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# THE EFFECTIVENESS OF THE ALGODOO-ASSISTED IBMRO MODEL IN IMPROVING PHYSICS PROBLEM-SOLVING SKILLS

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**ABSTRACT**

The IBMRO (Investigation-Based Multiple Representation Online) learning model is designed to improve physics problem-solving skills. However, its implementation requires the right tools so that the objectives can be achieved even though the learning process is carried out online. This study used Algodoo as a learning tool in the IBMRO model on parabolic motion. This study aims to analyze the effectiveness of the Algodoo-assisted IBMRO model in improving students' physics problem-solving skills. This research employed a pre-experimental one-group pre-test and post-test design, with 96 students divided into three classes. Before and after the learning process, students were given tests (pre-test and post-test). During the learning process, observations were made of student activities. After the learning was completed, students were given a questionnaire to assess their understanding of the learning. The pre-test and post-test scores were analyzed using paired t-test, Wilcoxon test, and n-gain. The percentage of observation and questionnaire data was calculated. The results showed that the average score of students' physics problem-solving skills increased significantly $\alpha$ = 5%, The average n-gain of physics problem-solving skills was in the medium category, the average n-gain of each indicator of physics problem-solving skills was in the medium to high category, student activities were relevant to learning, and students had a good response to learning. This study concludes that the Algodoo-assisted IBMRO model is effective in improving students' physics problem-solving skills.



Keywords: Algodoo; effectiveness; IBMRO; physics; problem-solving skills

## INTRODUCTION

Problem-solving skills are essential in 21st-century learning because they enable students to develop critical and adaptive thinking skills in addressing complex challenges. Integrating these skills into learning can support students' creativity and decision-making in real life (Rusmin et al., 2024). Additionally, problem-solving skills are among the essential skills and trends that students need to master today (Abtokhi et al., 2021). Studies show that students who develop these skills have higher cognitive abilities, deeper conceptual understanding, and more positive scientific attitudes (Singh, 2021). The development of problem-solving skills is not only relevant in an academic context but also crucial in achieving the Sustainable Development Goals (SDGs). These skills empower individuals to identify, analyze, and formulate innovative solutions to global challenges such as poverty, inequality, and climate change (Rini et al., 2023). By training students in these skills, education can directly contribute to achieving the SDGs, including quality education and partnerships to achieve goals, as it promotes interdisciplinary collaboration and the creation of sustainable, far-reaching solutions. Thus, problem-solving skills serve as a bridge between classroom theory and daily application, paving the way for a better future.

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Physics requires a strong conceptual understanding and application skills in solving problems. Physics learning cannot be separated from problem-solving skills, as many concepts are developed and understood through solving complex, contextual problems (Docktor & Mestre, 2019). Physics problem-solving skills involve applying mathematical formulas and require students to understand concepts, analyze physical situations, and develop strategic problem-solving approaches. The conceptual framework for physics problem-solving skills involves several key steps. First, focus on the problem, understand the physics concepts involved, and clearly define the problem. Second, plan the solution by choosing the appropriate approach, such as using relevant physics equations. Third, implement the plan by performing calculations and mathematical manipulations. Fourth, evaluate the solution to ensure consistency with physics principles and check the accuracy of the answer. Therefore, physics learning should facilitate students to solve physics problems.

One of the success indicators in physics learning is the improvement of problem-solving skills (Taasoobshirazi & Farley, 2013). Students are considered successful in learning physics if they can apply their knowledge to solve physics problems (Bellanca & Brandt, 2010; Jatmiko et al., 2016; Siswanto et al., 2018). However, several previous studies have shown that students struggle with solving physics problems and possess low physics problem-solving skills (Daniel et al., 2020; Bakri et al., 2021; Afifah & Hariyono, 2023; Dawana & Dwikoranto, 2024). Students solve physics problems mathematically. When asked to explain the results, they remain hesitant and unsure whether their answers are correct. 77.27% of students reported difficulty solving physics problems because they did not understand the problem, and 22.73% stated that they did not understand the underlying concept. Interviews showed they did not understand the steps or have a specific strategy for solving physics problems. (Siswanto & Saefan, 2014). Students often struggle to understand problems and plan effective solutions, indicating low problem-solving skills (Sartika & Humairah, 2018; Kuo et al., 2020). Students' mistakes in solving physics problems are partly caused by their tendency to apply intuitive and spontaneous reflective thinking triggered by prominent features that appear in the problem, rather than thinking deeply and reflectively (Sukariasih et al., 2024). Students use unclear approaches and memory-based approaches to solve physics problems (Riantoni et al., 2017). According to Fitroh et al. (2020), students struggle to formulate logical solutions and evaluate results, which leads to low problem-solving skills. Students experience difficulties in the physics subject, specifically in understanding questions (26%) and determining the correct formula (25%). Additionally, students experience difficulties with mathematical concepts: 63% struggle with substituting data into formulas, and 76% struggle with mathematical operations (Adianto & Rusli, 2021).

