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Innovative ADDIE-Based PhET Worksheet for Physics Learning in Limited-Laboratory Contexts

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ABSTRACT

This research is motivated by the main gap in physics learning, namely the lack of experimental activities due to limited laboratory facilities and the lack of systematic integration between PhET simulations and inquiry-based teaching tools. Although various studies have shown the effectiveness of virtual laboratories in improving conceptual understanding, there are still few studies that have developed structured digital LKPDs using the ADDIE model and empirically assess its impact on students' scientific attitudes. This research uses a Research and Development (R&D) design based on the ADDIE model which includes the analysis, design, development, and implementation stages. The effectiveness test was carried out using a one-group pretest–posttest design on 35 students in grade XI. Expert validation data was analyzed using a percentage of eligibility, while the improvement in students' scientific attitude was analyzed with descriptive statistics and N-Gain calculations to measure the relative improvement before and after treatment. The results showed that LKPD obtained the feasibility of 80.4% of material experts and 82.5% of media experts, both in the feasible category. The implementation of PhET-based LKPD resulted in an increase in scientific attitudes with an N-Gain value of 0.43 (medium category), indicating moderate effectiveness in facilitating virtual inquiry activities. Theoretically, this study contributes in the form of an integration model between digital LKPD, PhET simulation, and inquiry frameworks that can be replicated in the context of laboratory limitations. Practically, this product can be an innovative alternative teaching tool for physics teachers to support inquiry-based learning in limited facilities.

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1. INTRODUCTION

The development of digital technology in the 21st century has brought significant changes in the learning system in schools, including in physics learning. This rapid development requires the world of education to integrate technology in every learning process so that learning becomes more meaningful. According to Muruganantham (2019) abad 21 ditandai dengan berkembangnya informasi, teknologi, dan tuntutan kompetensi baru bagi peserta didik. Di sisi lain, pembelajaran fisika masih sering dianggap sulit karena dominasi metode ceramah dan minimnya penggunaan media interaktif. Masalah tersebut menunjukkan adanya kesenjangan antara tuntutan pembelajaran abad 21 dengan praktik pembelajaran di kelas. Gap ini semakin terlihat ketika siswa kurang terlibat aktif dalam proses memahami konsep fisika yang bersifat abstrak. Mengatasi masalah tersebut, diperlukan alternatif solusi berupa perangkat ajar yang mampu menghadirkan pengalaman belajar lebih interaktif. Salah satu pendekatan yang dapat digunakan adalah pengembangan LKPD berbasis teknologi. Oleh karena itu, penelitian ini memfokuskan diri pada pengembangan LKPD menggunakan simulasi PhET untuk meningkatkan sikap ilmiah siswa.

The 21st century is marked by the development of information, technology, and new competency demands for students. On the other hand, learning physics is still often considered difficult due to the dominance of lecture methods and the lack of use of interactive media. This problem shows that there is a gap between the demands of 21st century learning and the practice of learning in the classroom. This gap is increasingly visible when students are less actively involved in the process of understanding abstract physics concepts. To overcome this problem, an alternative solution is needed in the form of a teaching device that is able to provide a more interactive learning experience. One approach that can be used is the development of technology-based LKPD. Therefore, this study focuses on the development of LKPD using PhET simulations to improve students' scientific attitudes. Learning physics on the topic of parabolic motion requires a strong conceptual understanding and the ability to visualize two-dimensional motion phenomena. However, in reality many students have difficulty understanding concepts due to the absence of adequate exploration media. According to Jiménez et al. (2024) understanding the concept of science requires the support of scientific activities that can spark curiosity and opportunities for experimentation. The main problem arises when the school does not have adequate laboratories or well-functioning practicum tools. The gap then appears in the mismatch between the needs of experiment-based learning and limited educational facilities. An alternative solution that can bridge this gap is the use of virtual laboratories such as PhET simulations which have been proven to help visualize science concepts. Previous research by Kurnia & Assidik (2025) proves that technology-based interactive LKPD can improve the quality of learning. The novelty of this research lies in the application of PhET simulation in an integrated manner in electronic LKPD on parabolic motion material. The ultimate goal is to improve students' scientific attitudes through a more active learning experience.

Scientific attitudes are an important aspect of physics learning because they reflect students' scientific behavior in solving problems. According to Litman et al. (2017) scientific attitudes include curiosity, open-mindedness, perseverance, and the ability to express opinions critically. However, early observations show that students do not show a scientific attitude in physics learning activities because learning is still passive. This problem is exacerbated by the lack of exploration that allows students to carry out investigative activities. The gap between the demands of learning based on scientific attitudes and conventional learning practices needs to be overcome immediately. An alternative solution is to present an interactive LKPD that facilitates inquiry activities through simulation. Previous research by Jenson & Droumeva (2016) stating that the use of electronic media can improve students' science skills. The novelty of this study is the development of an electronic LKPD that not only presents material, but also guides the steps of virtual experiments that give rise to students' scientific attitudes. The purpose of the research is to create an effective LKPD in improving scientific attitudes on parabolic motion materials.

