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Implementation of the Numbered Heads Together Model Based on Problem Based Learning on Students' Interest and Understanding of Mathematical Concepts

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ABSTRACT

Mathematics is often perceived by students as a difficult and uninteresting subject, highlighting the need for a learning model that not only fosters interest but also strengthens conceptual understanding. Previous studies have shown a gap in the optimal integration of the cooperative Numbered Heads Together (NHT) model with the Problem Based Learning (PBL) approach, even though both have the potential to promote active engagement and stimulate critical thinking. This study aims to examine the effectiveness of implementing the PBL-based NHT model in improving students' interest and conceptual understanding of mathematics among tenth-grade students at MA Zainul Hasan Genggong. The research was conducted through Classroom Action Research, combining quantitative data (tests and questionnaires) and qualitative data (observations and interviews). The participants consisted of 21 students. The instruments included a learning interest questionnaire, multiple-choice tests to assess conceptual understanding, observation sheets, and interview guidelines. The results indicate an increase in the average learning interest score from 61% (moderate category) to 73% (high category), and an improvement in conceptual understanding from an average of 42.86% in Cycle I to 82.61% in Cycle II. The qualitative data supported these findings, showing students' more active involvement in discussions and problem-solving activities. Therefore, the integration of the NHT–PBL model proved effective in enhancing students' interest and conceptual understanding. These findings recommend strengthening problem-based cooperative learning designs by considering aspects such as time allocation, topic selection, and students' ability heterogeneity.

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Introduction

Mathematics is a discipline that plays a fundamental role in developing critical thinking and problem-solving skills, serving as an essential foundation for the advancement of science, technology, economics, and the social sciences (Kant & Sarikaya, 2021; Schmidt et al., 2022). However, despite its broad contributions, many students still perceive mathematics as a difficult, tedious, and irrelevant subject to everyday life (Boaler et al., 2022). This condition underscores a gap between the strategic global function of mathematics and students' learning experiences in the classroom. Such a discrepancy suggests that the challenge in mathematics education today is not only cognitive but also affective, requiring learning environments that make mathematical ideas more engaging and personally meaningful to students.

Learning interest is a key factor in bridging this gap. Interest acts as an internal driver that influences students' motivation, perspectives, and engagement in understanding abstract concepts (Tolqunovna & Leonodovna, 2024). Low interest often makes students passive, unable to grasp fundamental ideas, and view mathematics merely as rote memorization of formulas (Md Zain & Rahayu, 2023). This situation is also evident in a local context (tenth-grade students at MA Zainul Hasan Genggong) who demonstrate moderate enthusiasm and face difficulties in connecting mathematical concepts to real-life situations. This case exemplifies the global problem of the weak linkage between mathematical concepts and their contextual applications. Therefore, revitalizing students' interest through active, collaborative, and context-rich learning experiences becomes an urgent pedagogical priority.

In addition to interest, conceptual understanding is a crucial requirement for successful mathematics learning. Students with strong conceptual understanding are able to connect information, explain ideas, and apply them across different contexts (Md Zain & Rahayu, 2023). Conversely, procedural memorization without conceptual understanding often causes students to fail in solving non-routine or contextual problems (Adu-Gyamfi et al., 2020). These challenges highlight the need for a learning model that can simultaneously enhance interest and deepen conceptual understanding. This dual focus ensures that mathematics is not learned as a set of isolated procedures but as an interconnected system of ideas that can be transferred and applied flexibly.

Problem Based Learning (PBL) has been internationally recognized as an effective approach to promoting student engagement through the presentation of authentic problems relevant to real-life situations (Nemakhavhani, 2024). PBL positions students as active participants in constructing knowledge through interaction, information-seeking, and collaborative discussion (Hung & Amida, 2020). However, the effectiveness of PBL can be further strengthened when integrated with Numbered Heads Together (NHT), a cooperative strategy that ensures the participation of all group members, fosters collective responsibility, and minimizes individual dominance in discussions (Diana et al., 2023). The synergy between problem-oriented inquiry and structured collaboration within this hybrid design provides a balanced mechanism for promoting both cognitive depth and social accountability in learning.

