Journal of Innovative Physics Teaching
Volume 4, Issue 2 December 2026, 283 – 297
ISSN: 3021-8551 (Online)
Doi: https://doi.org/10.24036/jipt/vol4-iss2/180
https://jipt.ppj.unp.ac.id/index.php/jipt

Development of Teaching Material on Non-Central Collisions Based on Problem Based Learning Model Assisted by PhET Simulations

Shelly Salista Rahmayanti*, Budi Astuti, Putut Marwoto
Physics Education Study Program, Universitas Negeri Semarang, Central Java, Indonesia

Article Info

Article history:

Received month dd, yyyy
Revised month dd, yyyy
Accepted month dd, yyyy

Keywords:

Teaching Material
Non-Central Collisions
PhET Simulations
Problem Based Learning

ABSTRACT

Physics learning on non-central collisions is often challenging because students must understand abstract concepts and dynamic interactions, while existing instructional Material generally provide limited opportunities for conceptual exploration and problem-solving. To address this issue, this study developed instructional Material based on the Problem-Based Learning model supported by PhET simulations. This study aims to identify the characteristics, level of suitability, and student responses to the developed instructional Material. This study employs a Research and Development (R&D) method using the 4D model, which includes the Define, Design, Develop, and Disseminate stages. The research instruments included expert validation sheet, readability test sheets, and student response questionnaire. The results showed that the developed instructional Material integrated the PBL framework with PhET simulations, enabling students to solve contextual problems, explore concepts, and build understanding independently. The feasibility test yielded a score of 91.25%, categorized as "highly feasible" based on content, presentation, language, typography, and visual design. The readability feasibility test obtained 91.79%, categorized as "highly feasible," while student readability reached 98%, categorized as "easy to understand." Student feedback on the use of these instructional Material reached 89.5%, categorized as "very good." Based on these results, the developed instructional Material have strong potential as an effective learning resource for teaching non-central collisions in physics.

***Correspondence:**
Shelly Salista Rahmayanti, Physics Education Study Program, Universitas Negeri Semarang, Central Java, Indonesia.
· email : shellysalista172@students.unnes.ac.id

INTRODUCTION

Physics is a field of science that studies natural phenomena related to the environment and emphasizes the understanding of scientific concepts (Depari et al., 2024; Huda et al., 2023; Maulidinah & Ekasari, 2023). In the learning process, physics aims not only to provide an understanding of scientific concepts, but also to foster critical, logical, and systematic thinking skills in solving various problems (Bhakti & Napis, 2018). Effective physics learning should facilitate students in developing a deep conceptual understanding by connecting scientific principles with observable phenomena through appropriate learning strategies and instructional methods. Such approaches are expected to support meaningful learning, encourage the active construction of knowledge, and enable students to apply physics concepts effectively in various learning contexts (Juita, 2020). Conceptual understanding is essential in physics education because it helps develop students' innovative and critical thinking skills in solving problems (Sundari & Sarkity, 2021; Widhi et al., 2021).

The level of understanding of physics concepts is influenced by the appropriateness of the learning media (Rahmawati & Fianti, 2023; Sakti, 2019), teaching methods (Aristawati et al., 2018; Chan et al., 2021), as well as students' active engagement in the learning process (Depita, 2024; Kola et al., 2017; Nurmaulidina & Bhakti, 2020). According to research Rizkita & Mufit (2022), students' understanding of physics concepts related to Newton's laws was only 5.38%, while the rate of misconceptions reached 76.69%, indicating that students' understanding of physics concepts remains relatively low. This low level of conceptual understanding is influenced by students' lack of interest and motivation to learn, as well as a lack of in-depth practice problems (Riwanto et al., 2019). Based on this, teaching Material and resources are needed that can help students understand physics concepts in a more meaningful way through active engagement in the learning process. One of the key components of learning is instructional material, which serves as a systematic, structured learning resource aligned with learning objectives (Magdalena et al., 2020).

In physics education, particularly when teaching abstract concepts such as collisions, the availability of appropriate instructional material is essential to help students gain a deeper understanding of these concepts. Good instructional Material not only present information but also facilitate learning activities that encourage active engagement, problem-solving (Azhar et al., 2024), and the development of higher-order thinking skills (Sucipto, 2017). One approach that can be integrated into the development of instructional Material is Problem Based Learning, which emphasizes learning through the presentation of contextual problems as triggers for thinking, inquiry, and problem solving both independently and collaboratively (Mangoki et al., 2026). Research by Alfiah & Dwikoranto (2022) showed that the application of the PBL model supported by the PhET virtual laboratory on parabolic motion material was able to improve students' Higher Order Thinking Skills with an N-gain value of 0.56. In line with this study, Aina & Hariyono (2023) found that the implementation of a PBL model supported by PhET Simulation on the topic of the greenhouse effect was able to improve students' science literacy skills, with an N-gain value of 0.718 in the experimental class. Furthermore, Maharani *et al*. (2024) also demonstrated that the Problem Based Learning model supported by PhET simulations has a significant effect on physics learning outcomes in the topic of work and energy, with an average N-gain value of 0.59. Through PBL based instructional Material, students do not merely passively absorb concepts but are encouraged to identify problems, gather information, analyze, and draw conclusions based on the scientific thinking process (Husna et al., 2025).