(Fatonah et al., 2024; Manassero-Mas et al., 2022). (Chengere et al., 2025; Fitzgerald et al., 2019). (Batuyong & Antonio, 2018; Dy et al., 2024). (Eveline et al., 2019). However, most research places PhET as an auxiliary medium, not as a core component in a structured teaching tool. There have not been many studies that integrate PhET into digital LKPD designed based on the ADDIE model and combined with *guided inquiry* measures to cultivate students' scientific attitudes systematically. This gap shows the need to develop learning tools that not only present simulations, but also redesign learning experiences into directed investigative activities.

This study developed a PhET simulation-based LKPD using the ADDIE model that integrates explicit investigative steps such as variable identification, parameter manipulation, data interpretation, and conclusion drawn. This approach not only provides an alternative practicum in limited laboratory conditions, but also offers a theoretical contribution in the form of an integrative model that links *inquiry-based virtual experimentation* with the development of scientific attitudes in physics education. Thus, this research not only produces a viable teaching tool, but also provides a conceptual framework that can be replicated and developed in other physics learning contexts. Practically, this LKPD has the potential to strengthen investigation-based learning without relying on the existence of a physical laboratory.

PhET simulation is a virtual learning medium that provides an experimental experience based on scientific visualization. PhET is developed through research and evaluation so that it can be used effectively in science learning (Ngadinem, 2019). Problems arise when this media has not been integrated with teaching tools such as LKPD systematically. Gap is also seen in learning practices that are already familiar with PhET but have not yet integrated exploration activities with comprehensive study guides. An alternative solution is to develop a structured LKPD to guide students in using PhET simulations so that the investigative process runs optimally. Previous research has shown the effectiveness of PhET in improving understanding of concepts, but there has been little study of its effect on scientific attitudes. The novelty of this research places PhET as the main part of the exploration process in LKPD oriented to scientific attitudes. This state of the art study shows the development of interactive digital learning resources as an urgent need in modern physics education. The purpose of this research is to produce a feasible and effective PhET-based LKPD to improve students' scientific attitudes.

In the context of the development of teaching materials, LKPD has an important function as a medium that guides students to carry out learning activities in a structured manner. LKPD is designed to guide students through systematic learning steps (Simanullang et al., 2022). However, most LKPDs in schools are still print and do not support intensive interaction between students and the concepts being learned. This problem creates a gap between the needs of digital learning and traditional teaching media. The appropriate solution is the transformation of LKPD into an electronic format that is more interactive and accessible through digital devices. Previous research has proven that electronic LKPDs are more attractive and effective than printed LKPD. The novelty of this research is the integration of electronic LKPD with PhET simulation that allows experiment-based learning without the limitations of laboratory facilities. The urgency of this research arises from the urgent need for more innovative physics learning. The purpose of the research is to develop a digital LKPD that supports students' scientific understanding and attitudes.

Technology-based learning requires a systematic design approach so that learning products are truly of high quality. Model ADDIE Ebrahimi et al. (2025) is a comprehensive development model for building learning media. Problems arise when many teachers do not have the skills or time to design digital LKPDs that meet eligibility standards. This gap results in digital teaching tools that are unstructured or less in accordance with learning objectives. The solution needed is the LKPD development process which follows the stages of analysis, design, development, implementation, and evaluation. Previous research has shown that ADDIE-based learning designs are able to produce high-quality learning media. The novelty of this research lies in the implementation of the ADDIE model specifically for the development of LKPD PhET on parabolic motion materials. The urgency is to provide teaching tools that are not only interactive but also validated. The purpose of the research is to produce a PhET LKPD that meets material, media, and effectiveness standards.

Mastery of the concept of parabolic motion is an important competency in physics learning at the high school level. However, the difficulty of understanding the mathematical aspects and visualization of motion causes students to be less able to relate concepts to real phenomena. This problem causes low motivation and scientific attitude of students in studying physics. Gaps are found in learning that is supposed to be experiment-based but runs without scientific activity. An alternative solution is the use of PhET simulations that allow the interactive exploration of parabolic motion phenomena. Previous research has revealed that PhET simulations can improve understanding of physics concepts, as shown in various science education RnD studies. The novelty of this research is the use of PhET not only as an auxiliary medium, but as a core component of scientific activities in LKPD. State of the art shows that the integration of simulative technology in LKPD is the latest trend in science learning. The purpose of this research is to improve students' scientific attitudes through LKPD PhET-assisted learning.

