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The Effectiveness of the Virtual PhET-assisted *Discovery Learning* Model to Improve Students' Science Process Skills on Collision Material

Mubayyinah Muliyadi[1], El Indahnia Kamariyah[1], Suprianto[1]*

[1]*Pendidikan Fisika, Fakultas Keguruan dan Ilmu Pendidikan, Universitas Islam Madura, Jawa Timur, Indonesia*

This study aims to determine the effectiveness of the Virtual PhET-assisted Discovery Learning model in improving students' science process skills on collision material. This study uses a quantitative approach with a quasi-experimental method and a non-equivalent control group design. The research sample consisted of 40 students of grade XI MAN 1 Pamekasan who were divided into an experimental class and a control class, each consisting of 20 students. The sampling technique used cluster random sampling. The research instrument was a multiple-choice science process skills test consisting of a pretest and a posttest. Data analysis used the Shapiro-Wilk normality test, homogeneity test, Mann-Whitney test, and N-Gain test. The results showed that the posttest significance value in the Mann-Whitney test was 0.000 < 0.05, indicating that there was a significant difference between the experimental class and the control class after being given treatment. In addition, the results of the N-Gain test showed that the experimental class obtained an average of 91.33% with an effective category, while the control class obtained an average of 59.58% with a fairly effective category. Based on these results, it can be concluded that the Virtual PhET -assisted Discovery Learning model is effective in improving students' science process skills on collision material.

Keywords: Discovery Learning; Virtual PheT; Science Process Skills; Collision

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**Correspondence*
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INTRODUCTION

The rapid development of science and technology in the era of the industrial revolution 4.0 requires students to master 12th-century competencies to be able to adapt to changes and be competitive at the global level. Therefore, improving skills is crucial to producing quality and competitive human resources (Nazifah & Asrizal, 2022). One indicator widely used to evaluate the quality of a country's education is *the Programme for International Student Assessment* (PISA), conducted by *the Organisation for Economic Co-operation and Development* (OECD). The results of the 2022 *Programme for International Student Assessment* (PISA) show that student achievement in Indonesia is still below the average for member countries of *the Organisation for Economic Co-operation and Development* (OECD), particularly in aspects of reading, mathematics, and science literacy (Alfaruqi & Nurwahidah, 2025). The success of education depends on the curriculum that serves as the basis for directing the learning process (Syahrial, 2024). The government continues to innovate in education through curriculum updates, including the 2013 curriculum, which is oriented toward 21st-century learning. This learning aims to equip students with the 4C skills: *communication, collaboration, critical thinking and problem-solving, as well as creativity and innovation*. However, one important skill that still needs improvement is science process skills (Fitri et al., 2020). Science process skills are one of the essential and beneficial abilities students need to possess in studying science, particularly physics.

In science learning, science process skills serve as a means for students to construct conceptual understanding through the application of various scientific activities, including observation, hypothesis formulation, communication, drawing conclusions, and predictions (Ginting et al., 2022). This approach is designed to encourage students to discover facts, develop concepts and theories, and understand various phenomena through active involvement in scientific activities during learning (Arnun et al., 2022). In addition, science process skills include cognitive, psychomotor, and social aspects that can make learning more meaningful for students (Hariandi et al., 2023). Science Process Skills (SPS) are also a learning process that plays a role in building students' knowledge and problem-solving abilities. In addition, SPS can support the formation of students' scientific literacy because there is a positive relationship between SPS scores and students' scientific literacy levels (Purnamasari, 2020).

Science process skills are grouped into two main categories. First, basic science process skills that include observation activities to the ability to predict. Second, integrated science process skills that include variable identification to more complex skills, namely experiments (Azizah et al., 2023). The following indicators according to Rustaman (2007) aspects of Science Process Skills (SPS) include: (1). Observing (2). Grouping or classifying, (3). Interpreting (4). Predicting, (5). Asking questions, (6). Formulating hypotheses, (7). Planning experiments, (8) Using tools and materials, (9). Applying concepts, and (10). Communicating results (Nasir et al., 2023). Science process skills in physics learning can be measured optimally if teachers are able to implement innovative learning and are in accordance with student interests (Aditiyas & Kuswanto, 2024).

However, the reality in schools shows a different situation. Students' science process skills in physics learning are still relatively low. This problem is thought to be related to the lecture-oriented learning method and limited laboratory facilities, which hinder the optimal implementation of practical activities. This finding aligns with research by (Putri et al., 2022) which showed that students' science process skills are in the low category. Furthermore, (Ramadhan et al., 2020) also revealed that the science process skills of eleventh-grade students in Banjarmasin are still relatively low, due to the implementation of teacher-centered learning. This indicates that science process skills have not yet developed optimally and require appropriate learning.

One model that can be used to overcome this problem is the *Discovery learning model. Learning* that consists of several stages, namely stimulation*,* problem identification, data collection, data processing, verification, and generalization. The use of this model is expected to create more engaging learning, increase student engagement, and develop science process skills. In its implementation, students work in groups using worksheets to express ideas, provide responses, and solve problems collaboratively (Saputra & Sunaryono, 2022). Students often experience difficulties in understanding concepts, especially in physics learning, one of which is caused by the inability to connect new knowledge with prior knowledge (Oktaviani et al., 2025). Therefore, a student-oriented learning model is needed, such as directed inquiry-based learning, to support the effective use of media. *Discovery Learning* , developed by Jerome Bruner, emphasizes the active role of students in asking questions and drawing conclusions based on general principles. This concept is also supported by Piaget's view that states that students need to be actively involved in the learning process (Widia, 2020).