Based on the researchers' observations, students still struggle to understand the concepts of momentum and impulse because the learning process remains teacher centered. Teachers still deliver the material using conventional methods such as verbal explanations and videos resulting in students tending to be passive and their critical thinking skills not yet developing optimally (Mazaimi & Sary, 2023). Furthermore, collaboration among students remains minimal due to the lack of activities that encourage discussion and group work. In terms of facilities and infrastructure, there are no teaching Material specifically designed to explain non-central collisions, nor are there any experiments or simulations of non-central collisions available. These conditions prevent the learning process from effectively visualizing the concepts of momentum and impulse. In fact, the topic of non-central collisions involves changes in velocity, two-dimensional motion, and changes in momentum resulting from collisions, making it difficult to understand if explained solely through conventional methods (Husna, 2022; Yusuf & Indratno, 2016). To address this need, teaching Material are needed that can facilitate the visualization of abstract concepts through problem-solving activities, virtual experiments, and interactive learning experiences.

One tool that can be used is the PhET (Physics Education Technology) simulation, developed by the University of Colorado Boulder to help students understand scientific concepts through visual exploration and virtual experiments (Utama, 2025). The PhET simulation allows students to visualize and manipulate various physics variables such as position, velocity, force, energy, and momentum (Turnip, 2025), and is equipped with interactive features that facilitate the exploration of concepts (Wibowo, 2023). Using these simulations allows students to conduct virtual experiments, observe changes in variables, and independently analyze the relationships between physical quantities (Ulfia & Wahyuni, 2025).

Based on the above description, this study differs from previous research in that it develops Problem Based Learning based physics teaching Material specifically integrated with PhET simulations on the topic of non-central collisions. This development is expected to help students visualize the phenomenon of non-central collisions through more contextual and meaningful learning. Therefore, this study was conducted with the aim of developing Problem Based Learning based physics teaching Material supported by PhET simulations on the topic of non-central collisions.

METHODS

This study employs an R&D (Research and Development) research design, which is used to develop a product and test its feasibility. Development research is a systematic approach aimed at designing, developing, and evaluating a specific product or device to ensure it is suitable and effective for use (Waruwu, 2024). This study employs the 4D research model developed by Thiagarajan et al. in 1974. This model consists of four stages: Define, Design, Develop, and Disseminate. The Define stage involves identifying and determining the root causes of the problems encountered in physics learning through initial research observations, as well as conducting a needs analysis based on field data to serve as a reference for the development of instructional Material. Next, in the design stage, the instructional Material were designed by integrating the Problem Based Learning framework, which includes problem orientation, organizing students, guiding inquiry, developing and presenting results, as well as analyzing and evaluating problem-solving. Following the design phase, the development phase was carried out, culminating in product validation by subject matter and media experts, including one physics lecturer from Semarang State University and two physics teachers from SMA Negeri 3 Semarang. Once validated, the dissemination phase began, during which the instructional Material were pilot-tested on a limited scale with 11th-grade students at SMA Negeri 3 Semarang.

The suitability of the instructional Material was determined based on an assessment using a Likert scale administered to expert validators (Sugiyono, 2023). The assessment of the teaching Material' suitability was conducted using an evaluation instrument that focused on the relevance of the content, design, ease of use, and alignment with learning objectives. The total score for each evaluation indicator assigned by each expert validator can be converted to a percentage using the following formula (Fajrin et al., 2021).

$$P = \frac{f}{N} \times 100\% \qquad (1)$$

The percentage results were categorized according to the table to determine the suitability of the instructional Material. Instructional Material can be considered suitable if they meet the interpretation criteria shown in Table 1 (Fajrin et al., 2021).

Table 1. Criteria for Suitability of Instructional Material

Feasibility Percentage (%)	Criteria
81-100	Highly feasible
61-80	Feasible
41-60	Moderately feasible
21-40	Less feasible
<20	Highly infeasible

Next, a practicality analysis was conducted using a questionnaire to gauge students' responses to the developed instructional Material. The percentage of student responses can be calculated using Equation (1). Based on the calculations, the interpretation of students' responses regarding the use of the instructional Material can be categorized as shown in Table 2 (Kartini & Putra, 2020).

Table 2. Criteria for Students Response Percentages

Response Percentage (%)	Criteria
81-100	Excellent
61-80	Good
41-60	Fair
21-40	Poor
<20	Very poor

In addition, readability analysis of instructional Material is used to determine their readability level that is, the extent to which the content, language, and presentation of the material can be understood by students. The results of the readability analysis provide insight into the ease or difficulty learners have in understanding the content of the instructional Material, thereby serving as a basis for improving language use, terminology selection, and the presentation of material to make them more effective and better suited to the characteristics of the learners. The readability percentage of instructional Material can be calculated using Equation (1). Based on the results of the readability percentage calculation for non-central collision instructional Material, the scores obtained are then compared with the criteria according to Borhamuth in Table 3 (Widodo, 1995) in (Zidatunnur & Rusilowati, 2021).

Table 3. Readability Criteria for Instructional Material

Readability Percentage (%)	Criteria
$P > 57$	Easy to understand
$37 \leq P \leq 57$	Meets requirements
$P < 37$	Difficult to understand

RESULTS AND DISCUSSION

Results

This study produced a development product in the form of Problem Based Learning based instructional Material supported by PhET simulations on the topic of non-central collisions, which have been validated by experts. The learning model was developed using the 4D approach.

Definition Phase

The definition phase is a crucial stage of needs analysis that must be conducted before developing instructional Material. In this phase, the underlying problems encountered in physics learning are identified and determined through initial research observations. A needs analysis based on facts gathered in the field will serve as a reference for the creation of instructional Material. This stage also involves identifying learner characteristics by considering their abilities, motivation, and skills. This analysis aims to determine the characteristics of the target audience for the instructional Material. The results of the analysis are shown in Table 4.