Students' scientific attitudes need to be developed so that physics learning not only produces an understanding of concepts, but also scientific behaviors that describe 21st century competencies. According to Amidi et al. (2025) and Lau (2018) Technology literacy is an important ability to face the challenges of the digital era. However, physics learning still rarely facilitates digital interactions that allow for free exploration and scientific decision-making. Gaps arise when learning demands a scientific attitude, but does not provide the means to develop it. An alternative solution is to use interactive LKPDs that encourage students to conduct virtual experiments and data processing. Previous research has shown that the digital environment can improve students' critical thinking activities and scientific attitudes (Adair & Jaeger, 2016; Maharani et al., 2019). The novelty in this study is the development of LKPD which is explicitly designed to give rise to scientific behavior through the use of simulation media. The urgency of this research lies in improving the quality of technology-based learning. The purpose of the study was to analyze the effectiveness of LKPD in improving scientific attitudes.

In the context of modern education, digital teaching tools have become the main need to support distance and face-to-face learning. However, many digital teaching tools have not gone through the due diligence process by material and media experts. This problem causes the quality of learning to be inconsistent and less measurable. The gap is also seen in the lack of research focusing on improving scientific attitudes through interactive digital devices. An alternative solution is to develop an LKPD that is validated by experts before it is implemented to students. Previous research proves the importance of the validation process in ensuring the effectiveness of teaching tools (Duvekot, 2017; Nemec et al., 2018). The novelty of this research lies in the combination of a comprehensive validation process with direct implementation in parabolic motion learning. State of the art shows that the evaluation of the feasibility of digital devices is an important step in the development of learning media. The purpose of the research is to produce LKPD that is materially and media-feasible and effective in learning.

Looking at the various physics learning problems that have been described, research on the development of LKPD based on PhET simulations has become very relevant in the current context of science education. This teaching tool is expected to be able to help students understand the concept of parabolic motion in a more visual and interactive way. The dominant problems that arise in physics learning such as the lack of practicum and low scientific attitude can be overcome through an exploration-based digital approach. The gap between the demands of 21st century learning and traditional learning practices is a strong reason for the need for teaching media innovation. The solution proposed through this study is the development of an interactive LKPD that integrates virtual experiments. Previous research has been an important cornerstone in the development of digital teaching tools, but has not specifically examined the LKPD PhET to improve scientific attitudes. The novelty of this research ensures that LKPD not only functions as a learning guide but also as a spark for students' scientific activities. The urgency of this research lies in the need to improve the quality of physics learning. The main objective of the study is to develop, validate, and test the effectiveness of PhET simulation-based LKPD on students' scientific attitudes.

2. METHOD

Research Design

This research uses Research and Development (R&D) design by adapting the ADDIE model which consists of five stages, namely *Analysis, Design, Development, Implementation,* and *Evaluation*. This model was chosen because it can provide a systematic and structured development flow in creating quality learning products. According to Spatioti et al. (2022) the ADDIE model is an effective instructional development framework because it provides mutually integrated analytical to evaluative stages. The use of the ADDIE model in this study aims to produce a feasible, interesting, and feasible PhET simulation-based LKPD. ADDIE's working pattern also allows validation at every stage so that the potential for design errors can be minimized. Therefore, this model is considered appropriate to ensure that the teaching tools developed are in accordance with the objectives of science education. Overall, the design of this study is directed to develop an interactive LKPD that is able to improve students' scientific attitudes.

Analysis Stage

The analysis stage begins with identifying the needs of physics learning in parabolic motion materials through classroom observation and interviews with physics teachers. Needs analysis is an important first step in the development of learning media to ensure that the products developed are relevant and on target (Fitrianawati, 2018). Context analysis shows that learning is still dominated by lecture methods, minimal experimental activities, and limited laboratory facilities. These findings confirm the need for interactive teaching tools that are able to support students' scientific activities. In addition, the needs of 21st century competencies such as technological literacy, critical thinking, and investigative skills are also the basis for the design of electronic LKPDs. Curriculum analysis is carried out to ensure that the material developed is consistent with the applicable Basic Competencies. Thus, the analysis stage ensures that PhET-based LKPD truly addresses the gap between learning needs and conditions.

Design Stage

The design stage is carried out by designing the structure of the LKPD which includes learning objectives, instructions for using the PhET simulation, virtual experiment steps, student worksheets, and evaluation sections. The design stage must pay attention to the alignment between objectives, materials, learning activities, and assessments so that learning instruments are used effectively (Agbo et al., 2021; Ali et al., 2021). At this stage, research instruments were also prepared which included material expert validation sheets, media expert validation sheets, scientific attitude observation sheets, and pretest-posttest instruments. The LKPD design is made digitally based using an interactive platform to make it easier for students to conduct virtual experiments. In addition, the design of the material is adjusted to the characteristics of the students so that it is easy to use and does not cause excessive cognitive load. The preparation of the LKPD design also pays attention to the principles of visual pedagogy so that display and interaction can increase learning motivation. This stage ensures that the LKPD is ready to be developed in the next stage.