Based on previous research findings regarding the low problem-solving skills of students, it is urgent to address this problem. Physics learning that focuses solely on memorizing formulas without understanding problem-solving can lead to misconceptions and hinder knowledge transfer to new situations that do not support physics problem-solving skills (Kuo et al., 2020). Physics problem-solving skills must be practiced. A learning approach that focuses on developing these skills is key to reforming physics education. Jasman et al. (2024) recommend a more effective learning approach to improve physics problem-solving skills. Efforts to improve the quality of the learning process through innovative learning can significantly improve students' physics problem-solving skills (Kim et al., 2022; Dawana & Dwikoranto, 2024). Additionally, well-designed educational technology has significantly enhanced students' physics problem-solving skills (Zhou et al., 2023). Innovative learning and educational technology offer enhanced opportunities to enhance physics problem-solving skills.

One of the innovative learning models that utilizes technology to train physics problem-solving skills is the Investigation-Based Multiple Representation Online (IBMRO) model. This model has four learning phases that are implemented online: Orientation, Investigation, Multi-Representation Application, and Evaluation. The characteristics of this model are training physics problem-solving skills through multiple representations (verbal, images, graphics, and mathematics). A learning environment that supports the IBMRO model learning that 1) presents physics phenomena/simulations/demonstrations that are relevant to students; 2) presents scientific activities, multi-representation activities, and problem-solving; 3) provides tools for investigation, multi-representation, and solving physics problems (Jatmiko et al., 2024). The selection of educational technology in this learning model must facilitate learning using multiple representations. Technology such as interactive simulations, diagrams, and physics modeling software supports the development of physics problem-solving skills by providing direct feedback (Sirait et al., 2023; Zhou et al., 2023).

One of the educational technologies that facilitates multi-representation in physics learning is Algodoo. Algodoo is a simulation software compatible with PCs, tablets, smartphones, and smartboards. This software offers a digital learning platform that simulates the motion of objects that can interact with each other according to Newtonian mechanics and geometric optics, representing objects in two dimensions (Euler et al., 2020). Algodoo is a new technology in computer-based learning that is faster, easier to use, and accessible to users without knowledge of computational physics (Bodin et al., 2012; Gregorcic & Bodin, 2017; Euler et al., 2020). The characteristics of Algodoo include visualizing physical phenomena, features for investigating phenomena and their processes, physics modeling, problem-solving tools, and project assignments. Therefore, Algodoo is considered the right tool for physics learning using the IBMRO model. Each phase in the IBMRO model can be assisted using Algodoo.

Learning physics with the Algodoo-assisted IBMRO model has its own characteristics. Algodoo's advantage in presenting physics phenomena through graphics and mathematics will help facilitate the learning of the concept of parabolic motion. This is a novel approach to teaching physics that aims to enhance students' problem-solving skills. Each phase in the IBMRO model can be facilitated graphically and mathematically by Algodoo. Different modes of representation will assist in the process of solving physics problems.

In this study, physics learning was conducted using the Algodoo-assisted IBMRO model to enhance students' physics problem-solving skills. The purpose of this study is to analyze the effectiveness of the IBMRO model assisted by Algodoo in improving students' physics problem-solving skills. The physics problem-solving skills indicators, as adapted from Young and Freedman (2012), Selcuke et al. (2008), and Riantoni et al. (2023), consist of Identification (I), Organisation (O), Execution (E), and Evaluation (E).