Table 4. Summary of Needs Analysis Results

Aspect	Result
Learning problems	Students experience difficulty understanding non-central collisions.
Existing instructional Material	Less interactive and not integrated with PBL and PhET.
Student characteristics	Students require visual and inquiry-based learning resources.

Based on Table 4, the needs analysis identified three main findings that form the basis for the development of instructional Material. The results indicate that students still struggle to understand the concept of non-central collisions, highlighting the need for instructional Material that can facilitate conceptual understanding. Furthermore, existing instructional Material do not optimally support active learning because they are not integrated with the Problem-Based Learning (PBL) model and PhET simulations. The analysis also indicates that students require instructional Material that provide visual representations and inquiry-based learning activities to support concept formation. Therefore, the identified needs justify the development of Problem-Based Learning-based instructional Material supported by PhET simulations as appropriate solution to improve students' understanding of non-central collision concepts.

Design Phase

The design phase involves developing a preliminary design for the instructional Material based on the results of the needs analysis. During this phase, the format, structure, and components of the instructional Material to be developed are determined. The instructional Material are designed by integrating the Problem-Based Learning framework, which includes: problem orientation, organizing students, guiding inquiry, developing and presenting results, and analyzing and evaluating problem solving. Structurally, the instructional Material consist of several key, integrated components: a cover page, a preface, a table of contents, a concept map, learning outcomes, learning objectives, a description of the non-central collision concept, problem-based learning activities, experiments using PhET, and learning assessments. In the learning activities section, contextual problems are presented that guide students to investigate the concept of non-central collisions through exploration of the PhET simulation. The design of the instructional Material shown in Figure 1.

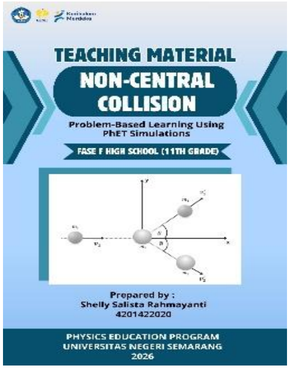

Figure 1. Preliminary Design of the PBL Instructional Material

The developed instructional Material were systematically organized according to the stages of the Problem-Based Learning model. Each section was designed to support students' conceptual understanding, beginning with contextual problems and continuing through guided investigations using PhET simulations before concluding with evaluation activities. The integration of PhET simulations into the learning activities enables students to visualize non-central collision phenomena that are difficult to observe directly, thereby facilitating concept exploration. Furthermore, the logical organization of the instructional Material, including concept maps, learning objectives, and structured activities, provides clear learning guidance and supports independent learning. Overall, the preliminary design demonstrates that the instructional Material were intentionally developed to integrate content, learning activities, and interactive simulations into a coherent learning resource that aligns with the objectives of Problem-Based Learning.

Development Phase

The development phase involves creating instructional Material based on the initial design, followed by product validation by subject matter experts and media experts comprising one physics lecturer from Semarang State University and two physics teachers from SMA Negeri 3 Semarang. The expert validators assessed several aspects, including content appropriateness, presentation, language, typography, and visual design. The feedback and suggestions provided by the expert validators were then analyzed to refine the instructional Material, ensuring the final product meets the intended needs.

Characteristics of the Instructional Material

The instructional Material developed are Problem Based Learning supported by PhET simulations on the topic of non-central collisions. The main characteristics of these Material are the integration of the five PBL components: problem orientation, organizing students for learning, guiding inquiry using PhET simulations, developing and presenting results, and analyzing and evaluating the problem-solving process. The instructional Material are structured in accordance with the Learning Outcomes (CP) and Learning Objectives (TP) of the Merdeka Curriculum and are supplemented with user guides, concept maps, content, inquiry activities, sample questions, exercises, and assessments. The integration of PBL syntax with PhET simulations enables students to build conceptual understanding through systematic and interactive inquiry activities. One of the key features of these teaching Material is the inclusion of PhET-simulation-based inquiry activities that guide students in conducting virtual experiments to analyze the phenomenon of non-central collisions. Through these activities, students can manipulate variables, observe changes in the motion of objects, analyze experimental data, and draw conclusions in accordance with the stages of Problem-Based

Learning. These activities support student-centered learning while facilitating conceptual understanding and problem-solving skills.

Suitability of Instructional Material

Instructional Material must meet suitability criteria, which include content, presentation, language, typography, and appearance. The suitability of instructional Material indicates that the developed product complies with the quality standards set by the National Education Standards Agency (BSNP), ensuring that the presented material is accurate, systematic, communicative, easy to understand, and capable of supporting the achievement of learning objectives (Hayati et al., 2025). The suitability of instructional Material is calculated using the percentage formula from Equation (1). After obtaining the percentage value, a conversion is performed according to the criteria set by Fajrin et al. (2021). The results of the instructional material suitability validation are presented in Table 5.