Based on previous research conducted by (Kholifah et al., 2024), it can be concluded that the application of the *Discovery Learning model* based on differentiated learning has an influence on improving students' creative thinking skills in science learning, especially in the physics sub-topic regarding waves. (Muhali & Sukaisih, 2023) also stated that the application of the Discovery Learning model combined with the concept map strategy has been proven to be able to improve students' metacognitive skills and critical thinking skills in physics learning. (Chusni et al., 2020) also revealed that the *Discovery Learning model* has the potential to significantly improve students' critical thinking skills in science learning through the process of analyzing phenomena and experimental results. The application of *Discovery Learning* assisted by the PhET virtual laboratory provides opportunities for students to gain direct experience through experiments in discovering physics concepts independently (Tupalessy et al., 2022).

One alternative used to address the limitations of practicum implementation is the use of virtual simulation media. PhET *(Physics Education and Technology)* is a digital simulation media developed by the University of Colorado to support science learning through exploratory activities and virtual experiments. This simulation allows students to conduct simulations and process data independently, thereby increasing interest and understanding of learning (Widia, 2020). Furthermore, the use of this media is an effective solution, especially for schools with limited laboratory facilities, because it can provide experimental experiences that resemble real practicums (Fitriani et al., 2024).

The success of using the PhET virtual laboratory in the physics learning process is supported by various previous studies with different learning models and materials, several previous studies and virtual PhET are able to improve learning activities, conceptual understanding, and students' thinking skills in physics as stated by (Saputra & Sunaryono, 2022) that there is an integration of PhET simulations in the *Discovery Learning model* which has been proven to have a significant impact on improving students' critical thinking skills compared to the application of conventional learning. (Admoko et al., 2019) also concluded that the implementation of the *Discovery Learning model* assisted by the PhET virtual laboratory is effective in minimizing students' misconceptions on all mechanical wave concepts. (Widia, 2020) also concluded that the application of the Discovery Learning learning model assisted by PhET media can improve the competence of class XI MIPA students at SMA Negeri 1 Tampaksiring.

Although previous studies have reported the positive effects of *Discovery Learning* and PhET simulation on students' critical thingking skills, conceptual understanding, metacognitive abilities, and misconceptions in physics learning (Admoko et al., 2019; Chusni et al., 2020; Widia, 2020; Saputra & Sunaryono, 2022), several gaps remain. Fist, most previous studies focused on cognitive outcomes such as conceptual understanding, critical thinking, and learning achievement, while limited attention has been given to Science Process Skills (SPS) as measured through Rustaman's indication. Second, studies specifically investigating the integration of *Discovery Learning* and PhET on collision material are still scarce, despite collisions being one of the physics topics that require strong concetual visualization and scientific investigation skills. Third, previous studies were predominantly conducted in general senior high school settings, whereas evidence from the Madrasah Aliyah context remains limitid. Therefore, this study addresses these gaps by examining the effectivenees of a virtual PhET-assisted *Discovery Learning* model in improving students' Science Process Skills based on Rustaman's indication on collision material in a Madrasah Aliyah setting.

The implementation of virtual laboratories through the *Discovery Learning model* can improve the effectiveness of physics learning and encourage active student involvement during the learning process. Through this model, students are expected to be more active in discovering concepts independently, understanding the material in depth, and developing critical thinking, analytical, and problem-solving skills. Problem-solving learning experiences and direct involvement have been shown to strengthen science process skills (Triani et al., 2023). This research also emphasizes the importance of assessing science process skills because they are an essential part of psychomotor competencies that support the learning process. Furthermore, (Widodi et al., 2023) stated that science process skills can develop if students utilize their thinking abilities optimally. These skills are also very important for understanding science comprehensively so that students are able to solve problems in everyday life (Anita & Turatea, 2022). The integration of *Discovery Learning* with PhET media is an innovation that is expected to improve science process skills.

Based on the indintified research gaps, this study aims to investigate the effectiveness of the Virtual PhET-assisted Discovery Learning model in improving students' Science Process Skills (SPS). Although previous studies have demonstrated the effectuveness of Discovery Learning and PhET simulation in enhancing conceptual understanding, critical thinking skills, learning achievement, and reducing misconceptions, the integration of both has been widely explored in physics education. Therefore, the novelty of this study does not merely lie in combining Discovery Learning and PhET, but in the strategic integration of PhET simulation into the stimulation, problem statement, and data collection stages of the Discovery Learning model. Though this a pproach, students are encouraged to observe collision phenomena, identify problems, collect evidence, formulate hypotheses, and costruct Science Process Skills based on Rustaman's indicators, furthermore, this study focuses specifically on collision material within the Madrasah Aliyah context and compares Discovery Learning assisted by PhET with STAD cooperative learning assisted by the same simulation media. This design enables a clearer examination of the contribution of the learning model while controlling for the influence of instructional media. Thus, the contribution of this study is primarily practical and pedagogical by providing empirical evidence regarding how the strategic placement of PhET simulations within specific Discovery Learning stages can effectively enhance students' Science Process Skills.

