



Bridging Manipulative Media and Problem-Based Learning: The Impact of Sunflower Clock Angle Media on Elementary Students' Motivation and Mathematics Learning Outcomes

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Abstract: This study aims to examine the effect of Sunflower Clock Angle media integrated with Problem-Based Learning (PBL) on elementary school students' learning motivation and mathematics learning outcomes. The study employed a quantitative approach using a quasi-experimental method with a nonequivalent pretest–posttest control group design. The participants comprised 32 fifth-grade students from SDN 1 Keser and SDN 2 Keser, Blora Regency, Indonesia, during the 2025/2026 academic year. Data were collected through tests, questionnaires, observations, and documentation and analyzed using inferential statistics, including simple and multiple linear regression analyses. The findings indicated that the integration of Sunflower Clock Angle media with PBL was significantly associated with students' learning motivation and mathematics learning outcomes ($p < .001$). The coefficients of determination indicated that the regression models explained 68.2% of the variance in learning motivation, 71.4% of the variance in mathematics learning outcomes, and 78.1% of the variance when both outcomes were considered jointly. Students in the experimental group demonstrated higher levels of learning motivation and mathematics achievement than those in the control group. The integration of manipulative and interactive media with PBL provided students with active, meaningful, and engaging experiences in geometry learning. This study contributes to the development of innovative mathematics instructional strategies by demonstrating the potential of integrating manipulative-interactive media with PBL in elementary school geometry education.

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Introduction

Mathematics learning plays an important role in developing students' logical, critical, systematic, and problem-solving thinking skills in elementary education. Mathematics is not only intended to improve students' computational abilities but also to help them understand concepts and apply them in real-life situations (Kaplan et al., 2011). However, Indonesian students' mathematics achievement remains relatively low based on the Programme for International Student Assessment (PISA) results, indicating that many students still experience difficulties in understanding and applying mathematical concepts meaningfully (OECD, 2023).

The rapid development of innovative learning strategies has encouraged educators to implement student-centred learning approaches and manipulative-interactive media in mathematics learning. Learning activities supported by innovative models and interactive media are considered more effective in improving students' engagement, motivation, and



conceptual understanding (Wulandari et al., 2023). Nevertheless, mathematics learning in elementary schools is still frequently dominated by conventional teacher-centered instruction. Lecture-based learning activities often cause students to memorize procedures without understanding concepts meaningfully, resulting in low participation and learning outcomes (Wahyuni et al., 2023).

These problems become more apparent in geometry learning, particularly on angle material, because students are required to understand abstract concepts involving visualization and measurement skills. Many students experience difficulties in identifying, comparing, and measuring angles because learning activities are still conducted verbally without optimal visual support (Utami et al., 2024). Consequently, students tend to perceive mathematics as difficult and less interesting.

Learning motivation is another important factor influencing mathematics learning outcomes. Students with high learning motivation tend to participate actively, complete assignments seriously, and demonstrate persistence during learning activities (Yogi Fernando et al., 2024). In contrast, students with low motivation often avoid challenging tasks and show low engagement during mathematics learning (Putri & Wilman, 2023). Learning motivation consists of four components, namely Attention, Relevance, Confidence, and Satisfaction, based on the ARCS motivational model (Keller, 2016). Therefore, learning activities should create attractive, relevant, and meaningful learning experiences to improve students' motivation.

One innovative learning model considered effective in improving students' motivation and mathematics achievement is Problem-Based Learning (PBL). Problem-Based Learning encourages students to solve contextual problems collaboratively through investigation, discussion, and problem-solving activities (Ardianti et al., 2022). Previous studies reported that Problem-Based Learning improved students' critical thinking skills, mathematics achievement, and learning motivation because students were actively involved during the learning process (Naufal et al., 2024; Winahyu et al., 2024). In addition, Problem-Based Learning also supports the development of higher-order thinking skills and conceptual understanding in mathematics learning (Surya & Syahputra, 2017).

