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# Implementation of PhET Simulation on Motion Material to Improve Problem Solving Skills of Middle School Students

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**Abstract:** This study aimed to enhance junior high school students' problem-solving skills through the integration of PhET simulations within a Problem-Based Learning (PBL) model. The research design employed was Classroom Action Research (CAR), carried out in two iterative cycles consisting of planning, implementation, observation, and reflection stages. A total of 60 Grade VII students from two parallel classes at a private junior high school in Surabaya participated in this study during the 2024–2025 academic year. Data collection involved pre-tests and post-tests for each cycle, focusing on both general learning outcomes and specific indicators of problem-solving ability. The data were analyzed quantitatively using the normalized gain (N-Gain) formula. Results showed that general learning outcomes improved from an N-Gain score of 0.29 in the first cycle (low category) to 0.69 in the second cycle (medium category). Problem-solving skills demonstrated a stronger gain, increasing from 0.47 (medium) to 0.85 (high). These improvements suggest that combining differentiated instruction and simulation-based learning effectively fosters students' conceptual understanding and higher-order thinking. The study concludes that the PhET-assisted PBL approach is a promising instructional model to develop both cognitive and analytical competencies in science education, particularly in motion and force topics.

**Keywords:** Motion Material; PhET Simulation; Physics; Problem Solving

## Introduction

Education is a fundamental pillar for improving the quality of human resources in Indonesia. In the 21st century, students are expected to master higher-order thinking skills, particularly the ability to solve problems effectively. This competence involves analyzing situations, identifying issues, and proposing logical solutions through a structured process (Ren & Tse, 2023). Such skills should be nurtured from an early stage through purposeful and well-designed learning experiences in schools (Istikomah et al., 2023). Moreover, learning becomes more meaningful when it is aligned with students' individual characteristics and allows them to reach their full potential. To support this, differentiated instruction has gained attention as a teaching strategy that responds to the diverse needs of students, particularly in terms of cognitive abilities, learning styles, and readiness. This approach emphasizes the importance of adaptive teaching practices and encourages teachers to design learning environments that are both inclusive and responsive (Vitaya et al., 2025).

According to the 2022 Programme for International Student Assessment (PISA) report released in December 2023, Indonesian students continue to show low performance in key academic domains. The data place Indonesia at 74th out of 81 participating countries in mathematics, 71st in reading, and 73rd in science. These outcomes reflect an ongoing gap in the quality of education and raise concerns about the nation's ability to prepare students for complex cognitive tasks. In line with these global findings, research within Indonesian schools has also reported that many students struggle with higher-order thinking, including problem-solving abilities (Suárez et al., 2023). Observations from

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classroom practices, particularly in junior high schools in Surabaya, indicate that students often have difficulty understanding previous science concepts and applying them to new problems (Baihaqi et al., 2024). This lack of conceptual grasp and reasoning ability suggests a broader issue related to how instructional strategies are implemented (Dam-O et al., 2024). Effective interventions, such as the use of structured problem-based learning models, have been shown to improve students' confidence and problem-solving competence. Therefore, addressing these challenges requires a shift toward more interactive and student-centered learning environments (Kurniawan et al., 2024).

Recent studies have consistently highlighted that students' problem-solving abilities in science education remain a persistent concern, often stemming from differences in motivation and conceptual understanding, particularly in abstract topics such as motion and force (Ruwiyah et al., 2021). These difficulties are exacerbated by science curricula that emphasize theoretical and mathematical content, which demand cognitive engagement that not all students can process within standard classroom time (Luchembe & Shumba, 2022). One pedagogical response to this challenge is differentiated instruction, which aims to accommodate students' diverse learning styles, cognitive readiness, and individual preferences (Ayasrah et al., 2024). Despite its potential, its classroom implementation frequently encounters practical limitations, including insufficient instructional time and the complexity of simultaneously managing varied learning paths also notes that teachers often struggle to adapt to students' individual needs without adequate support systems (Nasution et al., 2024). In light of these constraints, there has been a growing interest in leveraging digital innovations particularly interactive learning tools and virtual simulations to enhance student engagement and conceptual understanding (Muliyati et al., 2021). These media not only enable students to explore scientific concepts through variable manipulation and visual feedback but also serve as practical alternatives in contexts where laboratory access is restricted Furthermore, studies such as that of demonstrate that simulation-based learning can improve comprehension and foster more active learning environments, aligning with the broader shift toward flexible, student-centered science education (Sunaryo et al., 2021).