METHOD

This study uses a quasi-experimental approach to determine the effect of the application of *Discovery Learning* assisted by virtual PhET on students' science process skills on collision material . which is a study that provides treatment to independent variables to test its effect on the dependent variable. While the research design used is *a non-equivalent control group design* , which is a design involving experimental and control groups, both of which are given *a pretest* before the treatment is given. The pretest aims to obtain an overview of the initial conditions of the experimental group, and then a posttest is carried out after the treatment is given. The *posttest* aims to determine the final conditions and compare the changes that occur in each group. This study was conducted in the even semester of the 2025/2026 academic year located at MAN 1 Pamekasan While the target population of this study includes all students from two classes (XI-C & XI-D) MAN 1 Pamekasan. The research sample consisted of 20 students in the experimental class and 20 students in the control class so that the total sample was 40 students.

This research is a quasi-experimental research using a *Non-Equivalent Control Group Design.* The research design involves two sample groups, namely the experimental and control classes. Before the treatment was given, both groups were first given *a pretest* to determine the initial abilities of students. After the treatment process was completed, both groups were given *a posttest* to determine the final abilities of students. The learning process in the experimental class, namely class XI-C, was implemented using the *Discovery Learning learning model* assisted by virtual PhET, while in the control class, namely class XI-D, the STAD Cooperative learning model assisted by PhET was applied. The STAD cooperative learning model assisted by PhET was selected as the control treatment because STAD is well-established student-centeral learning model that promotes collaboration and active participation. By applying the same PhET simulation in both groups, this study was designed to examine the sffect of the learning model (Discovery Learning versus STAD) while controlling for the influence of instructional media.

The PhET simulation used in this study was Collision Lab developed by the University of Colorado Boulder. The simulation was integrated into the learning process to help students visualize collision phenomena, investigate momentum conservation, collect experimental data, and analyze the results through virtual experimentation. Prior to the implementation of the study, the instrument try-out was conducted in one meeting. The learning treatment was carried out over two meetings in both the experimental and cobtrol classes. Each meeting focused on collision materian and follewed the learning procedures specified in the respective learning models.The sample data collection technique used *cluster random sampling* . the research instruments consisted of teaching modules, lesson implementation observation sheets, and a Science Process Skills (SPS) test. The SPS test initially consisted of 10 multiple-choice items developed based on Rustaman's Science Process Skills indicators. Following the validity testing process, 8 items were declared valid and subsequently used as the pretest and posttest imstruments. Reability analysis using Cronbach's Alpha yielded a coefficient of $\alpha = 0{,}770$ Indicating that the instrument was reliable. Each correct answer was scored 1 point, while an incorrect answer was scored 0 point. The total score was then converted into a percentage scale. Data from the pretest and posttest were analyzed using normality, homogeneity, Mann-Whitney, and N-Gain tests.

Prior to conducting the study, an official research permit issued by Universitas Islam Madura was submitted to MAN 1 Pamekasan through the school's Integrated Service Unit (PTSP). After obtaining approval from the school authorities, the research was conducted in accordance with the school's regulations. Before the implementation of the study, students were informated by the physics teacher about the purpose and procedures of research. All collected data were used solely for research purposes, and the confidentiality of participants was maintained throughout the study.

RESULT AND DISCUSSION

Data analysis

Lesson Plan Observation Sheet

The following presents the results of monitoring the implementation of the Discovery Learning model assisted by virtual PhET and the STAD cooperative assisted by PhET.

[Table 1 about here.]

Based on Table 1, the implementation of learning using the *Discovery Learning model* assisted by virtual PhET obtained an average score of 3.5, categorized as good. This result indicates that all learning syntax has been implemented according to plan.

The stimulus and proof stage obtained the highest average score, namely 4.5, categorized as very good. This indicates that the use of virtual PhET is able to attract students' attention and help them in proving concepts through exploration and analysis activities. Meanwhile, the introduction, problem identification, data collection, and conclusion drawing stages obtained the good category with an average score of 3.5-4. There was an increase in scores in almost all syntax from the first meeting to the second meeting. This indicates that students are increasingly accustomed to participating in *Discovery Learning* assisted by virtual PhET. With good learning implementation, students have the opportunity to be actively involved in the process of discovering concepts, thereby supporting the improvement of science process skills and student learning outcomes.

[Table 2 about here.]

Based on Table 2, the implementation of learning using the STAD model assisted by virtual PhET obtained an average score of 3.5, categorized as good. This result indicates that all learning syntax has been implemented well during the learning process. The stage of guiding groups in working and learning and giving awards obtained a very good category with an average score of 4.5. This indicates that students are active in group activities and motivated to participate in learning. Meanwhile, the stage of presenting information, organizing students in groups, and evaluating or presenting learning outcomes obtained a good category with an average score of 3.5-4. The stage of conveying objectives and motivating students obtained an average score of 3, categorized as sufficient. Nevertheless, in general, there was an increase in the implementation of several learning syntax from the first meeting to the second meeting. This condition indicates that students are increasingly accustomed to participating in cooperative learning STAD assisted by virtual PhET. This good implementation of learning provides opportunities for students to interact, discuss, and collaborate in groups, thereby supporting the improvement of learning outcomes and science process skills.

Science process skills assessment sheet

This science process skills instrument assessment sheet is assessed by observers directly during the learning process, the analysis of the science process skills instrument assessment is assessed per indicator in the group.

[Table 3 about here.]

