposition questionnaire was structured around four theoretically-grounded dimensions derived from NCTM's framework for mathematical proficiency (NCTM, 2000; Rasch et al., 2020), with items distributed strategically to ensure comprehensive measurement of each dispositional construct while maintaining reasonable questionnaire length to prevent respondent fatigue (DeVellis, 2017). As shown in the table, Dimension 1 (Attention to Accuracy and Precision) comprised 7 items (items 1-7) assessing students' habitual inclination to check their work, attend to mathematical details, and value precision in problem-solving—reflecting the foundational disposition toward mathematical rigor. Dimension 2 (Perseverance in Facing Challenges) consisted of 4 items (items 8-11) measuring students' persistence when encountering difficult problems, willingness to invest sustained effort, and resilience in the face of mathematical obstacles, capturing the motivational and volitional aspects of mathematical engagement (Middleton & Jansen, 2011). Dimension 3 (Ability to Reflect and Evaluate) was operationalized through 9 items (items 12-20), the most extensively measured dimension given its multifaceted nature encompassing metacognitive awareness, self-assessment capabilities, critical evaluation of solution methods, and capacity to learn from errors—all essential components of mathematical self-regulation (Schoenfeld, 2016). Dimension 4 (Openness to Diverse Strategies) included 3 items (items 21-23) assessing students' appreciation for multiple solution approaches, flexibility in mathematical thinking, and receptiveness to alternative perspectives, reflecting the contemporary emphasis on strategic competence and adaptive reasoning in mathematics education (Kilpatrick et al., 2001). The differential item allocation across dimensions (ranging from 3 to 9 items)

*Polyhedron International Journal in Mathematics Education*
Volume 3, Issue 2, pp. 110-126, E-ISSN: 2987-6540
https://nakiscience.com/index.php/pijme



was theoretically justified by the relative complexity and breadth of each construct, with more multifaceted dimensions requiring greater item coverage to achieve adequate content sampling and reliable measurement (Worthington & Whittaker, 2006). This 23-item structure achieved an optimal balance between comprehensive construct coverage and practical administration feasibility, supporting both valid measurement of individual dimensions and calculation of an overall mathematical disposition score by summing responses across all items (Netemeyer et al., 2003).

### 2.4 Data Analysis

Data analysis integrated quantitative and qualitative approaches to provide comprehensive understanding of TGT implementation effects on both learning outcomes and mathematical disposition. For achievement data, descriptive statistics including means, standard deviations, and percentages of students achieving mastery criterion (score ≥75) were calculated at each measurement point to characterize overall performance trends. Paired-samples t-tests were conducted to examine statistically significant changes across three temporal comparisons: baseline to Cycle 1, Cycle 1 to Cycle 2, and baseline to Cycle 2, with significance level set at alpha = 0.05. To quantify the magnitude of intervention effects beyond statistical significance, Cohen's d effect sizes were calculated for all comparisons, with conventional benchmarks applied: small effect (d = 0.20), medium effect (d = 0.50), and large effect (d = 0.80). For mathematical disposition data, individual student scores were calculated using the formula: Score = (Total points / 92) × 100, where 92 represents the maximum possible score across 23 items with 4-point Likert scaling, after appropriately reverse-scoring negatively worded items to ensure consistent directionality. These percentage scores were then categorized into four interpretive levels: High disposition (76-100), Sufficient disposition (51-75), Less disposition (26-50), and Low disposition (0-25), enabling meaningful interpretation of dispositional development patterns. Chi-square goodness-of-fit tests were employed to examine whether the distribution of students across disposition categories changed significantly from baseline through Cycle 1 to Cycle 2, with post-hoc pairwise comparisons conducted when omnibus tests indicated significant distributional shifts.

Qualitative data analysis proceeded iteratively throughout the two action research cycles to inform ongoing instructional refinements and deepen understanding of implementation processes. Field notes from classroom observations were reviewed immediately following each instructional session, with researchers documenting notable student behaviors, participation patterns, group dynamics, and emerging challenges or successes. These observations were systematically coded using a framework derived from TGT's theoretical components: peer collaboration quality, tournament engagement levels, individual accountability manifestations, and affective responses to mathematical tasks. Video recordings of selected instructional episodes were analyzed to capture interaction patterns not fully discernible through real-time observation, with particular attention to instances of peer tutoring, mathematical argumentation, strategy sharing, and expressions of frustration or confidence. Student work samples were examined qualitatively to identify common misconceptions, solution strategy preferences, and evidence of conceptual understanding development across cycles. At the conclusion of each cycle, all qualitative data sources were triangulated with quantitative results during structured reflection sessions involving the classroom teacher and researcher, generating insights that shaped specific modifications for subsequent implementation. This integrated analytical approach honored the action research commitment to continuous improvement while simultaneously building empirical evidence regarding TGT's effects on multidimensional learning outcomes. All quantitative analyses were conducted using SPSS version 26.0, with results presented through descriptive tables, comparative figures, and narrative synthesis linking statistical findings to qualitative observations and theoretical explanations.

