



The Effectiveness of Problem Based Learning Assisted by Puzzle Teaching Aids on the Understanding of Geometry Concepts in Fourth Grade Elementary School Students

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ABSTRACT

*Understanding geometric concepts is an important skill in elementary school mathematics learning, but students still have difficulty understanding abstract concepts and lack concrete learning experiences. This study aims to analyze the effect of the Problem-Based Learning (PBL) model assisted by puzzle teaching aids on the understanding of geometric concepts of fourth-grade elementary school students. The study used a quantitative approach with a quasi-experimental method and a Post-Test Only Control Group design. The sample consisted of 39 students, consisting of 20 students in the experimental group and 19 students in the control group. The experimental group received puzzle-assisted PBL learning, while the control group received conventional learning. Data were collected through a geometry concept understanding test and analyzed using an independent-samples *t*-test. The results showed that the average post-test score of the experimental group was 79.75, while the control group was 70.79, with a difference of 8.96 points. The results of the hypothesis test showed a calculated *t* of 6.447 > *t* table 2.026 at a significance level of 5%. Thus, there was a significant difference in understanding geometric concepts between the two groups. Puzzle-assisted PBL can be an alternative learning method that encourages active involvement and helps students construct an understanding of geometric concepts through concrete experiences and problem solving.*

Keywords: *problem-based learning, puzzles, conceptual understanding, geometry, primary school*



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INTRODUCTION

Education is a crucial foundation for developing quality human resources. Through education, students develop their potential to possess spiritual and religious strength, self-control, personality, intelligence, noble character, and the skills needed by themselves, society, the nation, and the state (Pristiwanti, 2022). Elementary school (SD) plays a crucial role as the first level of formal education, establishing the foundation of students' knowledge, skills, and character. In this context, elementary school education is designed to develop critical thinking skills, creativity, and character in children from an early age.

Mathematics learning in elementary schools plays a crucial role in developing students' logical and analytical thinking skills. Mathematics aims to develop critical thinking, problem-solving, and the application of concepts in everyday life. Recent research shows that the integration of curriculum management, teacher professional development, and the use of

educational technology can contribute significantly to improving student learning outcomes (Aprianto & Wahyudi, 2023, p. 45). The role of teachers is crucial for the success of mathematics learning, particularly in improving students' problem-solving skills at the elementary school level.

Understanding geometric concepts in elementary school is often a challenge for students. Research shows that many students struggle to grasp geometry, particularly plane and solid geometry. This difficulty can be caused by several factors, including a lack of understanding of basic concepts, a lack of varied teaching models, limited interactive learning media, and limited visualization due to inadequate learning media (Putri & Aliyyah, 2024). Negative mindsets toward mathematics also contribute to elementary school students' difficulties understanding geometry.

The national education curriculum has undergone various changes to adapt to student needs and global challenges. The implementation of the Independent Curriculum (Curriculum Merdeka) represents a significant innovation in Indonesian education. This curriculum is designed to provide schools with flexibility in adapting learning to student characteristics and the surrounding environment, while also strengthening competency-based learning, differentiation, and project-based learning (Ministry of Education and Culture, 2022). In this context, a more contextual learning approach and the use of technology to facilitate visualization and understanding of geometric concepts are needed.

Problem-Based Learning (PBL) has been recognized as an effective solution to address various learning challenges frequently encountered in schools. Implementing the PBL model can develop students' abilities to analyze, evaluate, and create, making learning more meaningful. In addition to improving academic abilities, PBL also develops other skills such as creativity, communication, collaboration, and adaptation (Azizah & Hanipah, 2024). PBL positions problems as the trigger for the learning process, so students not only receive information but are also required to identify problems, organize information, develop problem-solving strategies, discuss alternative solutions, and evaluate the results. Empirical evidence shows that PBL has a positive impact on elementary school students' mathematical abilities. A meta-analysis by Suparman et al. (2021), for example, showed that PBL implementation had a significantly positive effect on elementary school students' mathematical abilities compared to conventional learning. Other meta-analyses have also shown that PBL is effective in improving Indonesian students' mathematical reasoning abilities (Fitriyah et al., 2022). These findings suggest that PBL has the potential to be a relevant approach to creating mathematics learning that is more oriented towards thinking and problem-solving activities.