Table 3 shows that the science process skills in the table show a change in the percentage of indicator achievement from the initial learning meeting in both classes, namely the experimental class and the control class (P1) to the second meeting (P2). In general, the experimental class showed a more consistent improvement than the control class. For the observation indicator, the experimental class obtained a constant score of 75 in P1 and P2. This indicates that students are starting to be able to maintain good observation skills after implementing the Discovery Learning learning model. Meanwhile, in the control class there was an increase from 70 to 75. This increase indicates that the observation skills of students in the control class improved during the learning process.

In the formulating hypothesis indicator, the experimental class obtained an increased score of 55 in P1 and 70 in P2, these results indicate that students' ability to formulate temporary assumptions has increased, in contrast the control class experienced an increase from 55 to 65. This increase indicates that students are beginning to be able to understand the relationship between variables in learning. In the communicating indicator, there was an increase in the experimental class from 65 to 70. This shows that students are increasingly able to convey the results of discussions and observations orally and in writing. Meanwhile, the control class also experienced a significant increase, namely from 35 to 55. Although it increased, the achievement of the control class showed relatively lower achievement when compared to the experimental class.

In the concluding indicator, the experimental class's score increased from 75 to 80. This result indicates that students are increasingly able to draw conclusions based on the data or experimental results obtained. Conversely, the control class experienced a decrease from 80 to 70. This decrease indicates that students still have difficulty connecting observation results with the concepts being studied. In the predicting indicator, the experimental class experienced a significant increase from 65 to 80. This indicates that students are increasingly able to predict an event based on concepts that have been understood. Meanwhile, in the control class, the score remained at 65, thus indicating no development in forecasting ability. Overall, the experimental class outperformed the control class in science process skills. This is evident from the more consistent increase in scores on almost all indicators in the experimental class, while in the control class some indicators decreased and others remained the same. Thus, the science process skills of students in the experimental class showed better results than those in the control class.

Results of pretest and posttest data on students' science process skills

Data on science process skills were obtained from pretests and posttests administered to the experimental and control classes. The tests consisted of eight multiple-choice questions that measured students' science process skills on collisions. The experimental class consisted of class XI-C students using the *Discovery Learning model.* Meanwhile, the control class consisted of class XI-D students using the STAD cooperative model. A summary of *the pretest* and *posttest results* for both classes is presented in Table 4 below.

[Table 4 about here.]

From Table 4 it can be seen that the pretest score in the experimental class of 20 students has a minimum score of 25 and a maximum score of 88 with an average of 53.12. These results indicate that the initial abilities of students in the experimental class are in the moderate category before being given learning treatment. The provision of learning treatment has been proven to contribute to improving student learning outcomes. This is shown by the posttest achievement in the experimental class which is in the score range of 75 to 100, as well as a higher average score than before the treatment was applied at 95.63. Thus, the posttest results show that most students in the experimental class experienced an increase in learning outcomes after applying the learning model used in the study.

In the control class, *the pretest results* showed a minimum value of 13 and a maximum value of of 75 with an average of 38.12. These results indicate that the initial abilities of students in the control class were relatively lower than those of the experimental class before the learning process took place. Meanwhile, the posttest results of the control class showed a minimum score of 50 and a maximum score of 100. Although there was an increase in learning outcomes after the learning process was implemented, the increase in the control class was not as large as the increase that occurred in the experimental class. Overall, the results of the descriptive statistical analysis showed that both classes experienced an increase in learning outcomes after the learning process. However, the experimental class showed better results than the control class, so it can be indicated that the *Discovery Learning model* applied to the experimental class had a positive influence in improving students' science process skills.

Data analysis

Normality Test

Normality testing is conducted as an initial step in the analysis to ensure that the data in each sample group meets the assumptions of normal distribution. In this study, the normality test was applied to students' science process skills data. The test was conducted using the Shapiro-Wilk test, which shows that the data is normally distributed if the significance value is > 0.05 (Iskandar et al., 2025). Conversely, if the significance value is less than 0.05, the data is not normally distributed. The calculation results are shown in the table.

[Table 5 about here.]

Based on Table 5, the results of the Shapiro-Wilk normality test show a pretest significance value of 0.066 in the experimental class. This value is greater than the 0.05 significance level (0.066>0.05), indicating that the pretest data for the experimental class is normally distributed. Meanwhile, the posttest results for the experimental class show a significance value of 0.000. This value is less than 0.05 (0.000<0.05), indicating that the *posttest data* for the experimental class is not normally distributed. The abnormal data may be influenced by technical constraints during the learning process, namely an unstable internet connection when using the PhET virtual simulation. This condition causes students to experience delays in accessing the simulation and leads to boredom in completing learning activities. As a result, student learning outcomes are uneven and impact the distribution of abnormal data. In the control class, the results of the pretest normality test obtained a significance value of 0.000. This value is less than 0.05 (0.011<0.05), indicating that the *pretest data* for the control class is not normally distributed. The posttest results for the control class showed a significance value of 0.05. Because this value is greater than 0.05 (0.071 > 0.05), the control class posttest data is declared normally distributed. Based on the results of the normality test, it can be seen that not all research data is normally distributed, as some data have a significance value of less than 0.05.

Homogeneity Test

The homogeneity test was conducted to determine whether the data variance from each research group was similar or homogeneous (Novia et al., 2025). In this study, the homogeneity test was applied to students' science process skills data. Data are considered homogeneous if the significance value is >0.05. Conversely, if the significance value is less than 0.05, the data are considered non-homogeneous.

[Table 6 about here.]