## METHODS

This study was conducted with science education students in an introductory physics class focused on parabolic motion (projectile motion). The design of this study was a one-group pre-test and post-test design: O1 X O2 (Fraenkel & Wallen, 2009). Before the student group learned about parabolic motion, they were given an initial test (pre-test) on physics problem-solving skills (O1). Then, they were given learning about parabolic motion using the Algodoo-assisted IBMRO learning model (X). After completing the learning process, they were given a final post-test (O2) with the same topic and problems as the pre-test.

The research sample was 96 science education students in the introductory physics class. The sample was taken by cluster random sampling. This technique is more straightforward because it is applied to groups or classes, so it does not require a significant amount of time (Fraenkel & Wallen, 2009). Classes were selected randomly to generalize the research results to the entire population. The sample in this study consisted of three classes (A, B, and C), each with 32 students.

This study employed written tests to collect data on physics problem-solving skills, observations to gather data on student activity, and questionnaires to collect data on student responses to learning. Problem-solving skill test questions are structured according to their indicators (identification, setup, execution, and evaluation) and accompanied by a scoring rubric. Observation sheets were prepared to monitor student activities relevant to learning, and questionnaires were used to gather student responses after the learning experience. The validity and reliability of these data collection instruments were determined using expert assessment, passing grades, and the percentage of agreement. The validity and reliability of the instruments used have been determined, including: the physics problem-solving skills test sheet (3.78: valid; 96.04%: reliable), student activity observation sheet (3.56: valid; 95.24%: reliable), and student response questionnaire (3.54: valid; 90.36%: reliable).

The study focuses on analyzing the effectiveness of the Algodoo-assisted IBMRO learning model to improve students' physics problem-solving skills. The analysis of the effectiveness of the Algodoo-assisted IBMRO learning model was carried out in several ways: (1) testing the difference in average scores between the pre-test and post-test statistically at $\alpha = 5\%$; (2) calculating the average n-gain; (3) to strengthen the analysis results, that the n-gain of each class increased consistently (there were no significant differences between classes for their n-gain scores), an analysis of the differences in the average n-gain scores between classes was conducted; (4) calculating the percentage of students' relevant activities; (5) calculating the average percentage of students' responses to learning. The collected data were then analyzed to determine the effectiveness of Algodoo-assisted IBMRO learning to improve students' physics problem-solving skills. The analysis of the effectiveness of the Algodoo-assisted IBMRO learning model was carried out by analyzing the average pre-test and post-test scores with (1) paired-sample t-test or non-parametric Wilcoxon's test analysis (Gibbons & Chakraborti, 2011; Şimşek, 2023). If $p < 0.05$, this indicates that there is a statistically significant difference between the pre-test and post-test scores; (2) calculating the average n-gain with the formula: n-gain = (post-test score – pre-test score) / maximum score – post-test score), with categories: (a) high if n-gain $\geq 0.70$; (b) medium if $0.70 >$ n-gain $\geq 0.30$; and (c) low if n-gain $< 0.30$ (Hake, 1998; Coletta, 2023); (3) independent-sample t-test or non-parametric analysis Mann Whitney U test (Gibbons & Chakraborti, 2011; Şimşek, 2023); (4) calculating the percentage of relevant student activities (relevant if > 60%); (5) calculating student responses to the Algodoo-assisted IBMRO teaching model (student responses are categorized as good if the average percentage of student response scores for each component is ≥ 75%).

## RESULTS AND DISCUSSION

The IBMRO model has four learning phases: Orientation, Investigation, Multi-Representation Application, and Evaluation. The face-to-face meeting was conducted online using Zoom, and the implementation of the phases utilized Algodoo. The learning is designed so that each stage can improve physics problem-solving skills, and then analyze its effectiveness. The Algodoo-assisted learning stages play a crucial role in enhancing learning effectiveness. The implementation is presented in Table 1.

**Table 1.** Implementation of Algodoo-assisted IBMRO Model

| No | IBMRO Model Phase | Algodoo Assistance |
|---|---|---|
| 1 | Orientation<br>Students observe a video of the motion of a kicked ball (parabolic motion) | Students simulate a ball kicked at an elevation angle of 45°. They calculate the maximum height and distance the ball reaches before it hits the ground, given an initial speed of 20 m/s for the kicked ball, and determine the time the ball is in the air (Figure 1). |
| 2 | Investigation<br>Students conduct an investigation related to the maximum height, maximum distance, and time when the ball is kicked (parabolic motion) | Students investigate the maximum height, maximum distance, and time when the ball is kicked or in parabolic motion (Figure 2) |
| 3 | Multi-Representation Application<br>Students create or present the results of investigations using multiple representations of physics. | Students study the images and graphs of parabolic motion and their mathematical calculations (Figure 3, Figure 4, and Figure 5) |
| 4 | Evaluation<br>Students evaluate their multi-representation results. | Students assess the appropriateness of multiple physics representations, including verbal, pictorial, graphic, and mathematical. |

The simulation of a kicked ball is a parabolic motion event. In this case, specific physical quantities have been determined, and other physical quantities are to be found.