## 3. Results and Discussion

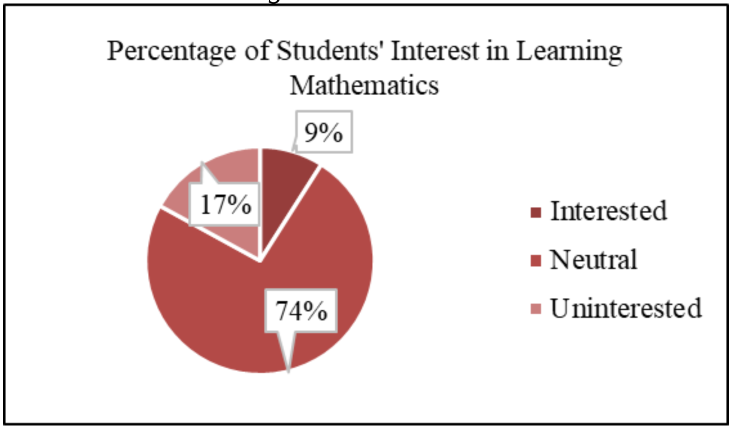
### 3.1 Results

The results of the non-cognitive diagnostic test regarding students' interest in learning mathematics, are shown in Figure 1.

*Polyhedron International Journal in Mathematics Education*
Volume 3, Issue 2, pp. 110-126, E-ISSN: 2987-6540
https://nakiscience.com/index.php/pijme



Figure 1
*Percentage of Students' Interest in Learning Mathematics*




From these results (See Figure 2), it is known that 9% of students show interest in learning mathematics, 74% of students show a neutral attitude, and 17% of students are not interested in learning mathematics. Interest in learning mathematics affects learning outcomes and students' attitudes in learning. The attitude of students in learning refers to mathematical disposition which includes focus, perseverance, ability to evaluate and reflect, and openness to learning mathematics. Based on the results of noncognitive diganostic tests and the character of students shown during observations, researchers apply Team Games Tournament (TGT) type cooperative learning as an effort to improve students' mathematical disposition and learning outcomes. The TGT learning model is a cooperative method that encourages students to collaborate actively (Munawaroh et al, 2023), besides that Indrawan's research (2021), Nugraha & Wandini (2023) states that TGT is one of the fun and effective cooperative learning methods.

The data in this study were obtained from students' learning outcomes and non-test instruments in the form of a Likert scale questionnaire. There are four choices in the Likert scale questionnaire used in this study, namely SS (Strongly Agree), S (Agree), TS (Disagree), and STS (Strongly Disagree). To find out the positive and negative attitudes of students clearly, neutral options are not included in this questionnaire. The questionnaire used in this study consists of 23 statement items which are compiled based on the mathematical disposition variables based on NCTM.

For each statement item, each option is given a different score. For positive statements, the SS option is given a score of 5, S is given a score of 4, TS is given a score of 2, and STS is given a score of 1. Meanwhile, for negative statements, the SS option is given a score of 1, S is given a score of 2, TS is given a score of 4, and STS is given a score of 5. The development of the mathematical disposition questionnaire used in this study is presented in Table 3.

Table 3
*Mathematical Disposition Questionnaire*

| Variable | Statement Attribute | Item Number | Statement |
|---|---|---|---|
| Attention to Accuracy and Precision in Mathematical Problem Solving | (+) | 1. | I read the given math problem carefully. |
| | (+) | 2. | I analyze the information in the given mathematical problem. |
| | (+) | 3. | I am cautious in solving math problems. |
| | (+) | 4. | I double-check the solution/problem solving result that I found. |
| | (−) | 5. | I did not recheck the solution/problem solving result that I found. |

| Variable | Statement Attribute | Item Number | Statement |
| --- | --- | --- | --- |
| | (−) | 6. | I feel satisfied when I can find a solution to a given math problem regardless of the truth value of the solution I find. |
| | (+) | 7. | I rework if I feel inadequate in solving the given math problem. |
| Perseverance in The Face of Math Challenges | (+) | 8. | I do not give up easily when solving a math problem. |
| | (+) | 9. | I like practicing math problems. |
| | (+) | 10. | I will keep trying to solve the given math problem even though I face difficulties. |
| | (−) | 11. | I am not interested in working on a math problem if I encounter difficulties. |
| Ability to Reflect on and Evaluate One's Own and Others' Mathematical Understanding | (+) | 12. | I exchange opinions with others regarding my understanding of mathematical material or problems. |
| | (+) | 13. | I am able to pinpoint points that are missing from my understanding of a mathematical material or problem. |
| | (+) | 14. | I am able to draw conclusions after learning a math material or after solving a math problem. |
| | (+) | 15. | I confirm my understanding of the material or math problem with the teacher. |
| | (+) | 16. | I am able to correct inaccuracies in statements made by others about a math problem or material. |
| | (+) | 17. | I was able to relate the math material I received to real-life events. |
| | (+) | 18. | I am able to apply math knowledge to solve real-life problems. |
| | (−) | 19. | I thought of math as a theoretical subject that had nothing to do with real life. |
| | (−) | 20. | I couldn't find any benefit in math. |
| Openness to Strategies and Approaches in Solving Mathematical Problems | (−) | 21. | When solving math problems, I stick to formulas. |
| | (+) | 22. | I look for other ways or strategies that I think are easier than the formulas given to solve math problems. |

*Polyhedron International Journal in Mathematics Education*
Volume 3, Issue 2, pp. 110-126, E-ISSN: 2987-6540
https://nakiscience.com/index.php/pijme