Numerous studies have demonstrated that integrating electronic learning media into classroom instruction can significantly enhance students' understanding of subject matter. In an effort to address limitations in conventional science teaching, previous researchers have introduced various forms of innovative and interactive media, particularly virtual experiments, as effective alternatives to traditional methods. Among these, PhET Interactive Simulations have gained recognition for providing engaging and accessible resources that support conceptual learning in science (Alsalhi et al., 2024; Bouchée et al., 2024; Ramaila, 2024). These tools are designed to present scientific concepts in a dynamic and student-friendly format, and research indicates that their use contributes positively to student learning outcomes. Furthermore, the integration of differentiated instruction with PhET simulations has shown potential in enhancing students' problem-solving skills, particularly for learners with varying levels of readiness and cognitive abilities. Despite this progress, no prior studies have provided a detailed implementation of PhET simulations within a structured and cyclic problem-based learning framework (Lestari & Mansyur, 2021). There is also a lack of systematic evaluations that measure the effectiveness of such instructional models in fostering students' ability to solve problems. The novelty of this research lies in its design, which combines problem-based learning stages with the use of PhET simulations to support students in developing consistent and measurable problem-solving skills over time.

Based on this background, to determine the extent of the increase in problem-solving skills and to apply fun learning to students, it is important to carry out this research. This research is one of the new breakthroughs related to innovation in innovative learning planning and the development of interactive learning that is responsible for improving students' problem-solving skills

## Method

This study employed a classroom action research (CAR) approach with a quantitative emphasis to measure the improvement in students' problem-solving abilities. The data were obtained through direct implementation of instructional interventions across two research cycles, allowing for systematic observation, reflection, and refinement of teaching strategies (Habibbulloh et al., 2024). Data were analyzed statistically using pre-test and post-test scores to calculate normalized gain (N-Gain) values (Hayati, 2019). The integration of multiple cycles aligns with the classroom-based inquiry model rather than a purely descriptive quantitative design. Data sources consisted solely of primary data, which included students' performance results from structured assessments and response questionnaires. Literature used to support interpretation was part of the discussion framework, not considered secondary data in the methodological sense.

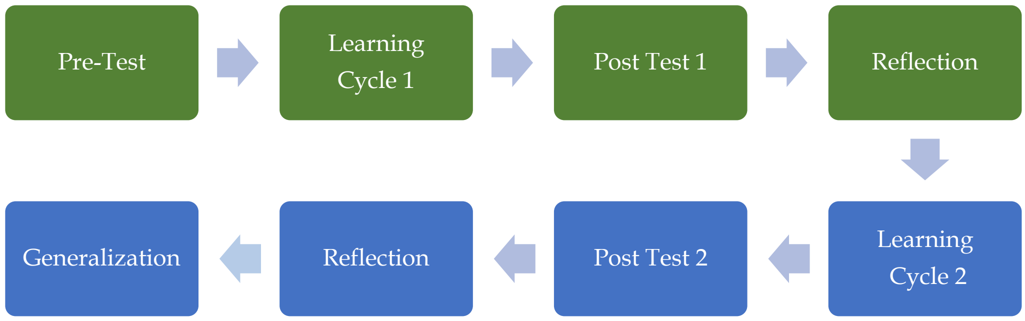


**Figure 1**. Research Flow

The research was conducted at a public junior high school in Surabaya during the 2024/2025 academic year, targeting Grade VII students at learning phase D. A total of 60 students, divided equally into two classes of 30 participants each, were involved in this study. One class functioned as the experimental group, receiving differentiated learning combined with PhET-based problem-based learning (PBL), while the other followed standard instruction. A set of 10 multiple-choice items was used to assess students' problem-solving abilities, accompanied by a student response questionnaire to capture affective feedback (Gea et al., 2024). The instrument design followed validated indicators of problem-solving skills categorized into four dimensions:

**Tabel 1.** Table of Problem-Solving Indicators and Questions

| Indicator | Information | Number of Question | Maximum Score | Cognitive Level |
|---|---|---|---|---|
| Identifying the problem (1) | Understanding the problem correctly, understand the context and gather relevant information. | 1 and 5 | 2.00 | C2 |
| Planning problem solving (2) | Stating and writing down the model or formula used to solve the problem, explain problems logically, convey relevant data and facts. | 2 and 6 | 2.00 | C3 |
| Solve problems according to plan (3) | Perform arithmetic operations correctly, determine the correct solution based on mathematical principles. | 3, 7, and 9 | 3.00 | C4 |
| Evaluate (4) | Draw conclusions from the answers obtained and recheck the calculations obtained. | 4, 8, and 10 | 4.00 | C5 |

**Table 2**. Indicators N-Gain

| Intervals ⟨g⟩ | Category |
|---|---|
| $\langle g \rangle < 0.3$ | Low |
| $0.30 \leq \langle g \rangle < 0.70$ | Sufficient |
| $0.70 \leq \langle g \rangle$ | High |

The results of the data acquisition were analyzed statistically through a difference test by obtaining an N-Gain score as a measure of improvement. N-Gain is a measurement value used to determine how much improvement there is in students' understanding or achievement after being given certain treatments. Comparison of value acquisition affects the level of student problem solving. The following are the N-Gain criteria used in analyzing the results of students' problem-solving skills.

## Result and Discussion

An initial assessment of students' cognitive abilities in solving problems was conducted through a pre-test administered in both classes prior to the intervention. The results indicated that the average score in the first class was 34, while the second class achieved a slightly higher average of 39. Following the implementation of instructional activities during the first learning cycle, students participated in a post-test designed to measure progress. The outcome of this assessment revealed a notable improvement, with the average score rising to 55.6 in the first class and 59.3 in the second class. These results suggest that the applied learning interventions began.

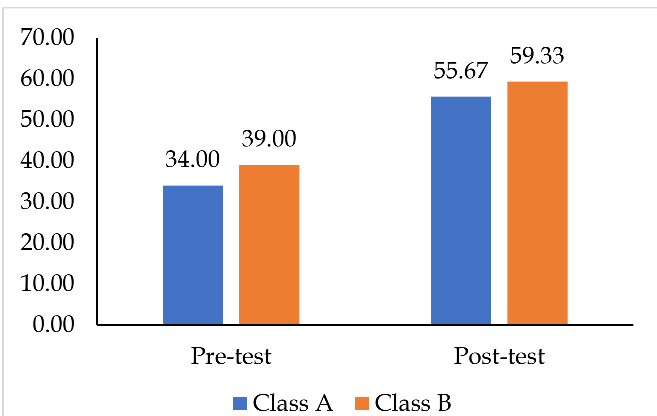


**Figure 2**. Students' Pre-test and Post-test Results Cycle I

This Figure 2 shows the difference in pre-test and post-test scores in cycle I in two classes that were the subjects of the study. There is an increase in student learning outcomes after the implementation of the first cycle of learning. Class A experienced an increase from an average score of 34 to 55.67, while Class B from 39 to 59.33. This increase indicates that the initial intervention has begun to show positive results in improving problem solving. However, this increase is not yet optimal and does not reflect overall success. This may be because students are still in the adjustment stage to the problem-based learning approach that is not yet fully familiar. Therefore, a follow-up cycle is needed by strengthening the differentiation strategy and contextualization of questions so that the results are more optimal.

Furthermore, in cycle 2 stage using the PBL as learning model with differentiating factors, the following problem-solving skill results were obtained.