Table 6 shows the results of the homogeneity test. It is known that the data is declared homogeneous if the significance value (Sig) is greater than 0.05. Conversely, if the significance value is less than 0.05, the data is declared inhomogeneous. Based on the results of the homogeneity test, the pretest significance value was obtained at 0.579. This value is greater than the significance level of 0.05 (0.579 > 0.05), so it can be concluded that the pretest data has a homogeneous variance. This indicates that the initial abilities of students in the research class were in a relatively similar condition before being given the learning treatment. Meanwhile, the posttest data obtained a significance value of 0.001. This value is less than 0.05 (0.001 < 0.05), so the posttest data is declared inhomogeneous. This condition indicates a difference in the variance of student learning outcomes after being given the learning treatment. Inhomogeneity in the posttest data can occur due to the influence of the learning model treatment which causes the increase in student abilities to vary in each group.

The results of the homogeneity test indicate that although students' initial abilities were relatively similar, after the learning process, there were differences in the variation of student learning outcomes. This indicates the development of students' abilities in the collision material. Thus, it can be concluded that the pretest data met the homogeneity requirements, while the posttest data did not. Therefore, in the next stage of analysis, a nonparametric Mann-Whitney test was performed.

Mann-Whitney test

The Mann-Whitney test is a nonparametric statistical test used to determine whether there are differences between two independent or unpaired groups. This test is used as an alternative to the independent sample t-test when research data does not meet the assumptions of normality and homogeneity. The results are shown in Table 7.

[Table 7 about here.]

Based on the results of the Mann-Whitney test shown in Table 7, the pretest significance value (Sig.) was 0.057. This value is greater than the significance level of 0.05 (0.057 > 0.05), so H0 is accepted. Thus, it can be concluded that there is no significant difference between the control class and the experimental class in the initial abilities of students before being given the learning treatment. This result indicates that both classes have relatively equal initial abilities so they are suitable to be used as research samples. Meanwhile, the results of the Mann-Whitney test on the posttest data show a significance value of 0.000. This value is smaller than 0.05 (0.000 < 0.05), so H_0 is rejected and H_1 is accepted. Thus, it can be concluded that there is a significant difference between *the posttest results of the control and experimental classes after being given the learning treatment. The difference in posttest* results shows that the treatment given to the experimental class has an effect on student learning outcomes compared to the control class. Therefore, the *Discovery Learning learning model* applied to the experimental class is proven to provide different results on student abilities after the learning process takes place.

[Table 8 about here.]

Discussion

The results of the study showed that students who learned using the *Discovery Learning model* assisted by virtual PhET simulations obtained better improvements in science process skills. This improvement occurred because students were actively involved in exploration activities, observations, and analysis of collision phenomena presented through interactive simulations. This can be seen from the results of the pretest and posttest data analysis in the experimental and control classes. The results of the descriptive statistical analysis showed that the average pretest score of the experimental class was 53.12, while the control class was 38.12. After being given treatment, the posttest score of the experimental class increased with a minimum score of 75 and a maximum of 100. Meanwhile, the control class also experienced an increase, but not as large as the experimental class. These results indicate that learning using the Discovery Learning model assisted by virtual PhET is able to improve students' science process skills more optimally than learning in the control class.

The research findings are also supported by observations of science process skills, which indicate an improvement in most of the observed indicators. This improvement is evident in students' abilities to formulate hypotheses, communicate observations, draw conclusions, and make predictions based on data obtained during the learning process. In the experimental class, almost all indicators experienced consistent improvement, such as formulating hypotheses, communicating, concluding, and predicting. This indicates that the *Discovery Learning model* actively engages students in the learning process through observation, experimentation, data collection, and drawing conclusions. The use of virtual PhET also helps students understand the concept of collisions more concretely through interactive simulations, making it easier for them to observe and analyze physical phenomena. The improvement in science process skills in the experimental class occurred because the Discovery Learning model provides opportunities for students to construct concepts independently through a process of discovery. According to Bruner's constructivism theory, the process of directly discovering concepts can increase students' understanding and engagement in learning.

The findings of this study can be interpreted though Bruner's constructed by learners through exploration and discovery. In the Discovery Learning model, students were not merely recipients of information but were actively engaged in observing collision phenomena, formulating hypotheses, collecting data, and drawing conclusions. The integration of the Collision Lab PhET simulation further supported this process by providing interactive visualizations that enabled students to explore abstract physics concepts independently. As a result, students developed a deeper conceptual understanding and stronger Science Process Skills through direct engangement with scientific inquiry activities.

Based on the results of the normality test using Shapiro-Wilk, it is known that not all data are normally distributed because there are several significance values that are smaller than 0.05. In addition, the results of the homogeneity test indicate that the posttest data is not homogeneous with a significance value of 0.000. Therefore, data analysis was continued using the nonparametric Mann-Whitney test. The results of the Mann-Whitney test showed that the pretest significance value was 0.057 > 0.05 so that there was no difference in the initial abilities of the experimental and control classes. This indicates that both classes had relatively equal initial abilities before being given treatment. Meanwhile, the posttest results showed a significance value of 0.00 < 0.05, which means there was a significant difference between the experimental and control classes after being given the learning treatment. Thus, the *Discovery Learning model* assisted by virtual PhET has been proven to have an effect on improving students' science process skills on collision material.