Mathematics learning media plays a crucial role in facilitating students' understanding of often abstract concepts. Appropriate use of media can make learning more engaging and interactive, thereby increasing student motivation. Puzzles are an effective form of learning media and have been proven to improve student learning outcomes in mathematics. Research shows that the use of puzzles in learning can enhance students' cognitive abilities and problem-solving skills (Agustin, 2020; Boonstra et al., 2023). Integrating learning media such as puzzles into geometry learning can help students construct understanding in a more concrete and interactive way.

Based on initial observations at SDN 2 Sumberwaru, Banyuputih District, several problems were identified in the learning of geometry mathematics in grade IV. First, the learning process tends to use conventional learning models that are less innovative, so they do not attract students' attention and make them quickly bored. Second, low interest, talent, and motivation of students in listening and understanding the material presented. Third, students are more passive in the learning process because they only sit, listen and take notes what the teacher says, even students do not dare to answer or ask questions when asked by the teacher.

These three problems result in student learning outcomes not achieving learning objectives in accordance with the expected competency standards.

To address these issues, learning innovations are needed that are capable of realizing the expected competency standards. Integration of PBL and learning tools puzzle display conceptual can form environment mutual learning complete. PBL provides structure pedagogical through problem authentic, investigative, collaborative, and collaborative solutions, while puzzles provide representation concrete that can manipulated student when explore draft geometry. In situation In this case, the problems given by the teacher can push student using puzzles to construct form, identify nature, comparing characteristics, as well as find connection interconceptual. The process furthermore can to be continued through discussion groups and arguments so that activity manipulative No stop at introduction form, but develop be a process of conceptualization and reasoning mathematical.

Although various studies have demonstrated the effectiveness of Problem-Based Learning (PBL) regarding mathematical abilities and the importance of manipulative media in geometry instruction, there remains a need to strengthen the research in this area. Studies on PBL at the primary school level have largely focused on general mathematical abilities, problem-solving, or mathematical reasoning, whereas research on manipulatives has primarily examined the use of concrete materials to aid visualization and the formation of geometric concepts. Consequently, there is a need for more robust empirical evidence regarding the integration of PBL with puzzle-based manipulatives specifically to enhance fourth-grade students' understanding of geometric concepts within the context of primary mathematics education in Indonesia. Research examining this combination of instructional model and media is significant, as it can provide insights not only into the effectiveness of PBL but also into whether the support provided by concrete representations such as puzzles can reinforce the process of concept construction when students encounter geometry problems.

This gap is relevant to the instructional conditions at SDN 2 Sumberwaru, Banyuputih District. Preliminary observations by the researcher revealed that mathematics instruction regarding geometry still tends to rely on conventional approaches; students remain relatively passive during the learning process, and the use of interactive or concrete instructional media is limited. Consequently, some students show a lack of engagement in asking questions, participating in discussions, and articulating answers when studying geometry. These initial findings underscore the need for an instructional intervention that not only transforms the teacher-student interaction model but also provides concrete representations enabling students to explore geometric concepts firsthand. These conditions in the field also provide an empirical context for testing the integration of Problem-Based Learning (PBL) and puzzle-based learning aids in this study.

Based on the theoretical analysis and empirical conditions, this study posits that the understanding of geometric concepts can be strengthened through the synergy of problem-based learning and manipulative experiences. Problem-Based Learning (PBL) offers students the opportunity to learn through problems and the process of inquiry, while puzzles provide concrete representations that can be observed and manipulated during problem-solving. Integrating the two approaches is expected to foster learning that is more active, contextual, and meaningful, while helping students connect concrete experiences with the geometric concepts being studied.

Therefore, this study aims to analyze the effect of the Problem-Based Learning (PBL) model, supported by puzzle-based learning aids, on the geometric conceptual understanding of fourth-grade elementary school students. Specifically, the study compares the geometric conceptual understanding of students receiving puzzle-assisted PBL instruction with that of students receiving conventional instruction. The study contributes by providing empirical evidence regarding the effectiveness of integrating a problem-based learning model with

simple manipulative media in teaching geometry to elementary school students. The findings are expected to offer practical implications for teachers in designing geometry lessons that are more concrete, interactive, student-centered, and focused on the construction of conceptual understanding.