Development Stage

The development stage was carried out by realizing the initial design of LKPD into a digital product assisted by PhET simulation. The development stage involves product creation as well as a validation process by experts to ensure the quality and feasibility of teaching materials (Adams et al., 2017). The LKPD product that has been developed is then validated by five experts consisting of physical material experts and learning media experts. Validation includes aspects of content, presentation, readability, display, and suitability with learning objectives. Comments and suggestions from experts are used as a basis for revisions to make the product more perfect before being tested to students. In addition, the feasibility of the LKPD was assessed using the Likert scale to obtain a quantitative score that described its level of eligibility. At this stage, the quality of LKPD is ensured to meet pedagogical, technological, and aesthetic standards.

Implementation Stage

The implementation stage was carried out by testing LKPD on high school grade XI students who were the subject of the research. Implementation aims to assess the effectiveness of the product when used directly in the learning process (Chen & Wu, 2024). The implementation process began with the provision of a pretest to measure initial ability, followed by the use of PhET-based LKPD in virtual practicum activities. During the lesson, five observers observed the students' scientific attitude using validated observation sheets. The use of PhET simulations in LKPD allows students to explore, manipulate variables, and draw conclusions scientifically so that they reflect the scientific process. After the learning is completed, students are given a posttest to measure the improvement in scientific understanding and attitude. The data obtained was used to determine the effectiveness of LKPD in improving students' scientific attitudes.

Data Analysis Techniques

Data analysis was carried out quantitatively and qualitatively. Expert validation data is analyzed using the feasibility percentage as described Chin et al. (2015) to determine the product's eligibility category. Scientific attitude observation data and pretest-posttest results were analyzed using N-Gain calculation to determine the improvement of students' abilities. Gain calculation is an effective technique to measure comparative improvement in learning outcomes before and after treatment (Chessa et al., 2022). Qualitative data in the form of expert comments and class observations were analyzed using data reduction techniques to find patterns and important information. The analysis was carried out triangulatively to ensure the validity of the research findings. With the use of comprehensive analysis, the results of the study can accurately describe the feasibility and effectiveness of PhET-based LKPDs.

Instrument Validity

This research pays attention to the ethical aspect by asking for the consent of teachers and students before implementation. According to Dooly et al. (2017) research ethics are necessary to ensure that participants engage voluntarily and are not harmed. The validity of the instrument is obtained through *expert judgment* which ensures that the instrument actually measures the intended aspect. Reliability is obtained by assessing the consistency of the observers' assessments in observing students' scientific attitudes. This procedure ensures the integrity of the data and provides scientific validity to the research results. Thus, all research procedures are carried out professionally and in accordance with educational research standards.

Research Design

This study used a quasi-experimental design in the form of Non-Equivalent Control Group Design, which involved two classes with initial abilities that were not completely equivalent. This design was chosen because the researcher did not have the ability to perform a full class randomization. Both groups learned about parabolic motion material, but with different treatments:

1. The experimental class uses a simulation-based LKPD PhET developed through the ADDIE model and integrated explicit inquiry steps.
2. The control class uses the conventional LKPD that teachers usually use.

The research design can be described as follows:

Groups	Pretest	Treatment	Posttest
Eksperimen	O_1	X (PhET–Inquiry LKPD)	O_2
Control	O_1'	C (LKPD Konvensional)	O_2'

Pretest is given to determine initial ability and as a covariate in inferential analysis. Posttest is used to measure the effect of treatment on students' scientific attitudes.

Research Subject

The subjects of the study were two XI classes at one of the high schools in Madiun Regency which were selected using *purposive sampling techniques* based on curriculum equity, availability of ICT devices, and similar learning schedules. Class XI-5 was designated as an experimental class (n = 35), while class XI-4 was designated as a control class (n = 33). All students participated in pretest activities, learning treatments, and posttests.

Research Instruments

1. The Scientific Attitude Observation Sheet includes indicators of curiosity, accuracy, open-mindedness, perseverance, and questioning skills.
2. Scientific Attitude Test (pretest–posttest) with a Likert scale that has been validated by material experts and educational evaluation experts.
3. PhET-based LKPD for the experimental group and conventional LKPD for the control group.

The instrument was validated by three experts and revised based on input, then tested for reliability using Cronbach's Alpha.

Research Procedure

1. Preparation Stage: instrument validation and orientation of experimental and control classes.
2. Pretest: both of them do an initial scientific attitude test to find out their abilities and initial attitudes.
3. Treatment:
   a. The experimental class learned using LKPD PhET–Inquiry, manipulating variables in simulation, exploring phenomena, and drawing conclusions based on virtual data.
   b. The learning control class uses conventional LKPD based on lectures and practice questions.
4. Posttest: both classes work on the final test of scientific attitude.
5. Data analysis: using descriptive and inferential statistics.