The integration of PBL and NHT is believed to create more meaningful, active, and contextual mathematics learning experiences. This collaboration not only emphasizes problem-solving but also nurtures teamwork, equitable participation, and the connection between mathematical concepts and students' real-life experiences. Therefore, this study aims to analyze the effectiveness of integrating PBL and NHT in improving students' conceptual understanding and interest in learning mathematics. By exploring this integration, the study seeks to contribute to the ongoing discourse on how cooperative learning and inquiry-based strategies can be combined to foster sustainable improvement in mathematics education practices.

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Method

Type of Research

This study employed the Classroom Action Research (CAR) method, implemented cyclically through the stages of planning, implementation, observation, and reflection. CAR was chosen because it aligns with the purpose of this study, to continuously improve the learning process in the classroom so that the outcomes can be directly experienced and evaluated in real situations. Research data were collected using a combination of quantitative instruments (learning achievement tests and learning interest questionnaires) and qualitative instruments (observation sheets, field notes, and documentation). The use of multiple instruments aimed to obtain a more comprehensive picture of students' improvement in learning interest and conceptual understanding of mathematics. The learning process in this study applied the Numbered Heads Together (NHT) model combined with the Problem Based Learning (PBL) approach. The instructional activities were conducted repeatedly in several stages, each consisting of multiple meetings emphasizing the phases of problem presentation, group discussion, data collection, problem analysis, and solution presentation. This approach allowed students to actively participate in collaborative activities with their groups, engage in discussions, and work together to formulate solutions to contextual problems relevant to real-life situations.

Research Subjects

The subjects of this study were all 21 students of class X D at MA Zainul Hasan Genggong, aged between 15 and 16 years, all of whom were female. The students had relatively homogeneous educational backgrounds, as they came from junior high schools (SMP/MTs) with similar curricula. The limited number of participants aligns with the characteristics of Classroom Action Research (CAR), which focuses on a single class. Therefore, the small sample size and gender uniformity do not reduce the relevance of the findings within the specific classroom learning context under investigation.

Instruments and Procedures

Several instruments were used in this study, including a questionnaire to measure students' learning interest, interview guidelines, observation sheets for classroom activities, and a multiple-choice conceptual understanding test. Data were collected through multiple methods (for instance questionnaires, interviews, and observations). The questionnaire measured students' responses to the learning implementation, particularly their perceptions of the learning quality and its influence on learning interest. Structured and in-depth interviews were conducted to obtain qualitative data regarding students' experiences and perspectives during the learning process. Non-participatory observation was employed to monitor classroom interactions and students' participation in learning activities. The conceptual understanding test consisted of ten multiple-choice items developed based on indicators of mathematical conceptual understanding in the relevant material, including the ability to solve contextual problems, analyze information, and apply mathematical concepts. The items varied in difficulty from easy to moderate to suit the average ability level of tenth-grade students. All test items underwent content validation by mathematics experts and experienced teachers, followed by item analysis that included validity and reliability testing. Thus, the instruments were considered valid and reliable for accurately representing students' conceptual understanding.

The instrument validity was assessed using Aiken's V index, calculated with the following formula:

$$V = \frac{\sum_{i=1}^{n} s}{n(c-1)}$$

where:
$s = r - lo$, the difference between the rater's score and the lowest possible score,
r = the score given by the rater,
lo = the minimum score on the rating scale,
c = the number of scale categories,
n = the number of raters.

According to Alifani et al. (2022), a V index below 0.4 indicates low validity; values between 0.4 and 0.8 indicate moderate validity; and values above 0.8 indicate high validity. Based on expert evaluation, the obtained Aiken's V indices were 0.92 for the teacher questionnaire, 0.89 for the student questionnaire, 0.97 for the ATP and teaching module assessment sheets, and 0.98 for both the interview guide and observation sheet. These results confirm that all instrument items possessed adequate validity according to the established criteria. To support the content validity analysis, the classification proposed by Sukardjo (as cited in Larasati, 2020) was used, as shown in Table 1.