Table 5. Results of Instructional Material Feasibility Test

Validator Code	Percentage	Criteria
V-1	87.5%	Highly Acceptable
V-2	93.75%	Highly Acceptable
V-3	92.5%	Highly Acceptable
Average	91.25%	Highly Acceptable

Table 6. Results of Instructional Material Suitability Assessment for Each Aspect

Assessment Aspect	Percentage	Criteria
Content Suitability	91.67%	Highly Suitable
Presentation Suitability	88.89%	Highly Suitable
Language Suitability	96.67%	Highly Suitable
Typography Suitability	94.67%	Highly Suitable
Visual Suitability	80.5%	Suitable

Based on the results of the instructional material feasibility analysis in Table 4, the Problem-Based Learning-based instructional material supported by PhET simulations on the topic of non-central collisions achieved an average feasibility percentage of 91.25%, meeting the criteria for being 'highly suitable" for use. Each aspect also showed an average percentage score of 80.5-96.67%, meeting the 'highly suitable" criterion. These results align with the findings of Yakop et al. (2024) which indicated that the developed instructional Material possess an excellent level of practicality, as evidenced by a 92.5% implementation rate and teacher and student responses falling within the "good" to "very good" categories. This is consistent with the research by Putri et al. (2026) who developed a physics module based on Problem-Based Learning aided by PhET virtual simulations on the topics of temperature and heat. The developed module achieved validity scores ranging from 0.83 to 1.00 classified as "highly valid" and practicality scores of 83-90%, thereby being deemed suitable for use in instruction.

Based on these previous studies, the instructional Material are suitable for use because they were developed in accordance with the requirements for instructional material development set forth by the National Education Standards Agency (BSNP). The high feasibility score indicates that the instructional Material developed meet the criteria for content feasibility, presentation feasibility, language feasibility, typography, and visual presentation (Panggabean et al., 2020). Furthermore, the integration of the Problem-Based Learning model with PhET simulations facilitates students in constructing concepts through problem-solving activities, exploration, and the visualization of physical phenomena (Ledjab et al., 2024), making the developed instructional Material suitable for use as a learning resource on the topic of non-central collisions.

Validation of the Readability Test Sheet

A readability test sheet is an instrument used to obtain data on the ease with which instructional Material can be understood by students, as assessed in terms of content appropriateness, test design, language use, and presentation of information (Astuti et al., 2024). The readability test sheet was validated by three validators. The suitability of the instructional material's readability test sheet was calculated using the percentage formula (1). Subsequently, the obtained score was adjusted according to the criteria proposed by Widodo (1995) in (Zidatunnur & Rusilowati, 2021). The results of the readability test for the instructional Material are presented in Table 7.

Table 7. Results of Readability Assessment

Assessment Aspect	Percentage	Criteria
Content Appropriateness	97.78%	Highly Acceptable
Test Construction	91.67%	Highly Acceptable
Language	82.22%	Highly Acceptable
Presentation	95.55%	Highly Acceptable
Average	91.79%	Highly Acceptable

Based on Table 7, every assessment aspect on the readability test sheet for Problem-Based Learning-based instructional Material supported by PhET simulations on the topic of non-central collisions received a "highly acceptable" rating. These results indicate that the developed instrument has met the acceptability requirements in terms of content, construction, language, and presentation, making it suitable for use as a data collection tool in research. In terms of content appropriateness, the score was 97.78%, falling into the "highly acceptable" category. This indicates that the content in the readability test sheet aligns with the measurement objectives and the readability indicators that were formulated. Regarding test construct validity, the score was 91.67%, falling into the "highly acceptable" category. These results indicate that the instrument's development complied with the principles of evaluation instrument construction, and that a well-constructed instrument will enhance the consistency of measurement results and minimize bias in the data collection process.

Furthermore, the language aspect received a score of 82.22%, falling into the "very acceptable" category. This score indicates that, in general, the language used in the readability test sheet adheres to the rules of proper and correct Indonesian and employs communicative sentences. (Baltu & Irawan, 2025). According to Darmawan et al. (2025), the use of clear language that leaves no room for misinterpretation is one of the key requirements in developing a survey instrument to ensure that all respondents share the same understanding of each statement item. Meanwhile, the presentation aspect received a score of 95.55%, falling into the "very acceptable" category. These results indicate that the instrument's layout was designed in a systematic, appealing, and user-friendly manner (Rahmawati et al., 2019). Furthermore, a systematic layout also supports the effectiveness of the data collection process, as respondents can understand the flow of the questionnaire without experiencing confusion (Sulianta, 2025).

Dissemination Phase

In this study, the dissemination phase was conducted on a limited scale. The instructional Material, which had undergone a revision process and were deemed suitable, were used directly with 11th-grade students at SMA Negeri 3 Semarang. A pilot test was conducted to evaluate the Material and ensure that they were practical to use.

Readability of Instructional Material

A readability test of Problem-Based Learning based instructional Material supported by PhET simulations on the topic of non-central collisions was conducted using a cloze test. The cloze test was developed using material from the instructional Material by omitting several words from the text (Das et al., 2019). Through this activity, readers are required to comprehensively understand the information contained in the text. According to Inawati (2019), the success rate in filling in the missing parts is closely related to reading ability. The better a reader's ability to interpret meaning both in terms of content and language use the higher their ability to accurately complete the cloze test (Kleijn et al., 2019). The results of the readability analysis of the instructional Material are shown in Table 8.

Table 8. Readability Test Results of Developed Instructional Material

Parameter	Value
Number of respondents	52
Total score	1020
Maximum score	1040
Mean score	19.62
Readability percentage (Cloze Test)	98%
Criteria	Easy to understand

The results of the readability test for physics teaching Material based on Problem Based Learning and supported by PhET simulations on the topic of non-central collisions showed an average score of 98%, meeting the criterion that the teaching Material are easy to understand. As presented in Table 8, the readability score indicates that students were able to correctly complete almost all omitted words in the cloze test, suggesting that the language, sentence structure, and organization of concepts were appropriate for their level of understanding. The high readability score also reflects that the developed instructional Material successfully presented the concepts of non-central collisions in a logical and systematic sequence, enabling students to follow the learning process with minimal difficulty. Furthermore, the integration of the Problem-Based Learning stages with PhET simulations contributed to improving readability by connecting contextual problems, interactive investigations, and conceptual explanations in a coherent learning process. Consequently, students were able to construct their understanding more independently while engaging with each stage of learning.