RESEARCH METHODS

Study This use approach quantitative with data collection using instrument research that has been determined, data analysis is quantitative / statistical, and aims for test hypothesis that has been formulated. Approach quantitative chosen Because study This try for measure the influence of the Problem Based Learning learning model on understanding draft geometry in a way measurable and objective (Sugiyono, 2021).

Based on type existing problems in research, researcher use type Quasi Experiment research which is method research that is not allows researchers do control full to condition variables experiment (Rukminingsih et al., 2020). The research design used is Post Test Only Control Group Design, where the design This implemented with use post test or test end for analyzed in see the influence of the applied learning model . The initial data study This taken through mark test Mathematics student previously.

Table 1. Research Design Post Test Only Control Group Design

Class	Treatment	Post Test
Experiment	X ₁ (PBL + Puzzle)	O ₁
Control	X ₂ (Conventional)	O ₂

Description: X₁ = Treatment with using the Problem Based Learning model tool Puzzle prop; X₂ = Treatment with using a learning model conventional; O₁ = Administration test end of class experiment at the end research; O₂ = Administration test end of class control at the end study.

Taking technique sample in study This using cluster random sampling, namely technique taking sample in which the units are selected is group or cluster, not individual (Handayani , 2020). Through technique this, researcher do randomization at the class level for choose which class will made into class experiments and classes control.

After sampling was carried out, obtained sample study as as follows: class 4A has 20 students as class experiments that will be accept treatment in the form of a Problem Based Learning model using tool Puzzle display, and class 4B has 19 students as class control that will accept learning with conventional models. The following is distribution sample study:

Table 2. Research Sample

No	Class	Amount Student
1	4A (Experiment)	20 students
2	4B (Control)	19 students
Amount		39 students

After sampling was carried out, obtained sample study as as follows: class 4A has 20 students as class experiments that will be accept treatment in the form of a Problem Based Learning model using tool Puzzle display, and class 4B has 19 students as class control that will accept learning with conventional models. The following is distribution sample study:

Table 3. Research Sample

No	Class	Amount Student
1	4A (Experiment)	20 students
2	4B (Control)	19 students
Amount		39 students

In this study, researchers used a t-test to test the hypothesis of whether there was a significant difference between the average learning outcomes of the experimental and control classes. The t-test was conducted using an independent sample t-test with the pooled variance t-test formula.

RESULTS AND DISCUSSION

Results

This research was conducted at SDN 2 Sumberwaru in three meetings using the Problem Based Learning (PBL) model. The experimental class in this study was class IV A with 20 students who received learning treatment using the Problem Based Learning model assisted by Puzzle media. Class IV B served as the control class with 19 students who received conventional learning. SDN 2 Sumberwaru implemented the Independent Curriculum in every lesson. Post-test data from both classes were analyzed to determine the effect of the learning model on students' understanding of geometric concepts. The following are the post-test results of the experimental class and the control group.

Table 4. Frequency Distribution of Post-Test Data for the Experimental Class

Interval	Fi	Xi	Xi ²	FiXi	FiXi ²	Faculty of Law
65-69	2	67	4,489	134	8,978	2
70-74	3	72	5,184	216	15,552	5
75-79	3	77	5,929	231	17,787	8
80-84	4	82	6,724	328	26,896	12
85-89	4	87	7,569	348	30,276	16
90-94	4	92	8,464	386	33,856	20
Total	20			1,595	133,345	

Note: Fi = Frequency; Xi = Median Value; Fcum = Cumulative Frequency

Based on the frequency distribution table in the experimental class, it can be seen that most students achieved scores above 75. There were 2 students (10%) who obtained scores of 65-69, 3 students (15%) obtained scores of 70-74, 3 students (15%) obtained scores of 75-79, 4 students (20%) obtained scores of 80-84, 4 students (20%) obtained scores of 85-89, and 4 students (20%) obtained scores of 90-94. This distribution shows that learning using the PBL model with Puzzle media increases student success in achieving minimum completion criteria.