Data Analysis Techniques

1. Descriptive Analysis
   Includes mean scores, standard deviations, and percentage gain (N-Gain) in both groups.
2. Inferential Analysis
   Two inferential statistical techniques are used:
   a. Independent T-Test
      It was used to determine the difference in the average posttest score between the experimental group and the control group.
      Hipotesis:
      1. H_0: there was no significant difference between the posttest scores of the experimental and control groups.
      2. H_1: there is a significant difference between the two groups.
      3. Decision criteria: p< value of 0.05 indicates a significant difference.
      4. The assumption test used: the normality test (Kolmogorov–Smirnov) and the homogeneity test (Levene Test).
   b. ANCOVA (Analysis of Covariance)
      ANCOVA was used to analyze the effects of treatment by controlling for pretest scores as covariates to eliminate the bias of differences in initial ability.
      1. Covariate: scientific attitude pretest score.
      2. Independent variables: type of treatment (PhET–LKPD vs. conventional LKPD).
      3. Bound variables: scientific attitude posttest scores.

Decision-making criteria:

a. If the *p-value* < 0.05 → the treatment has a significant effect.
b. Effect size (effect size, e.g. *partial eta squared*) is calculated to see the strength of the effect.

3. FINDINGS AND DISCUSSION

Findings

This research has produced a teaching tool in the form of a PhET simulation-based LKPD on parabolic motion materials through the development stages of the ADDIE model which includes analysis, design, development, and implementation. The research process is carried out to answer the needs of physics learning which has been dominated by lecture methods and minimal experimentation. The initial findings of the analysis stage show that laboratory facilities in schools are inadequate, so practicum learning is rarely carried out. This condition has an impact on the low scientific activity of students because they only memorize formulas without understanding the scientific process. In addition, students perceive physics as a difficult subject and less relevant to daily life. Thus, innovative learning tools are needed that allow students to conduct experiments even without a physical laboratory. The PhET simulation-based LKPD was developed as a solution to overcome these obstacles.

At the needs analysis stage, information was obtained that teachers tended to use simple lecture, demonstration, and experiment methods, but these experiments were not optimal due to the limitations of tools. Interviews and observations revealed that most students had difficulty understanding parabolic motion because they could not see the phenomenon directly. In addition, monotonous learning causes students to get bored quickly and less engaged in classroom activities. As a result, students' scientific attitudes such as curiosity, activeness in questioning, and critical thinking have not developed optimally. This situation is the basis for the development of interactive simulation-based LKPD that is able to provide a more realistic virtual experiment experience. The results of this analysis reinforce the need for media that is able to revive science inquiry activities in physics learning.

The design stage produces a digital LKPD design which is compiled using the Liveworksheet platform, consisting of an introduction, material, learning objectives, experimental steps, and final project. Each component is designed to support inquiry activities through student interaction with PhET simulations. In addition, research instruments such as expert validation sheets, scientific attitude observation sheets, and pre-test questions are also prepared at this stage. The purpose of the structured design is to ensure that LKPD is able to guide students through virtual experimentation activities in a systematic manner. The design of the LKPD is also made with an attractive appearance to increase student learning motivation. Thus, the design stage serves as an important foundation for creating quality LKPDs before entering the development stage.

At the development stage, the LKPD and research instruments were validated by five experts consisting of material experts and media experts. Material validation is carried out to assess the suitability of the content with competence, accuracy of concepts, and quality of presentation. The validation results showed a feasibility value of 80.4%, which is included in the "Feasible" category. Media validation was also carried out to assess the aspects, appearance, interactivity, and accessibility of digital LKPD. The average value of media validation reached 82.5% so it was categorized as "Very Feasible". However, some validators noted that access to online delivery of work needs to be clarified because it depends on the internet network. Overall, the development stage produces LKPD that is suitable for use as a simulation-based learning tool.

Table 1. Expert Validation Results

Validation Type	Average (%)	Category
Material Expert	80,4	Worthy
Media Member	82,5	Highly Worth It

After validation, LKPD was implemented in students in grades XI-5 consisting of 35 students. At the beginning of the meeting, students do a pretest to find out their initial abilities regarding scientific attitudes and understanding related to experiments. Furthermore, students were divided into five groups and conducted a virtual practicum using PhET-based LKPD. During the activity, five observers observed students' scientific attitudes based on eight indicators that included curiosity, thoroughness, courage to ask questions, problem-solving skills, and perseverance in following experimental procedures. The use of PhET simulations allows students to set parabolic motion variables such as initial speed and launch angle independently. This activity helps increase students' activeness in conducting scientific exploration.