The effectiveness of the learning model was also strengthened by the results of the N-Gain test. The experimental class obtained an average N-Gain of 91.33%, categorized as effective, while the control class obtained an average of 59.58%, categorized as quite effective. These results indicate that the implementation of the *Discovery Learning model* assisted by virtual PhET is more effective in improving students' science process skills compared to the STAD cooperative learning model implemented in the control class. Although both classes utilize PhET media, the learning process that takes place shows different characteristics. In the experimental class that implemented the *Discovery Learning model,* students were actively involved in the process of discovering concepts through the stages of problem identification, data collection, data processing, verification, and drawing conclusions. Meanwhile, in the STAD class, learning activities emphasized group work in understanding the material and completing the assigned tasks. Student involvement in the process of independent concept discovery in the *Discovery Learning class* provided a deeper conceptual understanding, resulting in higher average posttest scores compared to students in the control class that implemented the STAD cooperative learning model.

The improvement in science process skills in the experimental class occurred because the Discovery Learning model provided opportunities for students to discover concepts independently through the stages of stimulus, problem identification, data collection, verification, and generalization. This process encouraged students to actively engage in scientific activities such as observing, formulating hypotheses, analyzing data, and drawing conclusions. Furthermore, the use of virtual PhET helped visualize the concept of collisions in a concrete and interactive manner, making it easier for students to understand abstract physical phenomena. The use of virtual PhET helped students visualize the abstract concept of collisions through interactive simulations. This visualization made it easier for students to observe, analyze, and draw conclusions, allowing optimal development of science process skills.

The findings of this study support the results of previous studies which showed that PhET-assisted *Discovery Learning* was able to improve students' science process skills (Chusni et al., 2020) who stated that the discovery learning model was effective in learning because it was able to actively involve students in the process of observation, data collection, analysis, and drawing conclusions so that it could improve students' critical thinking skills and science process skills. And also (Haryanto et al., 2024) stated that the PhET-assisted *Discovery learning* model was effective in improving students' science process skills because it encouraged students to actively conduct observations, experiments, analysis, and drawing conclusions. (Rahmawati, 2021) also stated that the application of the *Discovery Learning model* was effective in improving students' critical thinking skills with an N-Gain value of 91.33 in the moderate category and showed a significant difference between the experimental class and the control class.

The findings of this study are also consistent with several international studies that have highlighted in science the effectiveness of discovery-based learning and interactive simulations in science education. Previous studies have reported that virtual simulations can enhance students' conceptual understanding, scientific phenomena in a dynamic and interactive environment. Similarly, discovery-oriented learning approaches have been shown to promote higher-order. Thinking Skills and active knowledge construction. The present findings extend this evidence by demonstrating that the integration of Discovery Learning and PhET simulations can effectively improve Science Process Skills in the context of collision material at the Madrasah Aliyah level.

CONCLUSION

Based on the research results, it can be concluded that the *Discovery Learning learning model* assisted by virtual PhET is effective in improving students' science process skills on collision material. This effectiveness is shown by the results of the Mann-Whitney test on the posttest data which obtained a significance value of 0.000 < 0.05 and the N-Gain results of the experimental class were 91.33% with an effective category. Thus, the application of the Discovery Learning model assisted by Virtual PhET was more effective in improving students' Science Process Skills than the STAD cooperative learning model assisted by the same PhET simulation on collision material. This study has several limitations that should be considered. The research was conducted in only one school and focused solely on collision material, which may limt the generalizability of the findings. In addition, the learning treatment was implemented over two meetings, so the long-term impact of the *Discovery Learning* model assisted by virtual PhET could not be fully examined. Future studies are recommended to involve large samples, different physics topics, and longer implementation period to provide a more comprehensive understanding of the effectiveness of the model.

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REFERENCES

Aditiyas, S. E., & Kuswanto, H. (2024). Analisis Implementasi Keterampilan Proses Sains Di Indonesia Pada Pembelajaran Fisika : Literatur Review. *Jurnal Penelitian Pembelajaran Fisika*, *15*(2), 153–166. https://doi.org/10.26877/jp2f.v15i2.15912

Admoko, S., Yantidewi, M., & Oktafia, R. (2019). The Implementation of Guided Discovery Learning Using Virtual Lab Simulation to Reduce Students' Misconception on Mechanical Wave. *Journal of Physics: Conference Series*, *1417*(1). https://doi.org/10.1088/1742-6596/1417/1/012089

Alfaruqi, A. Z., & Nurwahidah. (2025). Reflection on Indonesia's PISA Scores and the 2024 Madrasah Teacher Competency Assessment Results: Challenges in Enhancing Teacher Competence. *JURNAL PENDIDIKAN IPS*, *15*(1), 11–19. https://doi.org/https://doi.org/10.37630/jpi.v15i1.2559

Anita, H. (2022). Analisis Keterampilan Proses Sains Mahasiswa Pendidikan Biologi Pada Kegiatan Praktikum Mikrobiologi. *Prisma Magister: Jurnal Ilmiah Kependidikan*, *3*(2), 240–249. https://doi.org/https://doi.org/10.37478/jpm.v3i2.1765

Arnun, A., suyanti, Retno, D., Bunawan, W., & Larosa, fajar, S. (2022). Pengembangan Buku Ajar IPA Berbasis Keterampilan Proses Sains dalam Meningkatkan Kemampuan Berpikir Kritis Siswa Kelas. *Didaktika: Jurnal Kependidikan*, *13*(001), 365–374.