Table 1. Quantitative Score Criteria

Interval	Criteria
X > Mi + 1.8 Si	Very High
Mi + 0.6 Si < X ≤ Mi + 1.8 Si	High
Mi - 0.6 Si < X ≤ Mi + 0.6 Si	Moderate
Mi - 1.8 Si < X ≤ Mi - 0.6 Si	Low
X ≤ Mi - 1.8 Si	Very Low

Notes:
X = empirical score
Mi = ideal mean = ½ (maximum ideal score + minimum ideal score)
Si = ideal standard deviation = ⅙ (maximum ideal score – minimum ideal score)
Maximum ideal score = Σ item criteria × highest score
Minimum ideal score = Σ item criteria × lowest score

To ensure instrument reliability, internal consistency was tested using Cronbach's Alpha coefficient. For the teaching module assessment, observation, and interview guides, inter-rater reliability testing was applied. Referring to Gable's criterion, an instrument is considered reliable if the reliability coefficient is at least 0.70. The questionnaire used in this study achieved a reliability coefficient of 0.932, as analyzed using SPSS version 22.0 (Maulana, 2022). This indicates that the instrument demonstrated excellent internal consistency and was therefore appropriate for measuring students' learning interest and conceptual understanding in the implementation of the NHT model integrated with PBL.

Analysis

Qualitative data analysis in this study was conducted systematically following the approach of Miles & Huberman (1994), which includes four main stages: data collection, data reduction, data display, and conclusion drawing or verification. This approach enabled the researcher to simplify, organize, and interpret the data progressively so that the meaning of the findings could be accurately and comprehensively derived. The interactive components of data analysis used in this study are illustrated in Figure 1, which depicts the cyclical flow among data collection, reduction, display, and conclusion drawing.

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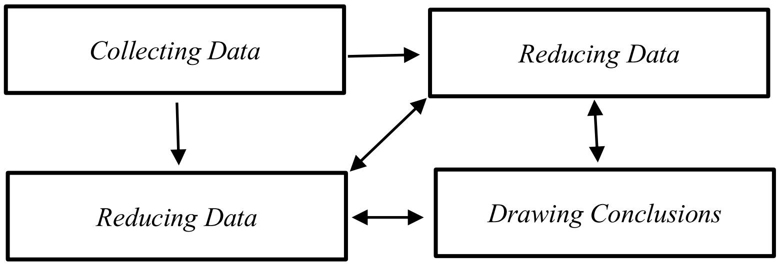

Figure 1. Interactive Data Analysis Components

The learning strategy applied in this study was designed to address the problems identified in class X D at MA Zainul Hasan Genggong and was implemented through several stages, each consisting of three meetings. The action cycles were continuously carried out until the predetermined success criteria were achieved. These criteria required that at least 75% of students obtain a score of 75 or higher on the conceptual understanding test, and that the class average score for learning interest reach the "high" category, with a minimum score of 69. Through this process, the integration of the Numbered Heads Together (NHT) model with the Problem Based Learning (PBL) approach was expected to significantly improve students' conceptual understanding while simultaneously fostering greater interest and engagement in learning mathematics.

Results

Table 2 presents the summary of students' affective and cognitive performance across three conditions: the initial stage, Stage 1, and Stage 2 of the classroom action research. The table illustrates progressive improvement in both dimensions following the implementation of the Numbered Heads Together (NHT) model integrated with the Problem Based Learning (PBL) approach. Affective data represent students' levels of learning interest, while cognitive data reflect their conceptual understanding as measured by the minimum mastery criterion (KKM = 75).

In the initial condition, students' affective responses were predominantly in the moderate category (61%), indicating limited enthusiasm and engagement in mathematics learning. Only 47.62% of students showed high interest, and none reached the very high category. This pattern correlates with the low cognitive results, where only 14.28% of students achieved mastery. Such findings reveal that conventional instruction failed to sufficiently stimulate students' motivation or deepen their understanding.