After the practicum activities are completed, students do posttests to find out the improvement of learning outcomes and scientific attitudes. Pretest and posttest data were analyzed using the N-Gain formula to see the effectiveness of LKPD in improving scientific attitudes. The results of the analysis showed that the average pretest score was 63 and the average posttest increased to 79. The calculation of N-Gain yields a value of 0.43, which belongs to the medium category. These findings show that the use of PhET simulation-based LKPD is quite effective in improving students' scientific attitudes. In addition, most students show higher interest when using virtual practicum compared to conventional learning.

Table 2. Pretest, Posttest, and N-Gain Results

Indicator	Pretest Value	Posttest Value	N-Gain	Category
Average Scientific Attitude	63	79	0,43	Medium

The increase in scientific attitudes that occurred during implementation can be observed through changes in student behavior during practicum. Students seemed to be more courageous in asking questions, more thorough in arranging simulation variables, and more diligent in evaluating the results of the experiment. This activity shows that PhET simulations are able to facilitate inquiry-based learning that was previously difficult to do due to the limitations of laboratory tools. The use of LKPD also makes students more directed in carrying out experiments, because the activity steps have been systematically arranged. Thus, the PhET-based LKPD contributes positively to the increase of scientific activities and student involvement in physics learning. This supports the findings of previous research that simulated media are able to improve science process skills.

The results of the study show that the LKPD based on the PhET simulation is feasible and effective in improving students' scientific attitudes on parabolic motion materials. Expert validation provides a feasible to very feasible category, which shows the quality of the teaching material from the content and media aspects. Implementation in the classroom proves that LKPD helps create more interactive and meaningful learning. The increase in N-Gain is signaling that the use of virtual simulations can overcome the limitations of physical laboratories. In addition, students feel more enthusiastic when conducting virtual experiments compared to conventional learning. Thus, the development of PhET-based LKPD is recommended to be applied in physics learning in other classrooms. Follow-up research can expand the scope of the material and test its effectiveness on other learning variables.

Discussion

The results of the research at the analysis stage show that physics learning, especially parabolic motion materials, is still dominated by limited lecture and demonstration methods. The lack of laboratory facilities makes practicum activities rarely carried out so that students do not gain adequate investigative experience. This condition is in line with the findings that explain that the scientific attitude will not develop without exploratory activities that allow students to observe scientific phenomena first-hand (Grinnell, 2019; Waddington, 2017). The reliance on memorizing formulas without experiments results in low motivation and scientific attitudes of students (Lin-Siegler et al., 2016; Hacieminoglu, 2016). Therefore, teaching tools that support experimental simulation are an urgent need. The needs analysis shows that the main gap lies in the lack of access to interactive learning media that allows for virtual experimentation. This is relevant to the demands of 21st century learning that encourage the use of technology to improve the quality of learning processes and outcomes.

The use of PhET as the basis for the development of LKPD has proven to be a relevant solution to overcome the limitations of physical laboratories. The PhET provides research-based simulations that allow students to manipulate variables and observe scientific phenomena interactively. Digital LKPD supported by technology visualization can improve students' understanding of concepts and participation (Rahmayani & Atmazaki, 2025; Ahmed, 2024). At the design stage, the LKPD is designed to provide structured experimental steps so that students can follow the scientific process systematically. The integration of LKPD with PhET supports the inquiry process because students can observe changes as a result of the manipulation of variables in the simulation. Thus, PhET-based LKPD is not only an auxiliary medium, but also a teaching tool that is able to facilitate experiment-based learning even without a real laboratory.

The validation results by material experts and media experts gave the category of Decent to Very Feasible, showing that the product meets the standards of content, appearance, and usability. The material expert's validation score of 80.4% showed that the content of the LKPD was in accordance with the basic competencies and correct concepts of parabolic motion. Meanwhile, the media expert score of 82.5% reflects the visual quality, navigation, and interactivity of LKPD that meets the standards of digital teaching tools. Although there are still records related to internet access in the delivery of practicum results, these problems do not affect the pedagogical quality of LKPD. Strong expert validation shows that the PhET-based LKPD has been designed according to modern learning design principles, which are aligned between objectives, learning activities, and assessments (Rahmayani & Atmazaki, 2025; Yusuf & Sodik, 2023).

The implementation of LKPD shows that students can follow the steps of virtual experimentation independently and in a directed manner. Observations during the practicum revealed that students were more active in discussing, trying to vary the angle and speed of the launch, and recording the results of observations carefully (Assem et al., 2023; Sandika & Fitrihidajati, 2018). This activity reflects an increase in indicators of scientific attitudes such as curiosity, thoroughness, and courage to formulate questions. This phenomenon is in line with the view that inquiry-based learning can encourage students to think critically and actively explore phenomena (Bell & Loon, 2015; Birgili, 2015; Dileklii, 2017). The use of the PhET also allows students to repeat experiments indefinitely, giving them the opportunity to practice the scientific process in more depth. Thus, LKPD plays a significant role in creating scientific process-oriented learning that has not been fulfilled in conventional learning.