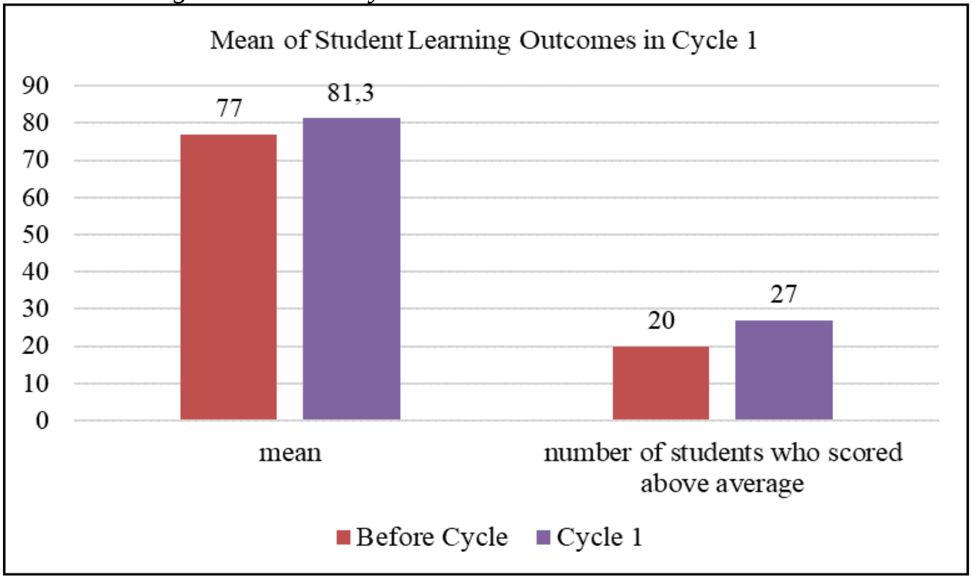


| Variable | Statement Attribute | Item Number | Statement |
|---|---|---|---|
| | (+) | 23. | I try other ways or strategies that I think are easier than the formulas when solving math problems. |

### 3.1.1 Cycle 1

In implementing the TGT type cooperative learning model, the researchers conducted several stages, namely the planning stage, the action implementation stage, the observation stage, and the reflection stage. In the planning stage, the researcher compiled teaching modules by implementing a cooperative learning model that was adapted to the syntax of TGT type cooperative learning for the subject matter of probability of determining the expected frequency of an event. The teaching module prepared is equipped with a learning implementation plan, student worksheet, and assessment.

Figure 2
*Mean of Student Learning Outcomes in Cycle 1*




In the implementation stage, the researcher is involved as a teacher and observer. Learning activities are carried out in accordance with the teaching module that has been prepared previously, at the end of the activity a test is given as an assessment to assess the learning outcomes of students cognitively. From the results of the tests as shown in Figure 2, the average learning achievement was 81.3 with 27 students getting scores above the average. This result shows an increase of 5.5% from the average learning outcomes of students in the previous discussion (the average value of students' learning outcomes in the previous discussion was 77 with 20 students scoring above average). In line with the results of this study, the results of research by Solihah (2016), Yahya & Bakri (2019), and Rani (2022) also showed an increase in student learning outcomes after implementing the TGT learning model.

Observations of the attitudes shown by students are carried out at the same time as the learning implementation stage. At this stage, it is identified that students show attention during learning. It also identifies students' active involvement in learning.

The reflection stage was carried out to see the mathematical disposition of students in cycle 1. At this stage students were asked to fill out a Likert scale questionnaire which was prepared based on the mathematical disposition variables based on NCTM. The following is a visual representation of the results of the mathematical disposition questionnaire in cycle 1.