Azizah, H., Sukarno, S., & Hartoyo, Z. (2023). Korelasi Antara Keterampilan Proses Sains Dengan Literasi Sains Siswa Madrasah Tsanawiyah Negeri Kota Jambi. *Physics and Science Education Journal (PSEJ)*, *3*(April), 1–9. https://doi.org/10.30631/psej.v3i1.1705

Chusni, M. M., Saputro, S., Suranto, & Rahardjo, S. B. (2020). The potential of discovery learning models to empower students' critical thinking skills. *Journal of Physics: Conference Series*, *1464*(1). https://doi.org/10.1088/1742-6596/1464/1/012036

Fitri, M., Yuanita, P., & Maimunah, M. (2020). Pengembangan Perangkat Pembelajaran Matematika Terintegrasi Keterampilan Abad 21 Melalui Penerapan Model Problem Based Learning (PBL). *Jurnal Gantang*, *5*(1), 77–85. https://doi.org/10.31629/jg.v5i1.1609

Fitriani, S. R., Doyan, A., Taufik, M., & Wahyudi, W. (2024). The Effect of the Guided Inquiry Model Assisted by PhET Media on Students' Critical Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, *10*(6), 3527–3532. https://doi.org/10.29303/jppipa.v10i6.4852

Ginting, Agnes, A., Darmaji, & kurniawan, Dwi, A. (2022). Analisis Pentingnya Keterampilan Proses Sains terhadap Kemampuan Berpikir Kritis di SMA Se-Kecamatan Pemayung. *Jurnal Pendidikan MIPA*, *12*(1), 1–7. https://doi.org/https://doi.org/10.37630/jpm.v12i1.542

Hariandi, J., Sitompul, S. S., & Habellia, R. C. (2023). Peningkatan Keterampilan Proses Sains Dengan Menerapkan Pendekatan Steam. *JPF(Jurnal P Endidikan Fisika) FKIP UM Metro*, *11*(2), 157. https://doi.org/10.24127/jpf.v11i2.7945

Haryanto, Asrial, Sanova, A., Widowati, A., & Saputra, A. (2024). *Generic Science Skills : PhET Application Based On Discovery Learnng*. *8*(1), 158–169. https://doi.org/10.22437/jiituj.v8i1.32441

Iskandar, A. A., Ully, R., Misbah, I., & Nursalman, M. (2025). Perbandingan Hasil Uji Normalitas dan Homogenitas Data Pretest dan Posttest Siswa dengan Menggunakan Software SPSS dan Microsoft Excel. *Jurnal Pendidikan Tambusai*, *9*(1), 290–303.

Kholifah, I. N., Muntaha, D., Studi, P., Fisika, P., & Kreatif, B. (2024). Penerapan Pembelajaran Discovery Learning Dalam Berdeferensial Untuk Meningkatkan Kemampuan Berpikir Kreatif Siswa. *OPTIKA : Jurnal Pendidikan Fisika*, *8*(2), 298–308.

Muhali, M., & Sukaisih, R. (2023). Guided Discovery Learning Model Using Concept Map Strategy to Improve Students Metacognition and Critical Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 554–563. https://doi.org/10.29303/jppipa.v9i1.3868

Nasir, M., Fahruddin, F., Haljannah, M., & Nehru, N. (2023). Implementasi Model Pembelajaran Problem Based Learning untuk Meningkatkan Keterampilan Proses Sains Siswa SMAN 5 Kota Bima. *JIIP - Jurnal Ilmiah Ilmu Pendidikan*, *6*(1), 289–296. https://doi.org/10.54371/jiip.v6i1.1370

Nazifah, N., & Asrizal, A. (2022). Development of STEM Integrated Physics E-Modules to Improve 21st Century Skills of Students. *Jurnal Penelitian Pendidikan IPA*, *8*(4), 2078–2084. https://doi.org/10.29303/jppipa.v8i4.1820

Novia, D., Husaeni, A., Gintara, A. R., & Nabila, G. F. (2025). Mengungkap Pentingnya Uji Normalitas dan Homogenitas dalam Penelitian : Studi Kasus dan Aplikasinya. *Jurnal Pendidikan Tambusai*, *9*(1), 829–839.

Oktaviani, M., Hawan, U., Nirahua, J., & Sapulete, H. (2025). Peningkatan Penguasaan Materi Fluida Dinamis Berbantuan Media Flipbook Heyzine dalam Model Pembelajaran Discovery Learning Increasing Mastery of Dynamic Fluid Material with the Help of Heyzine Flipbook Media in the Discovery Learning Learning Model. *Jurnal Penelitian Dan Pendidikan Fisika*, *10*(2), 59–63. https://doi.org/https://doi.org/10.36709/jipfi.v10i2.163

Purnamasari, S. (2020). Pengembangan Praktikum IPA Terpadu Tipe Webbed untuk Meningkatkan Keterampilan Proses Sains. *PSEJ (Pancasakti Science Education Journal)*, *5*(2), 8–15. https://doi.org/10.24905/psej.v5i2.20

Putri, Wita, A., Astalini, & Darmaji. (2022). Analisis Kegiatan Praktikum untuk Dapat Meningkatkan Keterampilan Proses Sains dan Kemampuan Berpikir Kritis. *EDUKATIF:JURNAL ILMU PENDIDIKAN*, *4*(3), 3361–3368. https://doi.org/https://doi.org/10.31004/edukatif.v4i3.2638