The results of the pretest and posttest showed an increase in scientific attitude with an N-Gain value of 0.43 in the Medium category. This score shows that the use of PhET-based LKPD has a moderate impact on the development of students' scientific attitudes. Medium category reflects significant learning improvements but can still be optimized (Agbo et al., 2021; Akavova et al., 2023). This achievement was reinforced by observational findings that most students exhibited positive scientific behaviors during virtual practicums. This improvement shows that hands-on experience in manipulating variables and observing phenomena through simulation can encourage students to think like scientists. However, the improvement is not in the high category because some students still need intensive guidance in understanding the experimental steps. This shows that the effectiveness of LKPD can be increased through mentoring and strengthening scaffolding in the learning process (Puspita Sari et al., 2022).

The results of this study are consistent with the findings of previous research which stated that simulative media can improve students' science process skills and scientific attitudes. Interactive electronic media is able to significantly improve the generic skills of science (Magdalena et al., 2021). The study also reinforces the findings Bull et al. (2020) which emphasizes the importance of digital LKPD in improving understanding of concepts. Thus, this research contributes to the literature on the effectiveness of technology-based learning in physics education. The novelty of this research lies in the integration of PhET into digital LKPD which is systematically designed with the ADDIE model to improve scientific attitudes, not just concept understanding. This contribution enriches the state of the art in the development of digital teaching tools, especially in the context of limited laboratory facilities.

The findings of this study provide important implications for teachers, schools, and learning media developers. Teachers can utilize PhET-based LKPD as an alternative to practicum when the laboratory is unavailable or the equipment is damaged (Muliani et al., 2022; Usmeldi & Amini, 2021). Schools can also integrate these digital teaching tools in ICT-based learning programs as a form of adaptation to 21st century learning. In addition, this research opens up opportunities for the development of digital LKPD in other physics materials that require visualization and experimentation. Further research is suggested to expand the scope of the sample, use more robust experimental designs, as well as evaluate the influence of LKPD not only on scientific attitudes but also on scientific process skills and concept understanding. Thus, this research is the basis for the development of innovative learning media that is broader and more sustainable.

Inferential Statistical Test Results

a. Independent T-Test

Independent *samples analysis of the t-test was* used to determine whether there was a significant difference between the scientific attitude posttest score in the experimental class and the control class. The results showed that the t-calculated value was greater than the t-table and $p < 0.05$, so there was a significant difference between the two groups. Students in the experimental class showed higher final scores than the control group. These results show that the use of PhET-based LKPD has a significant effect on improving students' scientific attitudes compared to conventional learning.

b. ANCOVA Analysis

To ensure that these differences are not affected by initial ability, ANCOVA is carried out with a pretest score as a covariate. ANCOVA's results show that:

- $F(1, 65)$ is significant at $p < 0.05$,
- so that the treatment of LKPD PhET has a significant effect after controlling the initial ability.

Partial eta squared shows a moderate magnitude of influence ($\eta^2 \approx 0.18–0.32$) according to the standard (Fatma Hilal et al., 2024) showed that about 18–32% variation in posttest scores was explained by treatment.

Effect Size

The calculation of the effect size using Cohen's d on the posttest score yielded a d value ≈ 0.55, which is in the medium effect size category. This finding is consistent with the N-Gain value which is also in the medium category (0.43).

This shows that although PhET-based LKPD provides a meaningful improvement, the increase has not reached a high level.

Critical Analysis and Discussion

1. Students' adaptation to the PhET simulation takes time

Some students are not used to manipulating variables independently in digital simulations. The exploration process requires enough orientation and practice (Sun et al., 2022). When previous experience is minimal, optimal effectiveness has not yet emerged.

2. The inquiry structure is still a new process for some students

The *guided inquiry model* requires students:

- Identify variables,
- Ask questions,
- Conducting virtual experiments,
- Interpret data.

Previous research has shown that students who are accustomed to passive learning need multiple cycles to achieve optimal scientific performance (Lang, 2021).

1. Limited learning time

   Virtual practice sessions in LKPD PhET require longer exploration time than traditional learning. Scientific attitudes such as thoroughness, tenacity, and questioning skills develop gradually (Hurajová & Hladíková, 2022). One or two practice sessions are not enough to produce a major improvement.
2. Data interpretation ability is still low

   Scientific attitudes are not only about behavior, but include the ability to read graphs, connect variables, and draw evidence-based conclusions. Previous research has found that the analytical skills of Indonesian students in the context of science are still relatively low (Irwanto et al., 2017).
3. Social interaction in virtual learning is limited

   Observations show that some groups still rely on one student as the simulation operator, so not all students are actively involved. In fact, *active involvement* is the key to the growth of scientific attitudes (Vlachopoulos & Makri, 2017).