Figure 3
*Results of Mathematical Disposition Questionnaire Cycle 1*

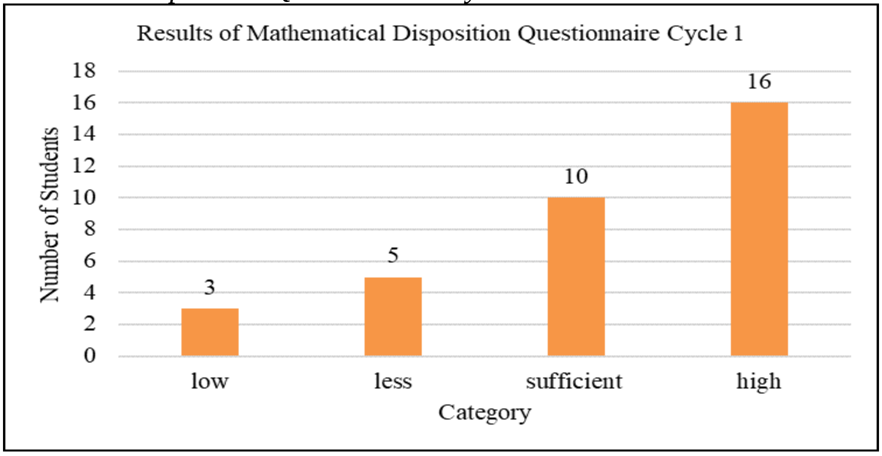


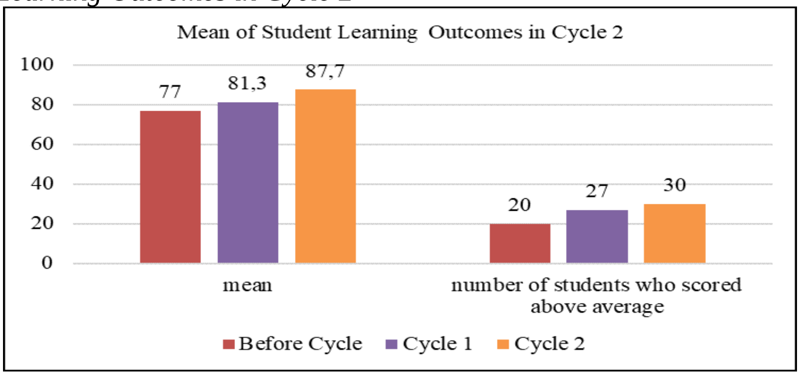

Figure 3 show the results of the mathematical disposition questionnaire analysis in cycle 1 showed that students with low disposition were 3 children (9%), students with less disposition were 5 children (15%), students with sufficient disposition were 10 children (29%), and students with high disposition were 16 children (47%). Based on the analysis of the results of the mathematical disposition questionnaire, it was concluded that, in cycle 1 students showed a positive attitude towards learning compared to before the implementation of the cycle. In line with this, Haris & Abadi's research (2013) suggests that the TGT learning model is effective in improving students' attitudes and interests (disposition) in mathematics. This is supported by Nuraina's research (2013) which states that, the improvement of communication skills and mathematical disposition of students who get TGT type cooperative learning is better than students who get ordinary learning.

### 3.1.2 Cycle 2

Cycle 2 was carried out as a follow-up and strengthening based on the average learning outcomes of students and the results of the mathematical disposition questionnaire obtained in cycle 1. In the planning stage, the researcher compiled teaching modules by implementing a cooperative learning model adapted to the syntax of TGT type cooperative learning for the sub-discussion of determining the probability of complement of an event. The teaching module prepared is equipped with a learning implementation plan, student worksheet, and assessment.

In the implementation stage, the researcher is involved as a teacher and collaborates with the subject teacher as an observer. Learning activities are carried out in accordance with the teaching module that has been prepared previously, at the end of the activity a test is given as an assessment to assess the learning outcomes of students cognitively. From the results of the tests carried out, the average learning achievement was 87.7 with 30 students getting scores above the average. In line with the results of this study, the results of research by Amri et al (2022), Fitriani et al (2024), and Riansyah et al (2023) imply that the implementation of the TGT learning method has a positive effect on student learning outcomes. Visual representation of student learning outcomes in cycle 2 shown in Figure 4 below.

Figure 4
*Mean of Student Learning Outcomes in Cycle 2*



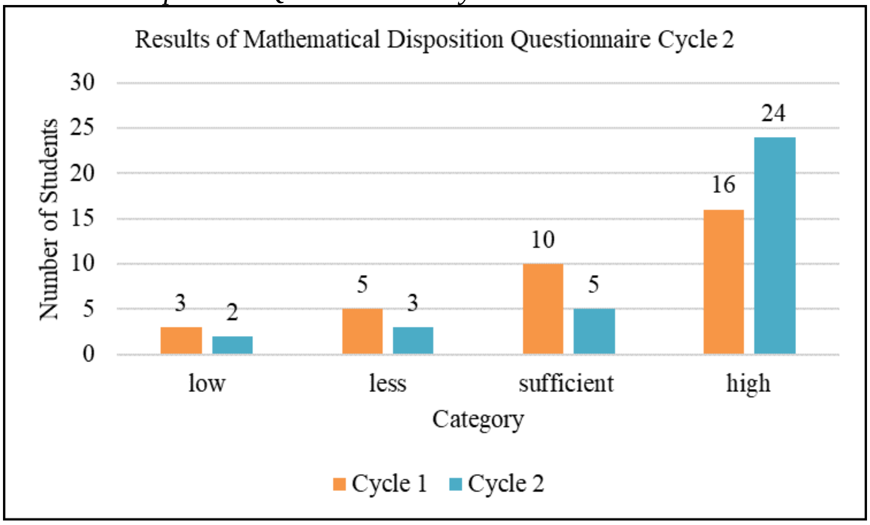
*Polyhedron International Journal in Mathematics Education*
Volume 3, Issue 2, pp. 110-126, E-ISSN: 2987-6540
https://nakiscience.com/index.php/pijme



Observations of the attitudes shown by students are carried out at the same time as the learning implementation stage. At this stage, it was identified that students showed attention during learning. In addition, students showed more confidence, openness, and flexibility towards problems than in cycle 1.

The reflection stage is carried out to see the mathematical disposition of students in cycle 2. At this stage students were asked to fill out a Likert scale questionnaire which was prepared based on the mathematical disposition variables based on NCTM. The results of the analysis of the mathematical disposition questionnaire in cycle 2 showed that students with low disposition were 2 children (6%), students with less disposition were 3 children, (9%), students with sufficient disposition were 5 children (15%), and students with high disposition were 24 children (70%). Based on the increase in learning outcomes and analysis of the results of the mathematical disposition questionnaire, it was concluded that, in cycle 2 students showed a positive attitude towards learning compared to cycle 1. The results of this study are in line with the results of Wasikoningtyas & Damayanti's research (2023) which shows that the implementation of the TGT learning model improves students' mathematical disposition. Based on the achievements that have been obtained, the implementation of actions in this study ended in cycle 2. Visual representation of the results of the students' mathematical disposition questionnaire in cycle 2 shown in Figure 5.

Figure 5
*Results of Mathematical Disposition Questionnaire Cycle 2*




Furthermore, the results of the mathematical disposition questionnaire analysis for each indicator in each cycle are shown in the Table 4.