Besides innovative learning models, manipulative-interactive media are also important in helping students understand abstract mathematical concepts concretely. Manipulative media provide direct learning experiences that help students visualize and explore mathematical concepts independently (Cahyono et al., 2024). Previous studies indicated that manipulative-interactive media improved students' conceptual understanding and mathematics learning outcomes significantly (Ismail et al., 2024). However, most previous studies focused on the implementation of Problem-Based Learning or manipulative media separately.

Limited studies have integrated Problem-Based Learning with manipulative-interactive media specifically designed for angle material in elementary schools. This empirical gap indicates the need for innovative learning strategies integrating student-centred learning models and manipulative media to create more meaningful mathematics learning experiences. Based on preliminary observations conducted at SDN 1 Keser and SDN 2 Keser, Blora Regency, mathematics learning was still dominated by teacher explanations and worksheet activities without optimal use of manipulative-interactive media. As a result, students tended to feel passive, less motivated, and experienced difficulties in understanding angle concepts.



One manipulative-interactive medium developed in this study is the Sunflower Clock Angle media. This media was designed in the form of a sunflower clock equipped with movable angle hands and angle indicators to help students visualize, measure, and compare angles directly through hands-on learning activities. The integration of the Sunflower Clock Angle media into Problem-Based Learning is expected to create more active, enjoyable, and meaningful mathematics learning activities.

Therefore, this study aims to analyze the effect of the innovation of Sunflower Clock Angle media in Problem-Based Learning on elementary students' motivation and mathematics learning outcomes. This study contributes theoretically to the development of innovative mathematics learning strategies integrating Problem-Based Learning and manipulative-interactive media. Practically, this study provides an alternative learning strategy for teachers to improve students' motivation and mathematics learning outcomes, particularly in geometry learning on angle material.

Research Method

This study employed a quantitative research design using a quasi-experimental method to investigate the effect of the innovation of Sunflower Clock Angle media in Problem-Based Learning on elementary students' motivation and mathematics learning outcomes. The quasi-experimental design was selected because the researcher could not fully randomize the participants in determining the experimental and control classes. Specifically, this study applied a non-equivalent pretest-posttest control group design involving an experimental class and a control class. The research design is presented in Table 1.

Table 1. Nonequivalent Pretest–Posttest Control Group Design

Group	Pretest	Treatment	Posttest
Experiment	O ₁	X	O ₂
Control	O ₃	–	O ₄

The participants consisted of 32 fifth-grade students selected using purposive sampling from SDN 1 Keser and SDN 2 Keser, Blora Regency, Indonesia, during the 2025/2026 academic year. The participants were divided into an experimental class receiving Problem-Based Learning assisted by the Sunflower Clock Angle media and a control class receiving conventional learning instruction.

Data were collected using questionnaires, tests, observations, and documentation developed based on the ARCS motivational framework and mathematics learning indicators. The learning motivation questionnaire measured four components, namely Attention, Relevance, Confidence, and Satisfaction (Keller, 2016). Mathematics learning outcomes were measured using pretest and posttest instruments on angle material. Instrument validity was established through expert judgment and product-moment correlation analysis, while reliability was tested using Cronbach's Alpha to ensure instrument consistency and accuracy.

Data collection was conducted during the second semester of the 2025/2026 academic year following permission from the participating schools. The research procedures included administering pretests, implementing Problem-Based Learning assisted by the Sunflower Clock Angle media in the experimental class, conducting conventional learning in the control class, administering posttests, distributing learning motivation questionnaires, conducting classroom observations, and collecting supporting documentation. Quantitative data were analyzed using descriptive and inferential statistical techniques with SPSS software. The data analysis procedures included normality tests, homogeneity tests, linearity tests, simple regression analysis, and multiple regression analysis to determine the effect of the innovation



of Sunflower Clock Angle media in Problem-Based Learning on students' motivation and mathematics learning outcomes.