After the first intervention cycle, a noticeable improvement occurred. The proportion of students in the high affective category increased to 61.9%, while learning mastery rose to 42.86%. The average interest score also increased from 61% to 68.1%. These results suggest that the initial integration of NHT within the PBL framework began to foster collaborative learning and improve students' focus on problem-solving activities. However, the moderate average still indicates that the approach required further refinement in task design and time management to achieve optimal engagement.

In the second cycle, substantial progress was observed. The percentage of students categorized as having high learning interest increased sharply to 80.95%, while the average affective score rose to 73%, placing it within the high category. Similarly, cognitive mastery improved significantly, with 76.19% of students achieving scores above the KKM threshold, and the average test score reaching 82.61. These outcomes demonstrate that iterative refinement (particularly through more contextual problem selection, structured group discussions, and the use of varied media) successfully enhanced both motivation and conceptual understanding.

The improvement in the learning process implementation, from 40% at the initial stage to 82.61% in Stage 2, further validates that students became more engaged, discussions were more effective, and the classroom atmosphere shifted toward collaborative inquiry. Overall, Table 2 indicates a strong positive relationship between the enhancement of students' affective engagement and their cognitive achievement, confirming that affective readiness plays a crucial role in supporting conceptual mastery within active and cooperative learning environments.

Table 2. Affective and Cognitive Data in the Initial Condition, Stage 1, and Stage 2

Variable	Interval	Criteria	Initial Condition	Target	Stage 1	Stage 2
Affective	x > 84	Very High	0%	15%	9.52%	19.05%
	68 < x ≤ 84	High	47.62%	58%	61.9%	80.95%
	52 < x ≤ 68	Moderate	52.38%	27%	38.1%	19.05%
	36 < x ≤ 52	Low	0%	0%	0%	0%
	x ≤ 36	Very Low	0%	0%	0%	0%
	Average	**Moderate**	61%		68.1%	73%
Cognitive / Skills	≥ 75 (Mastery Level)	Achieved	Moderate	High	Moderate	High
	Average (KKM = 75)		14.28%	70%	42.86%	76.19%
Learning Process	Implemented	Successful	40%	80%	54.35%	82.61%

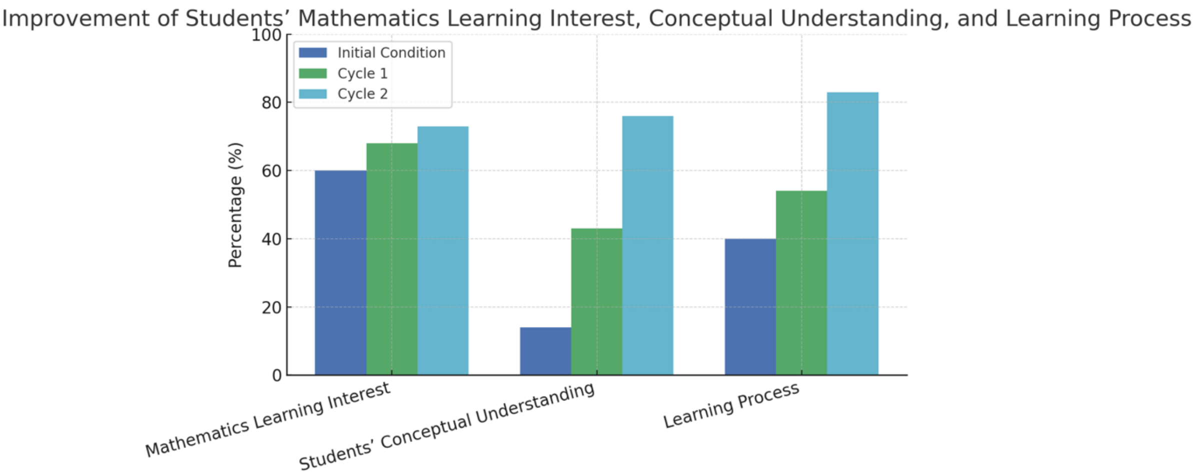

Figure 2. Improvement of Students' Mathematics Learning Interest, Conceptual Understanding, and Learning Process Across Cycles