Rahmawati, S. (2021). The effectiveness of discovery learning module classification of materials and its changes to enhance critical thinking skills. *Jurnal Inovasi Pendidikan IPA*, *7*(1), 74–84. https://doi.org/https://doi.org/10.21831/jipi.v7i1.33253

Ramadhan, T., Arifuddin, M., Studi, P., Fisika, P., & Keguruan, F. (2020). Pengembangan Bahan Ajar Model Quantum Teaching pada Materi Fluida Statis untuk Melatih Keterampilan Proses Sains Siswa How to cite : Ramadhan , T ., Arifuddin , M ., & Mastuang , M . statis untuk melatih keterampilan proses sains siswa . Jurnal Ilmiah Pen. *Jurnal Ilmiah Fisika*, *4*(3), 99–110.

Saputra, D., & Sunaryono, S. (2022). the Effect of Phet Simulation on the Discovery Learning Model on Critical Thinking Skills of Sma Students on Straight Motion Materials. *Inovasia*, *1*(1), 34–45. https://jurnal.institutsunandoe.ac.id/index.php/inovasia/article/view/20

Syahrial, A. (2024). Analisis Pembelajaran Fisika Terintegrasi Steam untuk Melatih Keterampilan Abad 21 dan Keterampilan Proses Sains Siswa pada Implementasi Kurikulum Merdeka: A Review. *Journal of Classroom Action Research*, *6*(4), 881–892. https://jppipa.unram.ac.id/index.php/jcar/article/view/5932

Triani, E., Darmaji, & Astaini. (2023). Identifikasi Keterampilan Proses Sains Dan Kemampuan Berargumentasi Siswa. *Jurnal Pendidikan Dan Pembelajaran IPA Indonesia*, *13*(1), 9–16.

Tupalessy, A., Kereh, C. T., & Singerin, S. (2022). Penggunaan Laboratorium Virtual Phet Dalam Model Discovery Learning Pada Materi Gerak Harmonik Sederhana. *Science Map Journal*, *3*(2), 47–55. https://doi.org/10.30598/jmsvol3issue2pp47-55

Widia, I. W. (2020). Penerapan Model Discovery Learning Berbantuan Media PhET Untuk Meningkatkan Kompetensi Siswa. *Indonesian Journal of Educational Development*, *1*(2), 262–273. https://doi.org/10.5281/zenodo.4004185

Widodi, B., Darmaji, & Astalini. (2023). Identifikasi Keterampilan Proses Sains Dan Kemampuan Berpikir Kreatif Siswa. *Jurnal Pendidikan Dan Pembelajaran IPA Indonesia*, *13*(1), 1–8. https://doi.org/10.23887/jppii.v13i1.57131

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LIST OF TABLES

TABLE 1 / Results of the RPP Observation Sheet in the Experimental Class with the Discovery Learning Model

No	Syntax	Meeting 1 (P1)	Meeting 2 (P2)	Average	Information
1	Introduction	3	4	3.5	Good
2	Stimulus	4	5	4.5	Very good
3	Identification of problems	4	4	4	Good
4	Data collection	3	5	4	Good
5	Proof	4	5	4.5	Very good
6	Draw a conclusion	3	5	4	Good
Average				**3.5**	**Good**

TABLE 2 / Results of the Lesson Plan Observation Sheet in the Control Class with the STAD Cooperative Model

No	Syntax	Meeting 1 (P1)	Meeting 2 (P2)	Average	Information
1	Conveying goals and motivating students	3	3	3	Enough
2	Presenting information	3	4		Good
3	Organizing students into groups	4	3	3.5	Good
4	Guiding groups in working and learning	4	5	4.5	Very good
5	Evaluation/presentation of learning outcomes	3	5	4	Good
6	Giving awards	4	4	4.5	Very good
	Average			**3.5**	**Good**

TABLE 3 / Science Process Skills Assessment Sheet According to Rustaman

No	Indicator	Experimental Class		Control class	
		P1	P2	P1	P2
1	Observing	75	75	70	75
2	Formulating a hypothesis	55	70	55	65
3	Communicating	65	70	35	55
4	Conclude	75	80	80	70
5	Predicting	65	80	65	65

TABLE 4 / Pretest Posttest Results Data

Variables	N	Minimum	Maximum	Average
Experiment Pretest	20	25	88	53.12
Experiment Posttest	20	75	100	95.63
Pretest Control	20	13	75	38.12
Posttest Control	20	50	100	75.00

TABLE 5 / Normality Test of Experimental Class and Control Class

Class	Shapiro-Wilk		
	Statistics	df	sig
Experiment Pretest	0.911	20	0.066
Experiment Posttest	0.632	20	0,000
Pretest Control	0.869	20	0.011
Posttest Control	0.912	20	0.071

TABLE 6 / Homogeneity Test of Experimental Class and Control Class

Variables	**Sig**	**Information**
Pretest	0.579	Homogeneous
Posttest	0.001	Not Homogeneous

TABLE 7 / Man-Whitney Test

Variables	Sig	Conclusion
Pretest	0.057	There is no difference
Posttest	0,000	There is a Difference

TABLE 8 / Results of the N-Gain Test for the Experimental Class and the Control Class

Class	N-Gain Score(%)			Conclusion
	Minimum	Maximum	Average	
Experiment	50	100	91.33	Effective
Control	20	100	59.58	Quite Effective