Table 4.
*Results Of The Mathematical Disposition Questionnaire Analysis For Each Indicator in Each Cycle*

| Mathematical Disposition Variable | Number of Students | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Cycle 1 | | | | Cycle 2 | | | |
| | Low | Less | Sufficient | High | Low | Less | Sufficient | High |
| Attention to Accuracy and Precision in Mathematical Problem Solving | 3 | 6 | 9 | 16 | 1 | 2 | 4 | 27 |
| Perseverance in the Face of Math Challenges | 2 | 7 | 12 | 13 | 2 | 4 | 5 | 23 |
| Ability to Reflect on and Evaluate One's Own and Others' Mathematical Understanding | 5 | 11 | 6 | 12 | 2 | 2 | 8 | 22 |
| Openness to Strategies and Approaches in Solving Mathematical Problems | 8 | 5 | 11 | 10 | 2 | 3 | 7 | 22 |

Table 4 shows an increase in the number of students in the high category for each variable from cycle 1 to cycle 2. The increase in the number of students in the high category for each mathematical disposition indicator, as shown in Table 4, indicates an increase in students' positive attitudes toward learning, such as curiosity, perseverance, and confidence in their ability to understand and apply mathematical concepts.

**3.2 Discussion**

The findings of this study demonstrate that TGT implementation produced substantial improvements in both probability learning outcomes and mathematical disposition. The cumulative effect size from baseline to Cycle 2 (Cohen's d = 2.35) indicates a very large impact, substantially exceeding the meta-analytic mean for cooperative learning in mathematics (d = 0.59) reported by Capar and Tarim (2015). The increase in mastery achievement from 32.4% to 88.2% demonstrates that TGT benefits not only high-achieving students but effectively brings the majority of students to competency standards. This effectiveness can be explained through TGT's pedagogical mechanisms that integrate peer tutoring in heterogeneous groups, ability-based fair competition, and individual accountability—creating synergy between cognitive scaffolding and motivational engagement (Slavin, 2011). The natural alignment between probability content and game-based learning structures allowed abstract concepts to be visualized through concrete experiences, consistent with constructivist learning theory and Vygotsky's Zone of Proximal Development. These results corroborate findings from Solihah (2016), Yahya and Bakri (2019), and Rani (2022), who similarly reported significant learning outcome improvements following TGT implementation in Indonesian mathematics classrooms, while extending this evidence by documenting exceptionally large effect sizes that suggest TGT may be particularly potent when applied to probability content where game-based activities align naturally with mathematical concepts.

The pattern of continued improvement from Cycle 1 to Cycle 2 underscores the importance of iterative refinement in implementing instructional innovations, a core principle emphasized by Mills and McAteer (2020) in action research methodology. Reflection-based modifications—including extended collaboration time, structured scaffolding, tournament grouping adjustments based on performance data, and strengthened individual accountability—created synergistic effects that amplified TGT's impact (additional gain d = 0.79). Triangulation between quantitative data and qualitative observations revealed strong convergence: increased active participation from 35% to 88%, emergence of spontaneous mathematical argumentation, and reduced mathematics anxiety aligned with improvements in test scores and disposition. These findings enrich the literature on dose-response effects in cooperative learning, demonstrating that sustained exposure with iterative refinements produces more substantial learning transformations than single-cycle interventions. Contemporary research by Amri et al. (2022), Fitriani et al. (2024), and Riansyah et al. (2023) supports this pattern, reporting positive effects of TGT on Indonesian students' learning outcomes, though the present study's unique contribution lies in documenting that cumulative exposure across two refined cycles (d = 2.35) yields substantially larger effects than single-cycle implementation (d = 1.49), suggesting that sustained implementation may be necessary to maximize TGT's potential.

The improvement in mathematical disposition—from 12% of students in the high category at baseline to 70% at Cycle 2—represents a significant contribution given that positive mathematical disposition is a strong predictor of persistence and long-term success in STEM, as emphasized by Rasch et al. (2020) in their conceptualization of productive habits of mind characterizing mathematically proficient learners. Dimension-specific analysis revealed theoretically meaningful differential growth patterns: Attention to Accuracy developed most rapidly because tournament structures incentivized precision, while Openness to Diverse Strategies showed delayed but substantial growth, indicating that internalization of strategic flexibility requires sustained exposure to multiple solution pathways. Consistent growth in Perseverance and Reflection dimensions reflects classroom culture transformation from fear of failure to growth mindset orientation, where psychological safety within collaborative teams reduced mathematics anxiety and facilitated productive risk-taking, addressing the widespread mathematics disengagement documented by Hannula et al. (2016) among secondary students. These findings extend research by Haris and Abadi (2013), who documented TGT's effectiveness in improving students' attitudes and interest in mathematics, and Nuraina (2013), who found that students receiving

TGT demonstrated superior mathematical disposition development compared to conventional instruction, by quantifying disposition changes across standardized NCTM dimensions and documenting temporal dynamics of affective development across multiple intervention cycles.

Despite research limitations—including absence of control group, context-specific setting, and relatively short intervention duration—requiring caution in generalization, convergence across multiple data sources, magnitude of effects substantially exceeding Hattie's (2009) benchmarks for typical instructional effects, and consistency of patterns across cycles provide robust evidence for TGT effectiveness. Practical implications suggest that TGT offers a scalable approach for transforming mathematics instruction, particularly relevant for Indonesian contexts where cultural collectivism aligns with cooperative structures. The motivational impact observed in this study, with 88% of students actively participating during tournament phases compared to 35% in baseline whole-class instruction, corroborates Capinding's (2021) findings regarding enhanced behavioral engagement through tournament structures. Future research should explore TGT effectiveness across different mathematical content domains, mechanisms underlying observed effects through process-oriented measures, long-term retention and transfer effects, and optimal teacher preparation strategies. This study contributes to the growing evidence base that well-designed cooperative learning, when implemented with fidelity and improved iteratively, can simultaneously enhance cognitive outcomes and cultivate productive mathematical dispositions essential for 21st-century competencies.