Initial Condition

Initial observations indicated that most students in class X D at MA Zainul Hasan Genggong faced difficulties in both affective and cognitive aspects. The learning interest questionnaire showed that 61% of students were in the moderate category, while the pretest results were below the minimum mastery criterion (KKM = 75). Interviews with three representative students revealed three main causes of low engagement: (1) limited mastery of prerequisite materials, (2) overreliance on monotonous lecturing methods, and (3) the perception that mathematics was disconnected from daily life. These findings suggest that students' disengagement was not solely due to the difficulty of mathematical content but also to the absence of meaningful learning experiences that connect abstract ideas to real-world contexts. The learning process tended to emphasize procedural fluency rather than conceptual exploration, causing students to perceive mathematics as rigid and uninspiring. This initial diagnosis reinforced the need for an instructional approach that fosters both emotional involvement and cognitive challenge.

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Stage I

The intervention integrating the Numbered Heads Together (NHT) model within the Problem Based Learning (PBL)framework was implemented over three meetings. The process followed five PBL phases: identifying problems, organizing activities, guiding exploration, presenting results, and evaluating solutions. At this stage, the average conceptual understanding score rose to 42.86, with 54.35% of students achieving mastery, while the learning interest score increased to 68.1% (still within the moderate category). Although the improvement was not yet optimal, the results indicated that collaborative engagement began to influence students' attitudes. Students showed initial enthusiasm during group discussions, yet some still relied heavily on peers to lead problem solving. This reflects a transitional phase in students' cognitive engagement, from passive knowledge reception to early stages of active inquiry. However, two limitations emerged. First, some problems used in class were not sufficiently authentic or relatable, resulting in uneven participation across groups. Second, time management during group work remained inefficient, with some teams continuing discussions while others presented their solutions. These issues highlight that in PBL-based designs, both the contextual relevance of the task and the structure of collaboration are critical to sustaining student engagement. The results at this stage, though modest, provided valuable feedback for refining the next cycle.

Stage II

Based on the reflection from Stage I, adjustments were made by selecting more contextual problem topics, structuring discussion time more clearly, and integrating diverse learning media. These refinements led to a substantial improvement: the average learning interest score reached 73 (high category), learning mastery increased to 76.19%, and the mean conceptual understanding score rose to 82.61. Students exhibited visible behavioral transformation, more confidence in expressing opinions, greater willingness to participate, and a tendency to ask questions spontaneously. The classroom atmosphere shifted from teacher-centered instruction to student-driven collaboration. These behavioral indicators reflected an enhanced sense of ownership and responsibility toward learning outcomes, a key feature of both cooperative and problem-based learning. The integration of NHT ensured equitable participation among group members, while the problem-based structure stimulated analytical reasoning and conceptual depth. The combination of these two frameworks created a synergy where social interaction became a medium for cognitive construction. Consequently, students not only memorized procedures but also reconstructed mathematical concepts through dialogue and reflection.

Final Results

Across both stages, there was a clear and consistent improvement in students' affective and cognitive performance. Learning interest increased from the moderate to the high category, while conceptual understanding improved significantly, with 76.19% of students reaching mastery. These quantitative outcomes were supported by qualitative data showing higher engagement, self-confidence, and initiative among students. The integration of NHT within PBL thus proved effective in addressing classroom learning barriers by enhancing collaboration, contextual reasoning, and reflective discussion. Overall, the findings confirm that the iterative implementation of NHT–PBL can bridge the gap between affective motivation and cognitive achievement in mathematics learning. This success demonstrates that when students are positioned as active problem solvers and collaborators, they develop a deeper understanding of mathematical ideas and a more positive disposition toward learning the subject.

Discussion

The increase in students' learning interest following the implementation of the NHT-based PBL model indicates that this instructional approach effectively promotes active student participation. This finding aligns with Rahmawati et al. (2023), who emphasized that cooperative strategies can enhance student engagement in the classroom, and supports the view of Munna & Kalam (2021) that active learning strategies strengthen the quality of learning interactions. In addition, the improvement in students' cognitive achievement during Stage II is consistent with the results of Odeh (2021), who found that PBL progressively enhances learning outcomes. In the present study, the integration of NHT played a crucial role in ensuring that all group members participated actively, preventing any student from remaining passive. This confirms the argument of Mariwati & Saija (2024) that increased learning interest directly contributes to improved conceptual understanding and academic performance.