Results and Discussion

Learning motivation data were obtained using questionnaires based on the ARCS indicators consisting of Attention, Relevance, Confidence, and Satisfaction. The average scores of students' learning motivation are presented in Table 2.

Table 2. Average Scores of Students' Learning Motivation

ARCS Indicators	Experimental Class	Category	Control Class	Category
Attention	84.25	Very High	63.12	High
Relevance	82.50	Very High	61.87	High
Confidence	79.38	High	59.75	Moderate
Satisfaction	81.50	Very High	60.00	Moderate
Average	81.38	Very High	61.19	High

Based on Table 2, the average learning motivation score of students in the experimental class was 81.38, while the control class obtained an average score of 61.19. The highest score in the experimental class was found in the Attention indicator with a score of 84.25, while the lowest score was found in the Confidence indicator with a score of 79.38. In the control class, the highest score was also found in the Attention indicator with a score of 63.12, while the lowest score was found in the Confidence indicator with a score of 59.75. Mathematics learning outcomes data were obtained through pretest and posttest assessments on angle material. The average pretest and posttest scores of students in the experimental and control classes are presented in Table 3.

Table 3. Average Scores of Students' Mathematics Learning Outcomes

Class	Pretest	Posttest
Experiment	63,12	88,56
Control	61,25	66,00

Based on Table 3, the average pretest score of the experimental class was 63.12 and increased to 88.56 in the posttest. Meanwhile, the average pretest score of the control class was 61.25 and increased to 66.00 in the posttest. The normality test was conducted to determine whether the research data were normally distributed. The results of the normality test for learning motivation and mathematics learning outcomes are presented in Table 4.

Table 4. Normality Test Results

Variable	Significance	Interpretation
Learning Motivation	0.200	Normal
Mathematics Learning Outcomes	0.184	Normal

Based on Table 4, the significance value of learning motivation was 0.200 and the significance value of mathematics learning outcomes was 0.184. Both significance values were greater than 0.05, indicating that the research data were normally distributed. The homogeneity test was conducted to determine the equality of variances between the experimental and control classes.

Table 5. Homogeneity Test Results

Variable	Significance	Interpretation
Learning Motivation	0.321	Homogeneous
Mathematics Learning Outcomes	0.287	Homogeneous

Based on Table 5, the significance value of learning motivation was 0.321 and the significance value of mathematics learning outcomes was 0.287. Both values were greater



than 0.05, indicating that the research data were homogeneous. The linearity test was conducted to determine the linear relationship between the independent and dependent variables. The results of the linearity test are presented in Table 6.

Table 6. Linearity Test Results

Variable	Significance	Interpretation
Learning Motivation	0.000	Linear
Mathematics Learning Outcomes	0.000	Linear

Based on Table 6, the significance values for learning motivation and mathematics learning outcomes were 0.000. These values were lower than 0.05, indicating that the relationships between the variables were linear. Hypothesis testing was conducted using simple regression analysis and multiple regression analysis to determine the effect of the innovation of Sunflower Clock Angle media in the Problem-Based Learning model on students' learning motivation and mathematics learning outcomes.

Table 7. Simple Regression Test Results

Variable	Significance	R Square
Learning Motivation	0.000	0.682
Mathematics Learning Outcomes	0.000	0.714

Based on Table 7, the significance values for learning motivation and mathematics learning outcomes were statistically significant ($p < .001$). The R-square value for learning motivation was 0.682, while the R-square value for mathematics learning outcomes was 0.714.

Table 8. Multiple Regression Test Results

Variable	Significance	R Square
Learning Motivation and Mathematics Learning Outcomes	0.000	0.781

Based on Table 8, the significance value was $0.000 < 0.05$ with an R Square value of 0.781. These results indicated that the innovation of Sunflower Clock Angle media in the Problem-Based Learning model simultaneously influenced students' learning motivation and mathematics learning outcomes.