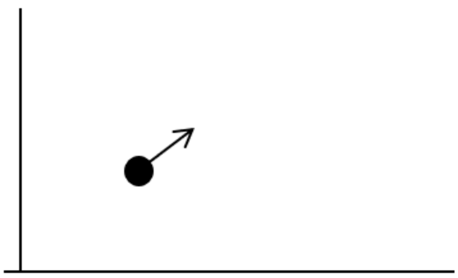

**Figure 1.** Simulation of a Kicked Ball (Parabolic Motion)

Figure 1 shows a simulation of a phenomenon in physics, namely a ball being kicked, which is called parabolic motion. Through this simulation, a graph was created using the Algodoo application. The Algodoo application can display physics phenomena in graphical format, allowing users to investigate specific physics quantities through these graphs.

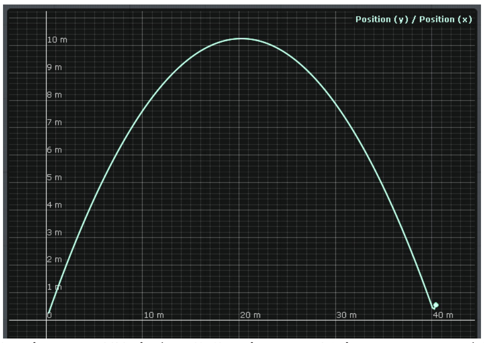


**Figure 2.** Investigation of Maximum Height, Maximum Distance, and Time in Parabolic Motion

The Algodoo application can generate graphs that confirm that a kicked ball follows a parabolic motion. The graphs show the parabolic trajectory, making it easy to understand. Figure 2 shows a complete parabolic graph.


**Figure 3.** Multi-Representation Application for Maximum Distance Problem-Solving

The Algodoo-assisted IBMRO learning model can guide students in learning parabolic motion using multi-representations. Figure 3 presents parabolic motion using graphical and mathematical representations. Students learn to solve problems involving parabolic motion through the use of graphs and mathematics.

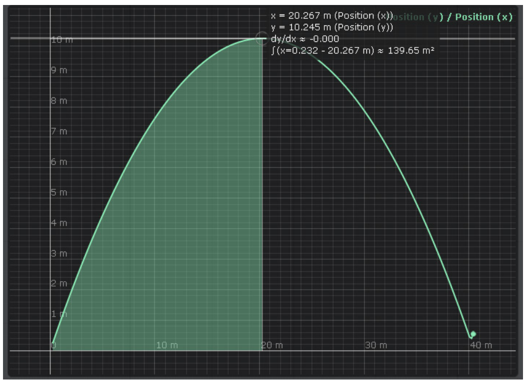


**Figure 4.** Multi-Representation Application for Maximum Height Problem-Solving

Students can use Algodoo to check and calculate the maximum height and maximum distance of a parabolic motion. Figure 4 presents multiple representations (graphs and mathematical) for the maximum height of a parabolic motion. Students can place the cursor at the highest point of the graph. In this way, students can immediately determine the maximum height. To see the farthest position, students can place the cursor at the farthest end of the parabolic motion graph, as shown in Figure 5.