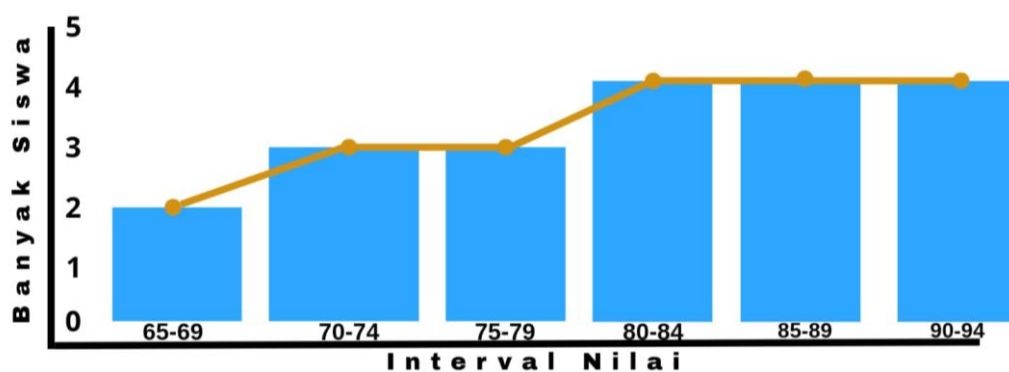


Figure 1. Class Experiment Distribution Frequency

Based on Figure 1, it can be seen that there are 2 students who got a score of 65-69, 3 students got a score of 70-74, 3 students got a score of 75-79, 4 students got a score of 80-84, 4 students got a score of 85-89, and 4 students got a score of 90-94.

Table 5. Frequency Distribution of Post-Test Data for the Control Class

Interval	Fi	Xi	Xi ²	FiXi	FiXi ²	Faculty of Law
60-64	2	62	3,844	124	7,688	2
65-69	5	67	4,489	335	22,445	7
70-74	5	72	5,184	360	25,920	12
75-79	3	77	5,929	231	17,787	15
80-84	3	82	6,724	246	20,172	18
85-89	1	87	7,569	87	7,569	19
Total	19			1,345	101,581	

In the control class, the frequency distribution shows that students are more spread out in the low and medium score intervals. There are 2 students (10.53%) who obtained scores of 60-64, 5 students (26.32%) obtained scores of 65-69, 5 students (26.32%) obtained scores of 70-74, 3 students (15.79%) obtained scores of 75-79, 3 students (15.79%) obtained scores of 80-84, and only 1 student (5.26%) obtained scores of 85-89. This distribution indicates that conventional learning is less than optimal in improving student learning achievement.

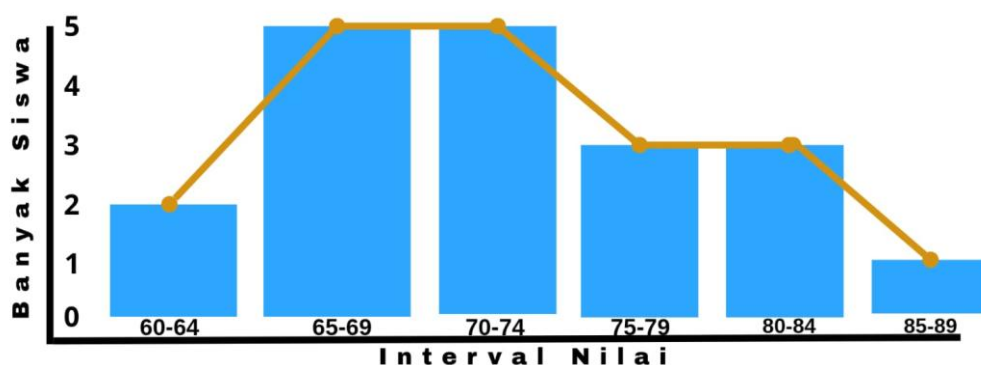


Figure 2. class control distribution frequency

Based on Figure 4.2, it can be seen that there are 2 students who got a score of 60-64, 5 students who got a score of 65-69, 5 students who got a score of 70-74, 3 students who got a score of 75-79, 3 students who got a score of 80-84, and 1 student who got a score of 85-89.

The results of the data normality and homogeneity tests have met the requirements for further statistical testing using the t-test. To determine the effect of the *Problem Based Learning learning model* using puzzle media on students' understanding of geometry concepts. A t-test (difference test) was carried out to see how influential the Problem Based Learning learning model using puzzle media was.

Based on the hypothesis test, it was found that the calculated t value was $6.447137709 > t$ table 2.026192463 and the significance value was 0.05, with the results stating that there was an influence of the problem-based learning model using puzzle media on students' understanding of geometric concepts.