From the perspective of novelty, this study offers a unique contribution compared to previous research. Most earlier studies examined either the effectiveness of PBL (e.g., Odeh, 2021) or NHT (e.g., Rahmawati et al., 2023) in isolation. In contrast, this study combines both within a single instructional framework, producing a dual effect: NHT ensures equitable participation among students, while PBL provides real-world contexts for problem solving. This combination effectively addressed the initial problem of students perceiving mathematics as monotonous and irrelevant to everyday life. Although the outcomes were positive, some challenges remain. Time management during group discussions and the selection of appropriate problems continue to be critical factors influencing success. This observation aligns with Yu & Zin (2023), who noted that the effectiveness of PBL largely depends on the contextual suitability of problems to students' characteristics. Furthermore, the limited sample size and the single-class context mean that the results of this study should be viewed as a practical contribution rather than a broadly generalizable conclusion.

In conclusion, the integration of the NHT–PBL model can be regarded as an innovative alternative strategy for enhancing students' interest and conceptual understanding in mathematics. These findings reinforce those of Rahmawati et al. (2023), who asserted that cooperative learning improves the effectiveness of instructional processes, while extending the discussion by demonstrating how a combined and more comprehensive model can further strengthen both engagement and achievement in mathematics learning. These findings reaffirm that learning models integrating social collaboration and contextual problem solving not only enhance students' affective engagement but also contribute to the development of deeper conceptual reasoning. Nevertheless, sustained exploration is still needed to examine how the NHT–PBL framework can be adapted across different mathematical topics and educational levels to ensure its broader applicability and long-term effectiveness.

Conclusion

The findings of this study demonstrate that implementing the Numbered Heads Together (NHT) model within a Problem Based Learning (PBL) framework fosters meaningful improvements in students' learning interest and conceptual understanding of mathematics. The application of NHT–PBL encouraged active participation, strengthened collaborative responsibility, and deepened students' engagement in exploring mathematical ideas. The combination of cooperative and problem-based strategies proved mutually reinforcing: while NHT ensured equitable participation among group members, PBL provided authentic contexts

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that promoted analytical and reflective thinking. This research extends prior work by integrating NHT and PBL into a single instructional design, offering a more comprehensive approach to developing both affective and cognitive dimensions of mathematics learning. The hybrid framework illustrates how collaboration and contextual inquiry can coexist to transform classroom interactions from procedural learning toward conceptual exploration. It thus provides an innovative alternative for promoting active, student-centered mathematics instruction in secondary education.

Despite its promising results, the study was limited to a small and context-specific sample, and factors such as time management and material complexity may influence the model's consistency. These limitations highlight the need for further investigations in broader and more diverse educational settings. Future research should examine the adaptability of the NHT–PBL framework across various mathematical topics and learning environments to validate its long-term impact on students' reasoning, collaboration, and problem-solving competencies. In essence, the integration of NHT and PBL bridges the social and cognitive dimensions of learning, demonstrating that mathematics education becomes more engaging, reflective, and conceptually grounded when students learn through cooperative inquiry within authentic problem contexts.

Conflict of Interest

The authors declare that there is no conflict of interest.

Authors' Contributions

The first author, A.Q.I., served as the principal contributor to this research. She was responsible for designing the research instruments, formulating the research ideas, collecting data, conducting data analysis and processing, and presenting the results and discussion. The second author, K.I.M., contributed by revising the manuscript and aligning the overall content to ensure coherence with the study's objectives and structure. The third author, L.D.P., assisted in refining the discussion and approved the final version of the manuscript. The total percentage of contributions for the conceptualization, preparation, and revision of this article is as follows: A.Q.I.: 50%, K.I.M.: 30%, and L.D.P.: 20%.

Data Availability Statement

The authors declare that the data supporting the findings of this study will be made available by the corresponding author, [A.Q.I.], upon reasonable request.

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