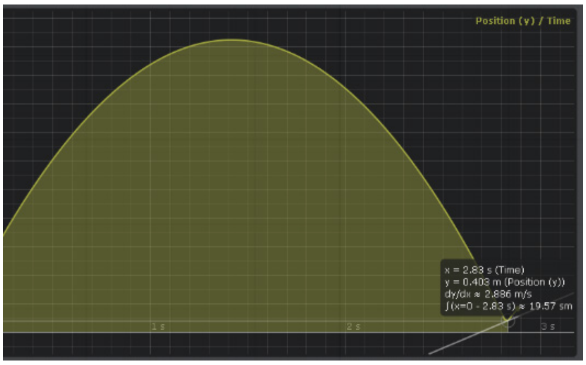


**Figure 5.** Multi-Representation Application for Time Problem-Solving in Parabolic Motion

Table 1, Figures 1, 2, 3, 4, and 5 demonstrate that Algodoo effectively supports each phase of IBMRO learning. This evidence supports students' processes and learning outcomes in achieving their objectives. The results of the average pre-test and post-test scores of physics problem-solving skills for classes A, B, and C are presented in Figure 6. The unshaded bars show the average pre-test scores, while the shaded bars show the average post-test scores.

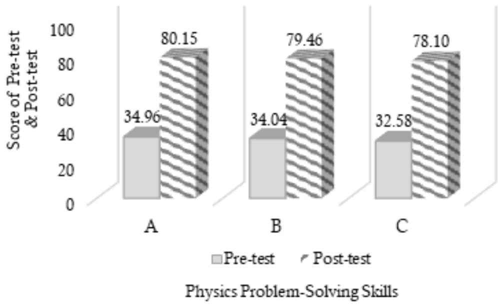


**Figure 6**. Average Pre-Test and Post-Test Scores for Physics Problem-Solving Skills

Figure 6 shows that the average scores of all classes on the pre-test and post-test physics problem-solving skills related to parabolic motion increased. Based on these results, a more in-depth analysis was conducted to determine the significance of the increase. The results of the analysis are presented in Tables 2, 3, and 4.

**Table 2.** Normality and Homogeneity of the Average Pre-test and Post-test Scores for Physics Students' Problem-Solving Skills

| Class | Score | ∑ Student | Average | Std. Dev | Normality, α = 0.05 | | Homogeneity, α = 0.05 | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Asymp. Sig. (2-tailed) | Normality | Asymp. Sig. (2-tailed) | Homogeneity |
| A | Pre-test | 32 | 34.96 | 4.84 | 0.062 | Yes | 0.226 | Yes |
| | Post-test | 32 | 80.15 | 5.62 | 0.058 | Yes | | |
| B | Pre-test | 32 | 34.04 | 4.24 | 0.200 | Yes | 0.027 | No |
| | Post-test | 32 | 79.46 | 5.32 | 0.200 | Yes | | |
| C | Pre-test | 32 | 32.58 | 5.14 | 0.061 | Yes | 0.954 | Yes |
| | Post-test | 32 | 78.10 | 5.46 | 0.067 | Yes | | |

Table 2 presents the results of calculating the normality and homogeneity of the pre-test and post-test scores for physics problem-solving skills. These results form the basis for determining the equality test of two means, specifically the paired t-test or Wilcoxon test, as presented in Tables 3 and 4.

**Table 3.** Results of Paired t-test/Wilcoxon test of the Pre-test and Post-test Scores for Physics Students' Problem-Solving Skills

| Class | Score | ∑ Student | Average | Paired t-test, α = 0.05 | | | Wilcoxon test, α = 0.05 | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | t | p | Decision | z | P | Decision |
| A | Pre-test | 32 | 34.96 | -61.83 | < 0.001 | Ho is rejected | | | |
| | Post-test | 32 | 80.15 | | | | | | |
| B | Pre-test | 32 | 34.04 | | | | -4.88 | < 0.001 | Ho is rejected |
| | Post-test | 32 | 79.46 | | | | | | |
| C | Pre-test | 32 | 32.58 | -54.56 | < 0.001 | Ho is rejected | | | |
| | Post-test | 32 | 78.10 | | | | | | |

The paired t-test and Wilcoxon test results show that the p-value is less than 0.001 for the A, B, and C classes. These results indicate a significant difference between the pre-test and post-test scores for physics problem-solving skills. There is also a significant increase at α = 5%. There is an increase in students' physics problem-solving skills after participating in learning using the Algodoo-assisted IBMRO model. Furthermore, an analysis of the increase in each indicator of physics problem-solving skills was also conducted to examine its effectiveness in greater depth. The results of this analysis are presented in Table 4.