These results also indicate that the developed instructional Material possess a very high level of readability, ensuring that the content, language usage, physics terminology, and presentation of concepts are well understood by students Furthermore, the use of communicative language, clear sentence structure, and the gradual presentation of concepts help students understand physics concepts that tend to be abstract and complex (Hackemann et al., 2022). Furthermore, research conducted by Harahap et al. (2024) explains that the selection of physics terminology in the instructional Material is also systematically organized, thereby making it easier for students to understand the relationships between physics concepts. According to Agustina & Febriani (2026), readability is one of the key indicators in determining the suitability of a text for a reader's ability. The higher the readability level of instructional Material, the easier it is for students to understand the content being presented (Nissa et al., 2023). Therefore, the readability score of 98% not only indicates that the developed instructional Material are easy to understand but also demonstrates that they are suitable for independent learning and have the potential to support students in constructing conceptual understanding through the implementation of Problem-Based Learning supported by PhET simulations.

Student Responses

Problem Based Learning based instructional Material supported by PhET simulations on the topic of non-central collisions were tested on 11th-grade students at SMA Negeri 3 Semarang who had already studied the topics of momentum and impulse. Student responses were collected through a questionnaire designed using a Likert scale (Sugiyono, 2023). Data were collected from 52 students, and their responses to the Problem Based Learning based instructional Material supported by PhET simulations were calculated using the percentage formula from Equation (1). After obtaining the percentage values, they were converted according to the criteria outlined by (Kartini & Putra, 2020). The results of the analysis of student responses are presented in Table 9.

Table 9. Students' Responses to Instructional Material

Assessment Aspect	Percentage	Criteria
Content Quality	90%	Very Good
Design and Presentation	89%	Very Good
Motivation	90%	Very Good
Relevance and Benefits	89%	Very Good
Average	89.5%	Very Good

Based on Table 9, the average percentage of student responses to the instructional Material was 89.5%, which meets the "very good" criterion. These results indicate that the instructional Material developed are in line with the students' needs and characteristics. In accordance with the research Ramli et al. (2024) which reveals that a positive response to instructional Material indicates that the Material developed are able to stimulate interest in learning, facilitate understanding, and effectively support the learning process. Furthermore, according to Lestari et al. (2026), The integration of Problem Based Learning with PhET simulations provides an interactive and contextual learning experience, making it easier for students to understand abstract physics concepts. Through the presentation of contextual problems and exploratory activities using simulations, students can build their understanding independently, connect the concepts they have learned to real world phenomena, and visualize physics concepts that are difficult to observe directly (Rosyad et al., 2026).

Discussion

The instructional Material developed are characterized primarily by the integration of the Problem-Based Learning model with PhET simulations to support the understanding of the concept of non-central collisions. The integration of these two components provides a more active learning experience because students are guided to discover concepts through problem solving and inquiry. The material on non-central collisions has a fairly high level of abstraction because it involves changes in the direction of motion and the relationships between several physical variables that are difficult to observe directly. Therefore, the use of PhET simulations provides visualization assistance so that students can observe the phenomena more concretely. These results are consistent with Ledjab et al. (2024) which states that the use of digital simulations in physics instruction can help students understand concepts through a process of exploration. Unlike previous studies, which have largely focused on developing PhET simulations for general physics topics such as temperature, heat, or momentum, this study contributes by developing specialized instructional Material on non-central collisions using a structured PBL approach.

The validation results show that the instructional Material were rated as "highly suitable," with an average percentage of 91.25%. This indicates that the Material met the criteria for content, presentation, language, typography, and appearance. The high suitability rating indicates that the instructional Material were systematically developed in accordance with learning needs. These findings are consistent with research Yakop et al. (2024) which indicates that technology-based learning tools have a high level of feasibility and practicality. In addition, the results of the study Putri et al. (2026) This indicates that the PBL based physics Material supplement by PhET simulations achieved a high level of validity, making it suitable for use in instruction. The consistency of these results suggests that the combination of the PBL model and virtual simulations is an effective approach to developing physics instructional Material.

A readability score of 98% indicates that the instructional Material are easy for students to understand. The high readability is attributed to the use of communicative language, the gradual introduction of concepts, and the systematic structure of the instructional Material. These results are consistent with Crossley (2025) which explains that the readability of instructional Material is related to students' ability to understand the information presented. In addition, Nisa et al. (2026) states that instructional Material with a high readability level can help students understand the material more effectively.

Student responses averaged 89.5%, falling into the "very good" category. This indicates that the instructional Material were able to provide an engaging learning experience that met students' needs. This positive response indicates that the use of contextual problems and PhET simulations can increase student engagement in learning. These findings support the research by Ramli et al. (2024) that interactive teaching Material can increase interest in learning and help students understand physics concepts.