The findings demonstrate that the innovation of Sunflower Clock Angle media in Problem-Based Learning significantly improved elementary students' motivation and mathematics learning outcomes. Students in the experimental class achieved higher motivation scores and mathematics learning outcomes compared to students in the control class. These findings indicate that the integration of manipulative-interactive media and Problem-Based Learning created more active and meaningful mathematics learning experiences.

The improvement in students' learning motivation was observed across all ARCS indicators, namely Attention, Relevance, Confidence, and Satisfaction, with Attention emerging as the highest indicator. This finding can be related to the visual design of the Sunflower Clock Angle media. Unlike a conventional analog clock, which generally presents a simple circular form with uniform visual elements, the Sunflower Clock Angle combines the familiar structure of a clock with a sunflower-shaped design, contrasting colors, and visually distinct components. The arrangement of the clock elements within the sunflower shape provides a more noticeable and distinctive visual stimulus for elementary school students. The combination of color, shape, and hands that can be directly manipulated may attract students' curiosity and encourage them to focus on the learning task. Thus, the visual and interactive characteristics of the media may explain why Attention received the highest ARCS score. These findings support previous studies reporting that Problem-Based Learning



can improve students' learning motivation and active participation during the learning process (Arifin et al., 2024; Winahyu et al., 2024).

The findings also indicate that students' mathematics learning outcomes improved significantly after the implementation of Problem-Based Learning assisted by the Sunflower Clock Angle media. Students became more active in group discussions, problem-solving activities, and direct angle measurement practices. The use of a manipulable sunflower-shaped clock enabled students to observe and measure angles directly rather than relying solely on abstract explanations or conventional clock representations. These activities helped students understand abstract angle concepts more concretely and meaningfully. This result is consistent with previous studies showing that manipulative-interactive media can improve students' conceptual understanding and mathematics achievement (Cahyono et al., 2024; Ismail et al., 2024).

From a theoretical perspective, the findings support constructivist learning theory, which emphasizes that students actively construct knowledge through direct learning experiences and collaborative activities (Surya & Syahputra, 2017). The implementation of Problem-Based Learning encouraged students to solve contextual problems independently and collaboratively, while the manipulative characteristics of the Sunflower Clock Angle provided opportunities to explore angle concepts through direct interaction with the learning medium. This combination supported students in connecting mathematical concepts with concrete learning experiences, resulting in improved conceptual understanding and learning engagement.

From a practical perspective, the findings emphasize the importance of integrating innovative learning models with manipulative-interactive media in elementary mathematics learning. The Sunflower Clock Angle media can serve as an alternative instructional medium for helping students understand geometry concepts, particularly angle measurement, in a more concrete and engaging manner. Its distinctive sunflower-shaped visual design may be particularly useful for attracting students' initial attention, while its manipulable components can support active exploration and participation. The findings therefore provide practical insights for teachers seeking to create student-centered mathematics learning environments that support both students' motivation and mathematics learning outcomes.

Conclusion

This study concludes that the innovation of Sunflower Clock Angle media in Problem Based Learning significantly improved elementary students' motivation and mathematics learning outcomes. The results confirm that the integration of manipulative-interactive media and Problem Based Learning created more active, meaningful, and engaging mathematics learning experiences. The findings highlight the critical role of innovative learning media in improving geometry learning, particularly angle material, in elementary schools.

Recommendation

Based on the findings, educators are recommended to implement Problem-Based Learning integrated with manipulative-interactive media to improve students' motivation and mathematics learning outcomes. Schools should support teachers' professional development by organizing regular training and peer-sharing sessions through Teacher Working Groups (KKG), providing opportunities for teachers to develop and test low-cost manipulative learning media, and conducting classroom reflection or lesson-study activities to evaluate their implementation. Schools should also allocate resources and provide access to materials



needed to develop innovative mathematics learning media. Future research should examine broader mathematics topics, larger samples, and additional outcomes such as critical thinking, creativity, and collaborative learning abilities.

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