**Table 4.** N-Gain Calculations for Each Physics Problem-Solving Skills Indicator

| Physics Problem-Solving Skills Indicator | Class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | A | | | B | | | C | | |
| | Pre-test | Post-test | n-gain | Pre-test | Post-test | n-gain | Pre-test | Post-test | n-gain |
| Identification | 1.34 | 2.65 | 0.79 | 1.29 | 2.59 | 0.76 | 1.17 | 2.45 | 0.70 |
| Set Up | 1.18 | 2.33 | 0.63 | 1.19 | 2.47 | 0.71 | 0.98 | 2.27 | 0.64 |
| Execute | 0.88 | 2.31 | 0.68 | 0.87 | 2.29 | 0.66 | 0.83 | 2.08 | 0.58 |
| Evaluation | 0.53 | 2.11 | 0.64 | 0.72 | 2.07 | 0.59 | 0.66 | 1.91 | 0.53 |

Based on Table 4, a graph was then created to present the average n-gain for each class. The graph is presented in Figure 7.

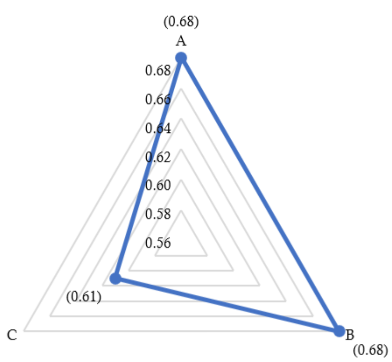


**Figure 7**. Average n-gain for each class (A, B, C)

Table 4 and Figure 7 present the results of the n-gain calculation for the average of each indicator of physics problem-solving skills. Each indicator of students in classes A, B, and C experienced an increase in the high and medium categories. The physics problem-solving skills of class A students showed an increase of 0.68 in the medium category. The Identification indicator increased in the high category (0.79). Other indicators increased in the medium category: Setup (0.63), Execution (0.68), and Evaluation (0.64).

The physics problem-solving skills of class B students also showed an increase of 0.68 in the medium category. The Identification and Set Up indicators increased in the high category by 0.76 and 0.71, respectively. The Set Up and Execute indicators increased in the medium category by 0.66 and 0.59, respectively. The physics problem-solving skills of class C students also showed an increase of 0.61 in the medium category. The Identification indicator increased in the high category (0.70). Other indicators increased in the medium category: Setup (0.64), Execution (0.58), and Evaluation (0.53).

The analysis shows that the Algodoo-assisted IBMRO model supports students in improving their physics problem-solving skills related to parabolic motions. This reinforces previous findings that physics learning with multi-representations can improve moderate physics problem-solving skills (n-gain score = 0.6) (Siswanto et al., 2018). Learning effectiveness is based on the process and learning outcomes (Dunkin & Biddle, 1974; Siswanto et al., 2018). In addition, students actively participate in learning (Eom et al., 2006; Jatmiko et al., 2024), and learning outcomes can increase because students have a positive response to learning (Zimmerman & Schunk, 2012; Chen & Zhang, 2021).

The Algodoo-assisted IBMRO learning model has a significant impact on improving students' physics problem-solving skills. Figure 1 shows the difference in students' average pre-test and post-test scores for physics problem-solving skills. The significant difference is evident in Table 3. The average score of students' physics problem-solving skills increased, as presented in Table 4. The increase in each indicator of physics problem-solving skills is in the medium to high category. Students experienced an increase in identifying problems, designing solutions, problem-solving, implementing them, and evaluating the results. They solved physics problems well after participating in learning using the Algodoo-assisted IBMRO model because the learning provided students with an understanding of concepts and the use of multiple representations to solve problems. Multiple representations can enhance conceptual understanding and problem-solving, and are key to effective problem-solving (Siswanto et al., 2018; Distrik et al., 2021; Schönborn et al., 2022; Susac et al., 2023; Jatmiko et al., 2024; Takaoğlu et al., 2024).