CONCLUSION

The instructional Material developed are characterized by the application of the Problem Based Learning model using PhET simulations to teach the topic of non-central collisions. The Material are designed to help students understand concepts through contextual problem-solving, conceptual exploration using interactive simulations, and student-centered learning activities. The feasibility test results for the instructional Material yielded a score of 91.25%, falling into the "highly feasible" category. These results indicate that the instructional Material meet the feasibility standards based on the evaluation criteria of the National Education Standards Agency, including content, presentation, language, typography, and visual design, and are therefore suitable for use as a learning resource. Additionally, the readability test results yielded a score of 91.79%, classified as "highly suitable." The readability test results showed a score of 98% based on the "easy to understand" criterion, indicating that the language, presentation of the material, and visual design of the instructional Material are easily understood by students. Learners' responses to the use of the instructional Material yielded a percentage of 89.5%, categorized as "very good," indicating that the Material are engaging, easy to use, and help learners understand the concept of non-central collisions. However, this study has limitations because responses to the instructional Material were assessed only among learners, not teachers. This was due to time constraints during the research process.

REFERENCES

Agustina, H., & Febriani, E. (2026). Analisis Keterbacaan Buku Kera yang Nakal dan Kura-Kura yang Baik Berdasarkan Pedoman Perjenjangan Pembaca Pendidikan Bahasa. *Jurnal Pendidikan Bahasa*, *16*(2), 187–193.

Aina, Q., & Hariyono, E. (2023). Penerapan PhET Simulations Pada Pembelajaran Fisika untuk Meningkatkan Kemampuan Literasi Sains Peserta Didik SMA Kelas X. *Jurnal Ilmu Pendidikan*

Dan Pembelajaran, *1*(2), 56–65.

Alfiah, S., & Dwikoranto. (2022). Penerapan Model Problem Based Learning Berbantuan Laboratorium Virtual PhET Untuk Meningkatkan HOTs Siswa SMA. *Jurnal Penelitian Pembelajaran Fisika*, *13*(1), 9–18.

Aristawati, N. K., Sadia, I. W., & Sudiatmika, A. A. I. A. R. (2018). Pengaruh Model Problem Based Learning Terhadap Pemahaman Konsep Belajar Fisika Siswa SMA. *Jurnal Pendidikan Fisika Undiksha*, *8*(1), 31-41.

Astuti, R. B., Supeno, & Purwantiningsih, A. (2024). Validitas dan Kepraktisan Bahan Ajar IPAS Berbasis Multirepresentasi Untuk Meningkatkan Keterampilan Kolaborasi Siswa Sekolah Dasar. *Jurnal Pendidikan: Riset Dan Konseptual*, *8*(4), 877–887.

Azhar, M., Wahyudi, H., & Yolanda, D. (2024). Integrasi Teknologi dalam Buku Ajar : Menyongsong Keterampilan Abad 21. *Uluwwul Himmah Education Research Journal*, *1*(1), 43–55.

Baltu, F. S., & Irawan, D. (2025). Analisis Kelayakan Bahasa Dalam Buku Teks Bahasa Indonesia Kelas III Sekolah Dasar. *Social, Humanities, and Education Studies (SHEs): Conference Series*, *8*(3), 597–605.

Bhakti, Y. B., & Napis, N. (2018). The development of Guided Inqury Work Sheet for Student with Physics Interactive Simulation. *Jurnal Pendidikan Fisika*, *7*(2), 124–130.

Chan, M. I. H., Septia, E. A., & Febrianti, K. (2021). Efektivitas Model Pembelajaran Terhadap Peningkatan Pemahaman Konsep Fisika Siswa SMA : Meta-Analisis. *2021*, *7*(2), 238–245.

Crossley, S. A. (2025). Developing Linguistic Constructs of Text Readability Using Natural Language Processing Language Processing. *Scientific Studies of Reading*, *29*(2), 138–160.

Darmawan, A. A., Zamsir, Widiastiti, A. A. I. P., Sugiharni, G. A. D., & Amir, F. L. (2025). *Pengembangan Instrumen Penelitian* (A. Charolina (ed.)). PT. Penerbit Naga Pustaka.

Das, B., Majumder, M., Phadikar, S., & Sekh, A. A. (2019). Automatic Generation of Fill-in-the-Blank Question With Corpus-Based Distractors for E-Assessment to Enhance Learning. *Computer Applications in Engineering Education*, *27*(6), 1485–1495.

Depari, S. S. B., Hamdani, D., & Medriati, R. (2024). Pengembangan Alat Peraga Viskositas Menggunakan Sensor Mini Reed Switch Magnetic Berbasis Arduino Uno. *Jurnal Penelitian Pembelajaran Fisika*, *15*(1), 18–30.

Depita, T. (2024). Pemanfaatan Teknologi Dalam Pembelajaran Aktif (Active Learning) untuk Meningkatkan Interaksi dan Keterlibatan Siswa. *TARQIYATUNA: Jurnal Pendidikan Agama Islam Dan Madrasah Ibtidaiyah*, *3*(1), 55–64.

Fajrin, V. P., Ruhiyat, Y., & Darman, D. R. (2021). Pengembangan Alat Peraga Fisika Crane Magnetic Pokok Bahasan Medan Magnet Pada Selenoida. *Jurnal Luminous: Riset Ilmiah Pendidikan Fisika*, *2*(1), 1-6.

Hackemann, T., Heine, L., & Höttecke, D. (2022). Challenging to Read, Easy to Comprehend? Effects of Linguistic Demands on Secondary Students' Text Comprehension in Physics. *International Journal of Science and Mathematics Education*, *20(1)*, 43–68.

Harahap, S. H., Sinaga, A. R. A., Stio, A. A., & Munthe, C. (2024). Memperkuat Ketepatan Bahasa dalam Menyampaikan Konsep Fisika [Strengthening Language Accuracy in Delivering Physics Concepts]. *Jurnal Pendidikan Tambusai*, *8*(2), 25965–25968.