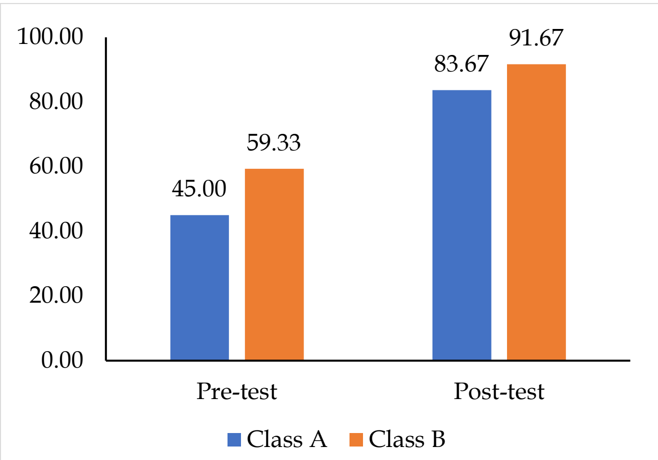


**Figure 3**. Students' Pre-test and Post-test Results Cycle II

The Figure 3, the post-test results showed a more significant increase compared to the previous cycle. Class A increased from 45 to 83.67, while Class B increased from 59.33 to 91.67. This increase reflects the effectiveness of the application of the problem-based earning model that has been adjusted differentially, both in terms of material, stimulus, and presentation approach. Reflection from the first cycle seemed to have a positive influence in improving the design of learning activities in the second cycle. By referring to the flow of classroom actions, improvements in strategies based on reflection were able to answer the shortcomings of the first cycle, especially in approaches that were more in line with students' initial abilities. This proves that the implementation of PBL that is right on target and adaptive can significantly improve students' understanding.

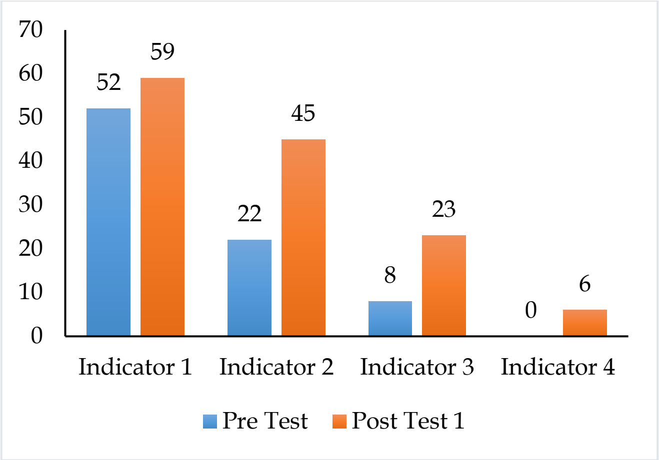


**Figure 4**. Student Problem Solving Skills Cycle I

The Figure 4, the analysis per indicator shows the inequality of achievement between dimensions of problem-solving skills. The first indicator (problem identification) shows the highest score from 52 to 59, while the evaluation indicator is stagnant at 6. The implementation and planning indicators have increased, but are still relatively low. These results indicate that students are still focused on the surface understanding aspect and have not been sufficiently trained to evaluate solutions or re-check the solution steps. In the context of PBL learning, evaluation is one of the high-level thinking skills that is difficult to achieve without reflective guidance. Therefore, the results in this figure are an important basis in determining the direction of improvement in cycle II, especially in emphasizing the evaluative aspect and implementing solutions systematically (Yusuf et al., 2024).

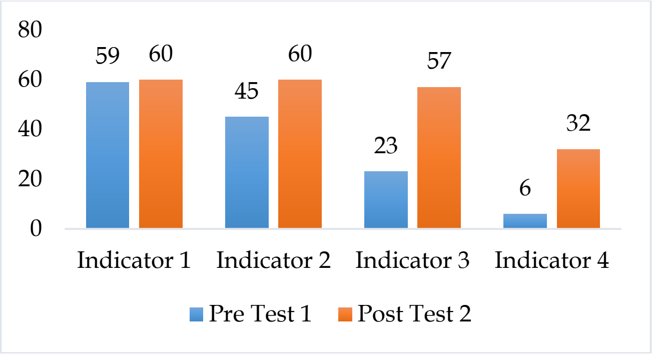


**Figure 5**. Students' Pre-test and Post-test Results Cycle II

The Figure 5, shows real success in improving the four indicators of problem-solving skills after the implementation of the PBL learning strategy in the second cycle. All indicators experienced significant improvement, especially the third indicator (solution implementation) and the fourth (evaluation), which were previously weak. The evaluation indicator increased from 6 to 32, indicating that students began to be able to reflect on the solution and re-check the answer results. This success is closely related to the differentiation strategy applied, which is able to accommodate the learning needs of students individually. This is in line with the principles of classroom action research, where continuous improvement and reflection-based action are the main keys to achieving better learning goals (Yuanata et al., 2023).