Discussion

Research conducted at SDN 2 Sumberwaru showed a significant difference in understanding of geometric concepts between students learning using the Problem-Based Learning model with the aid of puzzle media (the experimental class) and students learning using conventional methods (the control class). This finding aligns with previous research showing that innovative, problem-based learning models can significantly improve student learning outcomes (Cahyono et al., 2021).

Direct observations conducted during the study revealed differences in the learning atmosphere between the two classes. In the experimental class, students demonstrated a higher level of engagement in learning. Students were more active in asking questions, discussing in groups, and collaborating to solve problems presented through learning videos and the use of puzzle props. These learning activities align with the constructivist learning philosophy, which emphasizes that students construct their own knowledge through experience and interaction with the learning environment (Piaget in Mischke, 2021).

In contrast, in the control class, learning appeared more passive, with students receiving information from the teacher without much active involvement in the learning process. The lively classroom atmosphere, with off-task conversations, indicated a lack of student engagement with the learning material. This is consistent with research by Hardiyanto and Ariyani (2023), who found that conventional learning without a variety of methods and media tends to result in low levels of student engagement and suboptimal learning outcomes.

The use of puzzles in the PBL model has been shown to play a significant role in enhancing student understanding. Manipulative media such as puzzles allow students to concretely explore abstract geometric concepts. Research by Zaini et al. (2022) emphasized that the use of interactive and concrete learning media is highly effective in facilitating understanding of geometric concepts, especially for elementary school students who are still at the concrete operational stage.

The difference in average post-test scores between the two classes (79.75 for the experimental class vs. 70.79 for the control class, a difference of 8.96) demonstrates the significant impact of the PBL model. The superiority of the experimental class can be explained by several factors. First, the PBL model places students in an active role as problem solvers, which encourages the development of higher-order thinking skills (Bloom, Englehart, et al., 2020). Second, contextual problem-based learning enables students to understand the relevance of geometric concepts to everyday life. Third, group collaboration in PBL develops students' social and communication skills (Bransford, Brown, & Cocking, 2020).

The frequency distribution of post-test data also provides important information. In the experimental class, 70% of students achieved scores above 75 (10 out of 20 students), indicating that the majority successfully achieved the target understanding of geometry

concepts. In contrast, in the control class, only 42.1% of students achieved scores above 75 (8 out of 19 students). This difference in achievement percentages indicates that the PBL model is more effective in ensuring that most students master the expected competencies (Suryani, 2021).

Another aspect worth noting is that the learning outcome indicators, according to Gagne's taxonomy, measured by the post-test include intellectual skills, cognitive strategies, attitudes, verbal information, and motor skills. The results showed that students in the experimental class had better mastery of all indicators, particularly in the intellectual skill of analyzing and distinguishing the properties of geometric shapes (Nasution, 2021).

The validity and reliability of the tested test instruments provide confidence that the differences in results are not due to instrument weaknesses, but rather are truly the effects of the treatment provided. A calculated r value significantly greater than the table r in the validity test indicates that each item consistently measures what it is supposed to measure. High reliability in the Cronbach Alpha test ensures that the instrument produces stable and reliable results.

The fulfilled assumptions of normality and homogeneity provide validity to the use of the independent sample t -test. The significant calculated t -value ($6.447 > 2.026$) indicates that the difference in the means between the two groups is not the result of chance, but rather a real and statistically meaningful difference.

The effectiveness of PBL in this study can be explained through the characteristics of the learning process. PBL positions students as active subjects faced with problems, requiring them to understand the problem, identify relevant information, conduct investigations, discuss alternative solutions, and formulate conclusions. This series of activities provides students with the opportunity to not only memorize the properties or characteristics of geometric shapes but also understand the relationships between concepts through the problem-solving process. In this study, the problem-solving process is reinforced by the use of puzzles so that students can interact directly with representations of geometric shapes. Thus, students not only obtain information from teacher explanations but also build understanding through experience, object manipulation, discussion, and problem-solving.