Huda, I., Girei, M. M., & Keizi, F. (2023). Development of a Practical Tool for Linear Momentum Collisions Using a Microcontroller. *Journal of Educational Technology and Learning Creativity*, *1*(2), 42–49.

Husna, A., Ilmi, N., & Gusmaneli, G. (2025). Strategi Pembelajaran Berbasis Masalah dalam

Meningkatkan Kemampuan Berpikir Kritis Peserta Didik. *Katalis Pendidikan: Jurnal Ilmu Pendidikan Dan Matematika*, *2*(2), 76–86.

Husna, K. (2022). Penggunaan Alat Peraga Fisika Pada materi Jenis-Jenis Tumbukan Untuk Meningkatkan Prestasi Siswa. *Jurnal Kinerja Kependidikan (JKK): Facilities of Educator Career and Educational Scientific Information*, *4*(1), 161–177.

Inawati, I. (2019). Tingkat Membaca Pemahaman Mahasiswa terhadap Isi Wacana dengan Tes Rumpang. *Jurnal Bindo Sastra*, *3*(1), 23–28.

Juita. (2020). Identifikasi konsentrasi belajar siswadi sekolah menengah atas. *Schrödinger:Journal of Physics Education (SJPE)*, *1*(1), 24–29.

Kartini, K. S., & Putra, I. N. T. A. (2020). Respon Siswa Terhadap Pengembangan Media Pembelajaran Interaktif Berbasis Android. *Jurnal Pendidikan Kimia Indonesia*, *4*(1), 12-19.

Kleijn, S., Maat, H. P., & Sanders, T. (2019). Cloze Testing for Comprehension Assessment : The HyTeC-cloze. *Language Testing*, *36*(4), 553–572.

Kola, A. J., Gana, N. N., & Olasumbo, I. O. (2017). The lack of good governance in Nigeria and its impact on functional science education. *International Journal of Development and Sustainability*, *6*(9), 1036–1047.

Ledjab, F. A. W., Koli, K., Tahu, M. V. F., & Dewa, E. (2024). Inovasi Pembelajaran Fisika: Integrasi Problem Based Learning dan Simulasi PhET Pada Materi Gelombang Bunyi. *MAGNETON: Jurnal Inovasi Pembelajaran Fisika*, *2*(2), 112–119.

Lestari, Y. M., Aminoto, T., & Amnie, E. (2026). Pengembangan E-Modul Pembelajaran Berbantuan PhET Interactive Simulation pada Materi Energi Alternatif Peserta Didik SMA Negeri 10 Kota Jambi. *Jurnal Pendidikan MIPA*, *16*(1), 1–12.

Magdalena, I., Sundari, T., Nurkamilah, S., Nasrullah, & Amalia, D. A. (2020). Analisis bahan ajar. *Nusantara : Jurnal Pendidikan Dan Ilmu Sosial*, *2*(2), 311–326.

Maharani, N. N., Hikmawati, Susilawati, & Gunada, I. W. (2024). Pengaruh Model Problem Based Learning Berbantuan Media PhET Simulation Terhadap Hasil Belajar Pada Materi Usaha dan Energi. *Jurnal Ilmiah Profesi Pendidikan*, *9*(1), 539–545.

Mangoki, D., Judijanto, L., Ismadi, I., Lintong, F. D., Herlina, N. H., Navisah, S., Lumbu, A., Fatubun, R. R., S, S., & Pujowati, M. (2026). *Metode & Model-Model Pembelajaran* (I. K. Sari & I. Uzma (eds.)). PT. Sonpedia Publishing.

Maulidinah, M., & Ekasari, A. (2023). Application of E-Module to Identify Students' Science Process Skills in the Practicum of Refraction on Prisms. *Schrödinger: Journal of Physics Education*, *4*(2), 30–35.

Mazaimi, Z., & Sary, I. (2023). Perbandingan Efektivitas Pembelajaran Tradisional dan Pembelajaran Berbasis Video Di Sekolah Menengah Atas. *Teknologi Pendidikan*, *2*(1), 72–79.

Nisa, F., Akhsan, H., & Kistiono. (2026). Development and Validation of a PBL-Based Physics Module Integrating PhET and Local Contexts for Parabolic Motion to Foster Students ' Critical Thinking. *Jurnal Literasi Pendidikan Fisika*, *7*(1), 19–28.

Nissa, I. C., Febrilia, B. R. A., & Pangga, D. (2023). Uji keterbacaan buku ajar matematika dasar untuk mahasiswa program studi pendidikan fisika. *Jurnal Inovasi Pembelajaran Matematika: PowerMathEdu (PME)*, *2*(1), 1–8.

Nurmaulidina, S., & Bhakti, Y. B. (2020). Pengaruh Media Pembelajaran Online Dalam Pemahaman dan Minat Belajar Siswa Pada Konsep Pelajaran Fisika. *ORBITA: Jurnal Hasil Kajian, Inovasi, Dan Aplikasi Pendidikan Fisika*, *6*(2), 248–251.

Panggabean, N. H., Danis, A., & Nadriyah. (2020). Pengembangan Bahan Ajar Berbasis Mind

Mapping Pada Pembelajaran IPA Tema Lingkungan Sahabat Kita. *Jurnal Tunas Bangsa*, *7*(2), 204–218.

Putri, M., Akhsan, H., & Kistiono. (2026). Development of Temperature and Heat Teaching Modules Based on Problem Based Learning to Improve Students ' Critical Thinking. *Journal of Science Education Research*, *10*(1), 15–25.