Students can identify problems by noting physical quantities they know in the problem, writing down the problem, and understanding it by rewriting it using an appropriate format or representation. In this study, students used verbal and pictorial representations to understand the problem. If students can clearly understand the problem, they will master the key aspects of solving physics problems and consider effective strategies for their solution (Etkina et al., 2019). Several studies recommend the importance of understanding the problem in solving physics problems (Berge & Danielsson, 2013; Yeo & Tan, 2014; Milbourne & Wiebe, 2017; Park, 2020; Owusu et al., 2022; Gumisirizah et al., 2024; Sarkingobir et al., 2024). Effective physics problem-solving requires a deep conceptual understanding before applying mathematical calculations (Maries & Singh, 2023; Janariani et al., 2024)

Physics problem-solving consists of representing and solving problems. Problem identification determines the design, implementation, and evaluation of problem-solving. The Algodoo-assisted IBMRO learning model enables students to identify problems with multiple representations. This follows the results of previous studies, which suggest that understanding physics problems can be improved by guiding students to use representations (Bimba et al., 2013; Distrik et al., 2021; Schönborn et al., 2022; Jatmiko et al., 2024). In this study, students successfully identified problems related to parabolic motion using multiple representations. Multiple representations allow students to use various methods to understand problems and prevent them from relying directly on mathematical equations. This aligns with the theory of cognitive constructivism, which posits that students are actively engaged in acquiring information and constructing their knowledge (Moreno, 2010; Rahim et al., 2021).

Students can design, implement, and evaluate problem-solving, supported by their success in identifying problems, as presented in Table 4. They develop a physics problem-solving plan by identifying concepts, principles, formulas, and laws of physics to determine the appropriate mathematical equations. Furthermore, they implement the plan by substituting the physical quantities they know into the mathematical equations and performing mathematical calculations. They evaluate the results by checking the suitability between the answers and the problems, as well as verifying the units. This follows the results of previous studies that multiple representations support physics problem-solving (Distrik et al., 2021; Xing et al., 2022; Hahn & Klein, 2023)

Students' physics problem-solving skills increased due to relevant student participation or activities in learning using the Algodoo-assisted IBMRO model. Student activities were observed for each meeting by utilizing the breakout room facility on the Zoom Meeting application, and the average results are presented in Table 5.

**Table 5.** Student Activities in Learning Using the Algodoo-Assisted IBMRO Model

| Relevant Student Activities | Class A | | Class B | | Class C | |
|---|---|---|---|---|---|---|
| | f | % | f | % | f | % |
| Participation in discussion | 22.75 | 71.09 | 22.85 | 71.22 | 23.63 | 72.82 |
| Participation in investigation | 24.13 | 75.39 | 25.13 | 78.52 | 24.13 | 75.39 |
| Participation in multi-representations | 23.13 | 72.27 | 24.00 | 75.19 | 23.63 | 72.82 |
| Participation in evaluation | 25.13 | 78.52 | 25.13 | 78.52 | 22.75 | 71.09 |

Based on Table 5, student activities during learning are relevant to learning using the Algodoo-assisted IBMRO model. Students were arranged to learn about physics through parabolic motion by engaging in discussions to understand problems and design solutions, conducting investigations, utilizing multiple representations, and evaluating their progress. Student activities during learning increased, and they looked enthusiastic. Student participation in learning has a significant impact on their learning outcomes (Yildirim & Sen, 2020; Zhao, Wang, & Liu, 2023; Wagino et al., 2024; Kanphukiew & Nuangchalerm, 2024).

After learning, students respond to learning using the Algodoo-assisted IBMRO model. Student responses relate to the novelty, benefits, and interest in the Algodoo-assisted IBMRO model. Student responses to learning using the Algodoo-assisted IBMRO model are presented in Table 6.

**Table 6.** Student Responses to Learning Using the Algodoo-Assisted IBMRO Model

| Student Response | Class A | Class B | Class C |
|---|---|---|---|
| | Yes (%) | Yes (%) | Yes (%) |
| Novelty | | | |
| How lecturer teachers | 100.00 | 96.67 | 100.00 |
| Learning stages | 90.63 | 93.75 | 90.00 |
| Media/Application | 100.00 | 100.00 | 96.77 |
| Learning Activity | 96.67 | 93.75 | 100.00 |
| Learning atmosphere | 93.75 | 93.75 | 96.67 |
| Average | 96.21 | 95.58 | 96.68 |
| Benefits | | | |
| Training in physics problem-solving skills | 96.67 | 93.75 | 93.33 |
| Understanding physics concepts | 93.75 | 87.50 | 93.33 |
| Engaging learning | 93.75 | 90.63 | 90.63 |
| Average | 94.72 | 90.62 | 92.43 |
| Interests in the Algodoo-assisted IBMRO model | | | |
| Following topics | 96.88 | 100.00 | 100.00 |
| Other subjects | 96.88 | 93.33 | 96.88 |
| Average | 96.88 | 96.66 | 98.44 |

Table 6 shows that students responded well to learning using the Algodoo-assisted IBMRO model. The average student response is more than 75%, meaning that students support and are interested in the learning process using the Algodoo-assisted IBMRO model. They expressed interest in the Algodoo-assisted IBMRO model for learning the following topics and other subjects. Students' positive responses to learning can increase their participation, improving learning outcomes (Chen & Zhang, 2021; Smith & Lee, 2022).