Another important aspect of this study is the contribution of the use of puzzles in supporting the PBL learning process. Geometry is highly visual, so students need opportunities to observe, compare, arrange, decompose, and manipulate geometric objects. For elementary school students, direct experience with concrete objects can help connect abstract concepts with observable representations. The use of puzzles allows students to arrange, separate, combine, compare, and reconstruct geometric shapes. These activities provide concrete experiences that can be used as a foundation for understanding the properties and relationships between shapes. This finding is consistent with previous research demonstrating the effectiveness of the PBL model in improving student learning outcomes across various subject areas (Arends & Kilcher, 2020; Suparman et al., 2021; Fitriyah et al., 2022).

Practically, this research suggests that teachers should integrate innovative learning models such as PBL into their teaching practices in elementary schools, particularly in teaching abstract concepts like geometry. The use of concrete learning media such as puzzles can be an effective and affordable alternative to improve learning quality. Implementing this model requires thorough preparation, including developing problem-based learning scenarios relevant to students' lives and developing or procuring supporting learning media (Killen, 2020).

Overall, the results of this study indicate that students who participated in learning using PBL assisted by puzzle teaching aids had a statistically higher understanding of geometric concepts than students who participated in conventional learning. This finding is in line with previous research evidence regarding the effectiveness of PBL in mathematics learning and the benefits of manipulative media in helping students understand geometric concepts. The

contribution of this study lies in the integration of these two components in geometry learning for fourth-grade elementary school students. Thus, PBL assisted by puzzle teaching aids can be considered as an alternative geometry learning strategy that emphasizes problem solving, concrete experiences, active involvement, and the construction of conceptual understanding. Therefore, it is recommended that teachers and educational institutions consider adopting this learning model as part of a more varied and student-centered learning strategy.

CONCLUSION

Based on the research results and data analysis, it can be concluded that there is a significant difference in the understanding of geometric concepts between students taught using the Problem-Based Learning (PBL) model assisted by puzzle-based learning aids and those taught using conventional methods. The experimental group achieved an average post-test score of 79.75, while the control group achieved an average of 70.79, representing a mean difference of 8.96 points. The independent-samples t-test results showed a calculated t-value of 6.447, which exceeds the t-table value of 2.026 at a 5% significance level. These findings indicate that the implementation of PBL assisted by puzzle-based learning aids is associated with a higher level of understanding of geometric concepts compared to conventional instruction.

Research findings indicate that integrating Problem-Based Learning (PBL) with puzzle-based manipulatives can create a more active and concrete learning experience in geometry. PBL offers students opportunities to engage in understanding problems, conducting inquiries, discussing ideas, and formulating solutions, while puzzle manipulatives help them visualize and directly manipulate geometric objects. Combining these two components provides a learning alternative that helps students connect concrete experiences with the geometric concepts being studied.

In practical terms, the research results imply that primary school teachers might consider puzzle-assisted PBL as an alternative approach for designing geometry lessons that are more student-centered, interactive, and contextual. Furthermore, the use of puzzles is relatively simple, making them a suitable choice for concrete learning media in settings where access to educational technology is limited.

This study has limitations as it was conducted at a single school with a sample of 39 students and employed a post-test-only control group design. Consequently, the results primarily highlight the difference in post-test performance between the experimental and control groups but do not capture changes in individual student abilities from pre- to post-treatment. Future research should involve larger and more diverse samples, utilize a pretest-posttest control group design, and assess the sustainability of students' conceptual understanding through retention measurements. Additionally, future studies could compare puzzle-assisted PBL with other manipulative or digital media to determine the most effective learning conditions for supporting elementary students' understanding of geometric concepts.

Conflict of Interest

The authors declare that there are no conflicts of interest in this manuscript

Generative AI Statement

The authors disclose the limited use of generative artificial intelligence (AI) during manuscript preparation, exclusively for language improvement, grammar checking, and enhancing the readability and clarity of the manuscript.

Author Contribution Statement

Rahmat Hidayat contributed to the conceptualization of the study, research design, methodology, development of research instruments, data collection, data analysis,

interpretation of the findings, and preparation of the original manuscript draft. Putu Eka Suharmika contributed to the development and validation of the research methodology and instruments, data analysis, interpretation of the results, and manuscript review and editing. Ach Munawi Husein contributed to the conceptualization and supervision of the study, validation of the research procedures, interpretation of findings, critical review of the manuscript, and final approval of the manuscript. All authors contributed substantially to the completion of this study, reviewed and approved the final version of the manuscript, and agreed to take full responsibility for the integrity and accuracy of the work.

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