Rahmawati, A. R., Sarwi, S., & Darsono, T. (2019). Penyusunan Bahan Ajar IPA Fisika sebagai Upaya Peningkatan Literasi Sains Peserta. *UPEJ: Unnes Physics Education Journal*, *8*(2), 192-207.

Rahmawati, L. N., & Fianti, F. (2023). Analisis Pengaruh Media Pembelajaran Phet Simulations Terhadap Pemahaman Konsep Siswa Sma Negeri 1 Ungaran. In *Prosiding Seminar Nasional Fisika*, 361–369.

Ramli, M., Sakti, I., Idamayanti, R., & Basri, S. (2024). Pengembangan Bahan Ajar Fisika Berbasis Kearifan Lokal Pada Peserta Didik Kelas X di SMAN 4 Maros. *Karst: Jurnal Pendidikan Fisika Dan Terapannya*, *7*(1), 34–42.

Riwanto, D., Azis, A., & Arafah, K. (2019). Analisis Pemahaman Konsep Peserta Didik Dalam Menyelesaikan Soal-Soal Fisika Kelas X Mia Sma Negeri 3 Soppeng. *Jurnal Sains Dan Pendidikan Fisika*, *15*(2), 23–31.

Rizkita, N. I., & Mufit, F. (2022). Analisis Pemahaman Konsep dan Sikap Siswa Terhadap Belajar Fisika Pada Materi Hukum Newton Tentang Gerak. *JEP (Jurnal Eksakta Pendidikan)*, *6*(2), 233–242.

Rosyad, S., Avalentina, K. Z., Istiqomah, Sofiana, I. A., Puspitasari, E., & Putri, W. A. (2026). *Pembelajaran Kontekstual: Konsep dan Teori*. Naba Edukasi Indonesia.

Sakti, I. (2019). Pengaruh Penggunaan Media Pembelajaran Berbasis Videoscribe Terhadap Pemahaman Konsep Fisika Siswa SMP Ittihad Makassar. *PHYDAGOGIC: Jurnal Fisika Dan Pembelajarannya*, *1*(2), 49–54.

Sucipto. (2017). Pengembangan Keterampilan Berpikir Tingkat Tinggi Dengan Menggunakan Strategi Metakognitif Model Pembelajaran Problem Based Learning. *JP (Jurnal Pendidikan): Teori Dan Praktik*, *2*(1), 77–85.

Sugiyono. (2023). *Metode Penelitian Kuantitatif, Kualitatif, dan R&D* (Sutopo (ed.); Edisi Kedua). Penerbit Alfabeta Bandung.

Sulianta, F. (2025). *Praktis Membuat Instrumen Penelitian & Analisis Data*. Feri Sulianta.

Sundari, P. D., & Sarkity, D. (2021). Android-Based Digital Teaching Material as Online Learning in New Normal Era to Improve Physics HOTS for High School Students. *Journal of Natural Science and Integration*, *4*(2), 149–161.

Turnip, S. H. (2025). Pengaruh Metode Simulasi terhadap Pemahaman Konsep Siswa Kelas X pada Pembelajaran Kinematika Gerak. *Seminar Nasional Teknologi Dan Multidisiplin Ilmu (SEMNASTEKMU)*, *5*(1), 374–384.

Ulfia, N., & Wahyuni, S. (2025). Analisis Pengaruh Penggunaan Laboratorium Virtual (PhET Simulations) Terhadap Hasil Belajar IPA Siswa SMP: Study Literature Review. *Kalam Cendekia: Jurnal Ilmiah Kependidikan*, *13*(2), 1468–1478.

Utama, R. (2025). Review Software Simulasi untuk Pembelajaran Fisika Interaktif. *Jurnal Pendidikan Fisika Tadulako*, *13*(2), 95–106.

Waruwu, M. (2024). Metode Penelitian dan Pengembangan (R&D): Konsep, Jenis, Tahapan dan Kelebihan. *Jurnal Ilmiah Profesi Pendidikan*, *9*(2), 1220–1230.

Wibowo, H. S. (2023). *Pengembangan Teknologi Media Pembelajaran : Merancang Pengalaman Pembelajaran yang Inovatif dan Efektif*. Tiram Media.

Widhi, M. T. W., Hakim, A. R., Wulansari, N. I., Solahuddin, M. I., & Admoko, S. (2021). Analisis Keterampilan Argumentasi Ilmiah Peserta Didik Pada Model Pembelajaran Berbasis Toulmin's Argumentation Pattern (TAP) Dalam Memahami Konsep Fisika Dengan Metode Library Research. *PENDIPA: Journal of Science Education*, *5*(1), 79–91.

Yakop, S. S., Yusuf, M., & Buhungo, T. J. (2024). Analisis Kepraktisan Penggunaan Model Problem Based Learning Berbasis Phet Simulation Untuk Meningkatkan Pengetahuan Konseptual Fisika Pada Materi Elastisitas & Hukum Hooke. *Jurnal Jendela Pendidikan*, *4*(3), 257–265.

Yusuf, A., & Indratno, T. K. (2016). Bola Nirgesekan : Analisis Hukum Kelestarian Pusa pada Peristiwa Tumbukan Dua Dimensi. *Prosiding SKF*, *1*, 21–25.

Zidatunnur, S. F., & Rusilowati, A. (2021). Keterbacaan dan Kepraktisan Bahan Ajar Digital Gerak Melingkar Berbantuan Scratch Berbasis STEM untuk Mahasiswa. UPEJ: *Unnes Physics Education Journal*, *10*(2), 131-138.