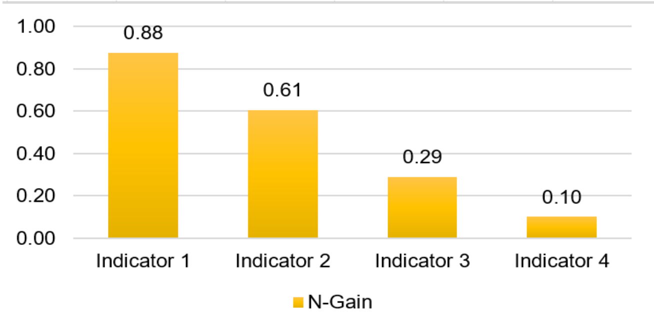


**Figure 6**. Cycle Problem Solving Skills Cycle I

The Figure. 6, the N-Gain value was used to measure the effectiveness of the improvement per indicator. The results showed that the first indicator obtained the highest gain value (0.88) in the high category, while the fourth indicator only obtained 0.10, which is included in the very low category. This inequality shows that although learning has produced results in the early stages of problem solving (identification), students have not been able to develop advanced skills such as evaluation and reflection (Akbar et al., 2024). This strengthens the conclusion that learning in cycle I is more about improving basic understanding and has not touched on higher critical thinking aspects. Therefore, strategies in cycle II need to be designed to encourage students to be more active in analytical and evaluative thinking, not just understanding the questions.

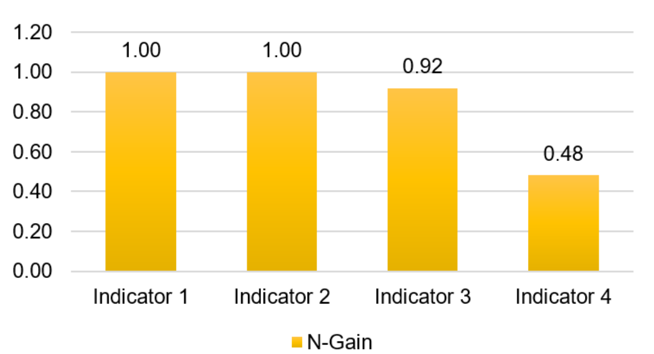


**Figure 7**. Problem Solving Skills Improvement Cycle I

The Figure 7, shows a summary of the average N-Gain of all indicators, with the highest value in indicator 1 (0.88) and the lowest in indicator 4 (0.10). The overall average N-Gain is at 0.47, which is categorized as moderate according to Hake (1999). This means that in general there is an increase in students' understanding of problem-solving skills after two learning cycles. However, the disparity between indicators shows that the increase is not even. In particular, evaluation skills are still a major challenge. This needs further attention in the next stage of learning. The scaffolding approach and the use of explicit feedback need to be strengthened so that students are able to independently assess the process and results of their completion. Students experienced an increase in problem-solving skills as seen from the results of the analysis in cycle I and cycle II. This was caused by several factors, including implementing fun, differentiated learning, and being assisted by PhET learning media (Hasnunidah et al., 2024).

The variation in students' N-Gain scores across and within classes can be attributed to several factors. One key factor is the difference in students' initial abilities, which influenced how they responded to both the pre-test and post-test. Additionally, the timing of the test administration played a role (Nkosi et al., 2024). In Class B, testing occurred in the morning when students were still fresh and focused, whereas in Class A, the testing took place during the final period of the day when students were less conditioned, thus affecting their concentration and performance. Figures 2 and 3 reveal that most students demonstrated improvements particularly in Indicator 1—identifying and understanding problems. However, indicators 2 (planning), 3 (executing), and 4 (evaluating) still showed limited progress across both classes. This suggests that while students were able to recognize problems, they struggled with developing and applying appropriate solutions, which led to inaccuracies in implementation and reflection. In the first learning cycle, shown in Figure 4, students generally improved in their ability to identify problems (Helmi & Arafah, 2024; Zulfaniar & Palloan, 2024). They could comprehend the problem context and clearly state known and unknown variables. Nevertheless, significant gaps remained in their ability to solve and evaluate problems using proper conceptual reasoning. This indicates a lack of mastery in applying strategies to reach correct conclusions and conduct self-evaluation (Putri et al., 2024; Tommy et al., 2024).