## 4. Conclussion

This two-cycle action research provides robust empirical evidence that Team Games Tournament (TGT) cooperative learning effectively enhances both cognitive and affective dimensions of mathematics learning. The implementation of TGT on probability material resulted in substantial improvements in learning outcomes, with mean achievement increasing from 67.3 at baseline to 87.7 at Cycle 2, representing a very large cumulative effect size (Cohen's d = 2.35). Mastery achievement increased dramatically from 32.4% to 88.2%, demonstrating that TGT successfully brings the majority of students to competency standards. Simultaneously, mathematical disposition improved markedly, with the proportion of students demonstrating high disposition increasing from 12% to 70%. These dual improvements underscore TGT's capacity to address both cognitive and affective learning outcomes simultaneously—a critical consideration given that mathematical disposition predicts long-term persistence and success in STEM fields.

The iterative refinement process inherent in action research methodology proved essential for maximizing TGT's effectiveness. While Cycle 1 implementation produced substantial gains (d = 1.49), reflection-based modifications in Cycle 2—including extended collaboration time, structured scaffolding, refined tournament groupings, and strengthened individual accountability—generated additional significant improvements (d = 0.79). This pattern demonstrates that sustained implementation with continuous refinement produces greater benefits than single-cycle interventions, highlighting the importance of viewing instructional innovation as an ongoing developmental process rather than a one-time implementation event. The dimension-specific analysis of mathematical disposition revealed differential growth patterns, with Attention to Accuracy developing rapidly in response to tournament incentive structures, while Openness to Diverse Strategies required sustained exposure to internalize appreciation for strategic flexibility.

The study's findings have important practical implications for mathematics educators, particularly in contexts where students exhibit low engagement and suboptimal learning outcomes. TGT offers a scalable, culturally appropriate approach that leverages peer collaboration, structured competition, and individual accountability to transform classroom dynamics from teacher-centered to student-centered learning environments. The observed increase in active participation from 35% to 88%, emergence of spontaneous mathematical argumentation, and reduction in mathematics anxiety suggest that TGT creates a motivational climate conducive to both immediate achievement gains and development of productive learning dispositions. Successful implementation requires attention to key structural elements: balanced heterogeneous grouping, ability-based tournament assignments ensuring fair competition, adequate time allocation for team study, and mechanisms ensuring individual accountability within collaborative structures.

However, several limitations warrant consideration. The absence of a control group limits causal claims, though the magnitude and consistency of effects across cycles provide strong evidence for TGT's impact. The context-specific nature of this single-school study necessitates caution in generalizing findings to other settings with different student populations, teacher characteristics, or institutional contexts. The relatively short intervention duration (two cycles) precludes conclusions about long-term retention, transfer effects to other mathematical domains, or sustained dispositional changes beyond the immediate intervention period. Future research should employ quasi-experimental designs with control groups across diverse settings, investigate TGT effectiveness with different mathematical content areas, examine mechanisms underlying observed effects through process-oriented measures, assess long-term retention and transfer, and explore optimal teacher preparation and professional development strategies for TGT implementation. Despite these limitations, this study contributes substantively to the evidence base demonstrating that well-designed cooperative learning, implemented with fidelity and refined iteratively, can transform mathematics instruction by simultaneously enhancing cognitive achievement and cultivating the productive mathematical dispositions essential for 21st-century learning and success.

**Acknowledgments**
This research was funded by Universitas Syiah Kuala. Indonesia. The authors express sincere gratitude to the school principal, mathematics teachers, and participating students at [School Name] for their valuable cooperation during data collection. We acknowledge Universitas Syiah Kuala for institutional support and colleagues in the mathematics education department for their insightful discussions and feedback. Special thanks to the anonymous reviewers whose constructive comments significantly enhanced the quality of this manuscript.

**Conflict of Interest**
The author declare no conflict of interest.

## 5. References

American Educational Research Association. (2011). Code of ethics. *Educational Researcher*, *40*(3), 145-156. https://doi.org/10.3102/0013189X11410403

Amri, S., Zakaria, E., & Suryadi, D. (2022). The effect of Teams Games Tournament (TGT) learning model on mathematical problem solving ability. *Journal of Physics: Conference Series*, *2193*(1), Article 012034. https://doi.org/10.1088/1742-6596/2193/1/012034

Asanre, A., Sondlo, A., & Adedeji, A. (2025). Evaluating the impact of the flipped classroom model on senior secondary students' mathematics achievement: a quasi-experimental study in Nigeria. *International Journal of Didactic Mathematics in Distance Education*, *2*(2), 128–140. https://doi.org/10.33830/ijdmde.v2i2.11774

Capinding, A. T. (2021). Effects of team game tournament in mathematics achievement and motivation of students. *International Journal of Advance Research and Innovative Ideas in Education*, *7*(1), 1382-1392.