Physics learning using the Algodoo-assisted IBMRO model has been proven effective in improving students' physics problem-solving skills in parabolic motion. This reinforces the results of previous studies, which indicate that Algodoo has a significant impact on students' problem-solving skills (Alan et al., 2019). The novelty of this study lies in the fact that each phase of the IBMRO model is facilitated by Algodoo, which trains physics problem-solving skills through multi-representation based on online investigations. This finding follows Vygotsky's social constructivist theory, which has four main implications: social learning, zone of proximal development, scaffolding, and cognitive apprenticeship (Slavin, 2011; Lasmawan & Budiarta, 2020). Social learning is done through interactions with others. The zone of proximal development is the zone between the actual level of development indicated by independent ability and the level of potential development that can be achieved under the guidance of a more expert person. Scaffolding is related to adequate assistance during learning (Damanhouri, 2021; Nguyen, 2024). Meanwhile, cognitive apprenticeship is the stage-by-stage acquisition of expertise by students in their interactions with lecturers or more experienced students. The principle of cognitive apprenticeship is that students gradually develop their abilities through guided learning experiences.

This study makes a significant contribution to the development of innovative learning models in physics education, particularly in enhancing physics problem-solving skills through multiple representations. The use of Algodoo in this study expands the scope of technology utilization in the multi-representation learning process, as revealed through online investigations. The results of the study indicate that each phase in the IBMRO model can be facilitated effectively by Algodoo, which not only supports conceptual understanding but also trains students to identify, design solutions, execute, and evaluate physics problem-solving holistically. Another contribution is empirical evidence that students' physics problem-solving skills have significantly improved, as indicated by overall scores and specific indicators. Additionally, student activities during learning demonstrated high participation and relevance to the learning process. Positive student responses confirmed that this learning was academically effective, engaging, and motivating. This empirical evidence reinforces previous findings on the effectiveness of learning based on process and learning outcomes (Dunkin & Biddle, 1974; Siswanto et al., 2018). Active student participation in learning, as well as their responses, also strengthens this effectiveness (Eom et al., 2006; Zimmerman & Schunk, 2012; Siswanto et al., 2018; Chen & Zhang, 2021; Jatmiko et al., 2024). This makes the Algodoo-assisted IBMRO model a strong pedagogical alternative in physics learning.

The results of this study have important implications for physics learning. First, learning that combines investigation, multiple representations, and interactive technology can serve as a reference for designing student-centered learning and encouraging active participation in understanding abstract concepts. Second, the use of appropriate tools can improve physics problem-solving skills. Third, teachers are expected to be more open and ready to utilize simulation media such as Algodoo as a tool in online learning.

Furthermore, from a theoretical perspective, this study strengthens Vygotsky's social constructivism theory, which emphasizes the importance of social learning, scaffolding, and zone of proximal development through investigative activities, multiple representations, and guidance in the learning process. In a practical context, the application of the Algodoo-assisted IBMRO model has the potential to be further developed in other physics topics and even in other science courses that require a multi-representation approach and dynamic simulation. For the successful implementation of its wider use, support is needed to develop competencies in the use of learning technology and provide adequate infrastructure.

## CONCLUSION

This study concludes that learning using the Algodoo-assisted IBMRO model is proven effective in improving students' physics problem-solving skills in parabolic motion. This conclusion can be seen from the significant increase in the average physics problem-solving skills score, the average n-gain in the medium category, the average n-gain of each physics problem-solving skills indicator in the medium to high category, student activities relevant to learning, and good student responses to learning. This study provides implications that learning that combines investigation, multiple representations, and Algodoo applications can be a reference in designing learning centered on improving conceptual understanding and physics problem-solving skills. The Algodoo-assisted IBMRO model has the potential to be further developed in other physics topics and even in other science courses that require a multi-representation approach and dynamic simulation.

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