Recognizing this issue, the second cycle of instruction was redesigned to include simulated learning through PhET, an interactive platform. As illustrated in Figure 5, the use of simulations helped students visualize and better understand abstract concepts. The average N-Gain in Class A increased to 0.60 (moderate category), while Class B achieved an N-Gain of 0.78 (high category), resulting in an overall combined gain of 0.69 (Hasyim et al., 2024). These results demonstrate that students' performance across all four indicators improved due to the enhanced learning experience. Specifically, their planning, implementation, and evaluation processes became more coherent and effective, supporting the idea that a well-structured problem-solving sequence can significantly improve outcomes (Faizah et al., 2024; Ridani & Arianingrum, 2024; Setiani et al., 2024).

The introduction of differentiated learning strategies further contributed to improved results. Students worked in groups where they could support each other and share knowledge. This collaborative environment ensured that no single group outperformed the rest excessively. The joyful and inclusive atmosphere created through differentiation allowed learning to become more engaging and accessible. As a result, the problem-solving skill N-Gain rose from 0.29 (low) in Cycle 1 to 0.69 (moderate) in Cycle 2. Additionally, students who showed improvement in problem-solving abilities increased from a moderate average of 0.47 to a high average of 0.85 in the second cycle.

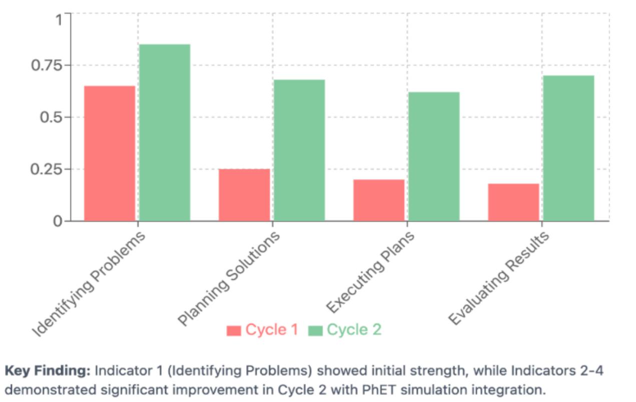


**Figure 8.** Problem-solving indicators performance

The implementation of Problem-Based Learning (PBL) combined with differentiation had a strong impact on student outcomes. Through two iterative cycles, PBL encouraged students to engage with real-world problems that demanded analytical thinking, decision-making, and reflective evaluation. This helped cultivate logical, creative, and collaborative skills—essential components of 21st-century competencies (Liana et al., 2023; Liswar et al., 2023). Furthermore, these findings can serve as a valuable reference for educators and curriculum designers aiming to enhance student-centered, problem-oriented instruction (Medeiros et al., 2024). However, the study is not without limitations. The focus on a single learning model and the use of a relatively small and homogenous sample restrict the generalizability of the results. The findings may not fully represent outcomes from alternative instructional strategies or broader educational contexts. Additionally, the sample distribution across both cycles was not optimally balanced, which may have influenced the consistency of the data (Rianti et al., 2024; Verawati & Hikmawati, 2021).

## Conclusion

The findings of this study demonstrate a substantial enhancement in students' learning outcomes, as evidenced by the increase in N Gain scores from 0.29, categorized as low, in the first cycle to 0.69, categorized as moderate, in the second cycle. Additionally, students' problem-solving abilities showed a notable improvement, with N Gain values rising from 0.47 (moderate category) to 0.85 (high category) between the first and second cycles. These results suggest that the implemented learning model is effective in fostering both cognitive development and the acquisition of problem-solving competencies. Nevertheless, the study is subject to certain limitations, particularly regarding the scope of the sample, which was restricted to two classes within a single school environment, thereby limiting the generalizability of the findings. Furthermore, the assessment employed was confined to multiple choice formats, which may not fully capture the complexity of students' understanding and reasoning. In light of these constraints, it is recommended that future research include a broader and more heterogeneous sample, encompassing diverse educational settings, and utilize varied forms of assessment such as multiple response or open-ended essay questions to obtain more comprehensive insights. Further investigations might also consider extending the study to encompass other topics within the physics curriculum or explore interdisciplinary applications in different subject areas.

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**Author Contributions**
Conceptualization, N.H, M.A, M.S, M; methodology, N.H and M.A; validation, M.S and M.; formal analysis, N.H; investigation, N.H and M.; resources, N.H and M.S.; data curation, N.H and M.S.; writing-preparation of initial draft, N.H; M.A and M.S.; writing-review and editing, N.H and M., visualization, M.A and M.S. All authors have read and approved the published version of the manuscript.

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**Conflicts of Interest**
The authors declare no conflict of interest.

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