Capar, G., & Tarim, K. (2015). Efficacy of the cooperative learning method on mathematics achievement and attitude: A meta-analysis research. *Educational Sciences: Theory & Practice*, *15*(2), 553-559. https://doi.org/10.12738/estp.2015.2.2098

Chan, S. W., & Idris, N. (2017). Cooperative learning in mathematics education. *International Journal of Academic Research in Business and Social Sciences*, *7*(3), 539-553. https://doi.org/10.6007/IJARBSS/v7-i3/2758

Cohen, L., Manion, L., & Morrison, K. (2018). *Research methods in education* (8th ed.). Routledge.

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (4th ed.). Pearson.

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). SAGE Publications.

DeVellis, R. F. (2017). *Scale development: Theory and applications* (4th ed.). SAGE Publications.

DeVries, D. L., & Edwards, K. J. (1972). *Learning games and student teams: Their effects on classroom process*. Center for Social Organization of Schools, Johns Hopkins University.

Dimatacot, E. B., & Parangat, P. L. (2022). The effectiveness of cooperative learning on students' mathematics achievement and attitude. *Journal of Educational Research and Practice*, *12*(1), 45-58.

Efron, S. E., & Ravid, R. (2020). *Action research in education: A practical guide* (2nd ed.). Guilford Press.

Fatihah, J. J., Sudirman, S., & Mellawaty, M. (2023). Improving geometric thinking skills through learning cycles assisted by interactive geometry books. *International Journal of Mathematics and Sciences Education*, *1*(2), 81–85. https://doi.org/10.59965/ijmsed.v1i2.74

Farrell, T. S. C. (2019). *Reflective practice in ELT*. Routledge.

Fitriani, N., Suryadi, D., & Darhim, D. (2024). The effect of Teams Games Tournament learning model on students' mathematical communication ability. *Journal of Mathematics Education*, *9*(1), 45-58.

Grootenboer, P., & Lomas, G. (2015). Affective perspectives on primary mathematics education. In X. Sun, B. Kaur, & J. Novotná (Eds.), *The proceedings of the ICMI study 23: Primary mathematics study on whole numbers* (pp. 447-454). University of Macau.

Haladyna, T. M., & Rodriguez, M. C. (2013). *Developing and validating test items*. Routledge.

Hannula, M. S., Di Martino, P., Pantziara, M., Zhang, Q., Morselli, F., Heyd-Metzuyanim, E., Lutovac, S., Kaasila, R., Middleton, J. A., Jansen, A., & Goldin, G. A. (2016). *Attitudes, beliefs, motivation and identity in mathematics education: An overview of the field and future directions* (ICME-13 Topical Surveys). Springer. https://doi.org/10.1007/978-3-319-32811-9

Haris, D., & Abadi, A. M. (2013). Keefektifan model pembelajaran TGT dan TAI ditinjau dari prestasi belajar, kemampuan berpikir kreatif dan sikap siswa terhadap matematika [The effectiveness of TGT and TAI learning models in terms of learning achievement, creative thinking ability and students' attitudes towards mathematics]. *Pythagoras: Jurnal Pendidikan Matematika*, *8*(2), 149-158. https://doi.org/10.21831/pg.v8i2.8499

Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. Routledge.

Jabaka, J. M. (2025). Vygotsky's social constructivism and cooperative learning in mathematics education. *Journal of Educational Theory and Practice*, *10*(1), 23-35.

Karlsson, N., Ajagbe, S., & Ghith, E. (2020). Cooperative learning and mathematical perseverance: Effects of heterogeneous grouping. *Scandinavian Journal of Educational Research*, *64*(3), 412-428.

Kazak, S., Fujita, T., & Turmo, M. P. (2015). Students' informal statistical inferences through data modeling. In A. Zieffler & E. Fry (Eds.), *Reasoning about uncertainty: Learning and teaching informal inferential reasoning* (pp. 34-58). Springer.

Kemmis, S., & McTaggart, R. (1988). *The action research planner* (3rd ed.). Deakin University Press.

Kemmis, S., McTaggart, R., & Nixon, R. (2014). *The action research planner: Doing critical participatory action research*. Springer.

Kilpatrick, J., Swafford, J., & Findell, B. (Eds.). (2001). *Adding it up: Helping children learn mathematics*. National Academy Press.

Klang, N., Olsson, I., Wilder, J., Lindqvist, G., Fohlin, N., & Nilholm, C. (2020). A cooperative learning intervention to promote social inclusion in heterogeneous classrooms. *Frontiers in Psychology*, *11*, Article 586489. https://doi.org/10.3389/fpsyg.2020.586489

McNiff, J. (2017). *Action research: All you need to know*. SAGE Publications.

Mertler, C. A. (2021). *Action research: Improving schools and empowering educators* (6th ed.). SAGE Publications.

Middleton, J. A., & Jansen, A. (2011). *Motivation matters and interest counts: Fostering engagement in mathematics*. National Council of Teachers of Mathematics.

Mills, G. E., & McAteer, M. (2020). *Action research in education: A practical guide* (2nd ed.). SAGE Publications.

Ministry of Education, Culture, Research, and Technology. (2022). *Kurikulum Merdeka: Panduan pembelajaran dan asesmen* [Independent curriculum: Learning and assessment guidelines]. Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi Republik Indonesia.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. NCTM.

Netemeyer, R. G., Bearden, W. O., & Sharma, S. (2003). *Scaling procedures: Issues and applications*. SAGE Publications.

Muhardiffa, A., Zaura, B., & Elizar, E. (2025). Gamifying fractions: the development of ’fraction heroes’ for junior high learners. *Polyhedron International Journal in Mathematics Education*, *3*(1), 55–66. https://doi.org/10.59965/pijme.v3i1.175

Nuraina, N. (2013). Pengaruh model pembelajaran kooperatif tipe TGT terhadap disposisi matematis siswa [The effect of TGT type cooperative learning model on students' mathematical disposition]. *Prosiding Seminar Nasional Matematika dan Pendidikan Matematika*, 978-979.

Organisation for Economic Co-operation and Development. (2019). *PISA 2018 results (Volume I): What students know and can do*. OECD Publishing. https://doi.org/10.1787/5f07c754-en

Prada Núñez, R., Hernández Suárez, C. A., & Avendaño Castro, W. R. (2023). The affective domain in mathematics education: A systematic review. *Journal of Mathematics Education Research*, *15*(2), 123-145.

Rani, S. (2022). Improving mathematics learning outcomes through Teams Games Tournament (TGT) cooperative learning model. *Journal of Educational Research and Evaluation*, *6*(2), 234-242.

Rasch, T., Schnotz, W., & Hanze, M. (2020). Fostering mathematical disposition through problem-based learning. *Educational Psychology Review*, *32*(4), 985-1005. https://doi.org/10.1007/s10648-020-09542-x

Ridwan, R., Zulkardi, Z., & Darmawijoyo, D. (2022). Meta-analysis of cooperative learning effects on mathematics achievement in Indonesia. *Indonesian Journal of Mathematics Education*, *5*(1), 34-48.

Riansyah, F., Suherman, S., & Rohaeti, E. E. (2023). The implementation of Teams Games Tournament to improve students' mathematical understanding and self-efficacy. *Infinity Journal*, *12*(1), 89-102. https://doi.org/10.22460/infinity.v12i1.p89-102

Sadeghi, K., Barzegar, K., & Valizadeh, M. (2021). The relationship between traditional teaching methods and mathematics anxiety: A longitudinal study. *Educational Research Review*, *33*, Article 100394. https://doi.org/10.1016/j.edurev.2021.100394

Salam, A., Hossain, A., & Rahman, S. (2015). Effects of using Teams Games Tournaments (TGT) cooperative technique for learning mathematics in secondary schools of Bangladesh. *Malaysian Online Journal of Educational Technology*, *3*(3), 1-11.

Schoenfeld, A. H. (2016). Learning to think mathematically: Problem solving, metacognition, and sense making in mathematics. *Journal of Education*, *196*(2), 1-38. https://doi.org/10.1177/002205741619600202

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. Basic Books.

Siller, H., & Ahmad, J. (2024). Mathematics anxiety and its relationship with teaching approaches: An international perspective. *International Journal of Science and Mathematics Education*, *22*(1), 145-162.

Slavin, R. E. (2011). Cooperative learning. In R. Mayer & P. Alexander (Eds.), *Learning and cognition in education* (pp. 160-166). Elsevier. https://doi.org/10.1016/B978-0-12-387691-1.00033-5

Solihah, A. (2016). Pengaruh model pembelajaran Teams Games Tournament (TGT) terhadap hasil belajar matematika [The effect of Teams Games Tournament (TGT) learning model on mathematics learning outcomes]. *SAP (Susunan Artikel Pendidikan)*, *1*(2), 121-130.

Sudirman, S., Mellawaty, M., Yaniawati, P., & Indrawan, R. (2021). Augmented reality application: What are the constraints and perceptions of the students during the covid 19 pendemic’s 3D geometry learning process?. In *Journal of Physics: Conference Series* (Vol. 1783, No. 1, p. 012007). IOP Publishing.

Sudirman, S., Rodríguez-Nieto, C. A. ., & Bonyah, E. (2024). Integrating ethnomathematics and ethnomodeling in Institutionalization of school mathematics concepts: A study of fishermen community activities. *Journal on Mathematics Education*, *15*(3), 835–858. https://doi.org/10.22342/jme.v15i3.pp835-858

Stringer, E. T. (2014). *Action research* (4th ed.). SAGE Publications.

Taber, K. S. (2018). The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in Science Education*, *48*(6), 1273-1296. https://doi.org/10.1007/s11165-016-9602-2

Taufan, M., Dejarlo, J. O., Rosa, A. J., Hidayat, R., & Sunanto, E. (2024). Involving students and prospective mathematics teachers through the use of the Think Pair Share design: The impact on increasing students' activeness and learning outcomes in plane geometry. *International Journal of Didactic Mathematics in Distance Education*, *1*(1), 47–53. https://doi.org/10.33830/ijdmde.v1i1.7876

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education*, *2*, 53-55. https://doi.org/10.5116/ijme.4dfb.8dfd

Vankúš, P. (2021). Affective factors in mathematics education: The role of emotions, attitudes, and beliefs. *European Journal of Contemporary Education, 10*(1), 209-225.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Worthington, R. L., & Whittaker, T. A. (2006). Scale development research: A content analysis and recommendations for best practices. *The Counseling Psychologist*, *34*(6), 806-838. https://doi.org/10.1177/0011000006288127

Wright, T. (2020). Schön's reflective practice model and teacher development. *Professional Development in Education*, *46*(2), 234-247.

Yahya, A., & Bakri, F. (2019). The effectiveness of Teams Games Tournament on students' mathematics achievement in junior high school. *Journal of Physics: Conference Series*, *1185*(1), Article 012076. https://doi.org/10.1088/1742-6596/1185/1/012076

Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). SAGE Publications.