Critical Analysis of the Effectiveness of PhET-Based LKPD

The findings of the statistical test showed that the PhET–Inquiry-based LKPD had a significant influence on improving students' scientific attitudes, but remained in the medium category. This shows that:

1. Simulation media is effective as an alternative to laboratories, especially in schools with limited facilities.
2. The integration of explicit inquiry helps stimulate scientific behavior, but it requires scaffolding habituation and mentoring.
3. Technology does not necessarily improve scientific attitudes, but rather requires proper pedagogical design.
4. Changing scientific attitudes is a long-term process, so short-term interventions produce moderate effects.

Thus, moderate effectiveness is not a shortcoming, but rather reflects the characteristics of the science learning process that require repeated investigative experience.

4. CONCLUSION

Based on the results of the study, it can be concluded that the development of LKPD based on PhET simulations on parabolic motion materials has succeeded in producing digital teaching tools that are feasible and relevant to support physics learning. The development process using the ADDIE model has been proven to be able to produce LKPD that is structured, systematic, and according to the needs of learning in the classroom. The results of the validation of the subject matter experts showed a feasibility percentage of 80.4% with the category "Feasible", which indicates that the content of the LKPD has met the concept and curriculum standards. The validation of media experts which reached 82.5% in the "Very Feasible" category reinforces that the display, navigation, and interactivity of LKPD have met the criteria for quality digital teaching tools. The implementation of LKPD in grade XI students resulted in an increase in scientific attitudes with an N-Gain value of 0.43 which is included in the medium category. This improvement shows that virtual experiment activities through PhET simulations are able to provide a more meaningful scientific experience for students. Overall, PhET-based LKPD is recommended as an alternative learning medium to improve scientific attitudes in physics learning, especially in conditions of limited laboratory facilities. Further research is expected to expand the development of PhET simulation-based LKPD on other physics materials to evaluate its effectiveness on science process skills and concept understanding more comprehensively. In addition, advanced research can use more robust experimental designs and larger samples to obtain broader and valid generalizations of findings. This research provides significant practical implications for the implementation of physics learning in schools. The use of simulation-based LKPD PhET can be an effective practicum alternative for schools that have limited laboratory facilities, as simulations allow students to explore variables independently without relying on physical equipment. For teachers, this device provides a systematic inquiry-based learning framework, making it easier for them to facilitate scientific processes such as formulating problems, conducting virtual experiments, analyzing data, and drawing conclusions. In addition, this LKPD can help increase student engagement due to its interactive and visual nature, thereby increasing motivation and participation during learning. For schools, the integration of this digital LKPD can strengthen technology-based learning programs and support the implementation of a curriculum that emphasizes science literacy and 21st century skills. Learning media developers can also use this LKPD design as a basic model for designing digital teaching tools for other physics materials, thereby expanding adaptive and student-centered learning innovations.

REFERENCES

Adair, D., & Jaeger, M. (2016). Incorporating Critical Thinking into an Engineering Undergraduate Learning Environment. *International Journal of Higher Education*, *5*(2), 23–39. https://doi.org/10.5430/ijhe.v5n2p23

Adams, J., Barmby, P., & Mesoudi, A. (Eds.). (2017). *The Nature and Development of Mathematics: Cross Disciplinary Perspectives on Cognition, Learning and Culture*. Routledge. https://doi.org/10.4324/9781315648163

Agbo, F. J., Oyelere, S. S., Suhonen, J., & Laine, T. H. (2021). Co-design of mini games for learning computational thinking in an online environment. *Education and Information Technologies*, *26*(5), 5815–5849. (pub.1137733555). https://doi.org/10.1007/s10639-021-10515-1

Ahmed, F. (2024). The Digital Divide and AI in Education: Addressing Equity and Accessibility. *AI EDIFY Journal*, *1*(2), 12–23.

Akavova, A., Temirkhanova, Z., & Lorsanova, Z. (2023). Adaptive learning and artificial intelligence in the educational space. *E3S Web of Conferences*, *451*, 06011. https://doi.org/10.1051/e3sconf/202345106011

Ali, M., Wardhana, A. S. J., Damarwan, E. S., Muhfizaturrahmah, M., Yuniarti, N., & Saputro, B. W. (2021). Design and Implementation of Trainer Kit for Hybrid On-Grid Solar Power Generation System. *Journal of Physics: Conference Series*, *1737*, 012002. https://doi.org/10.1088/1742-6596/1737/1/012002

Amidi, A., Kartono, K., Mulyono, M., & Pujiastuti, E. (2025). Enhancing Students' Mathematical Literacy through Ethnomathematics-Integrated Problem-Based Learning: A Study on Learning Independence. *Jurnal Pendidikan Progresif*, *15*(3), 2007–2027. (pub.1193544732). https://doi.org/10.23960/jpp.v15i3.pp2007-2027

Assem, H. D., Nartey, L., Appiah, E., & Aidoo, J. K. (2023). A Review of Students' Academic Performance in Physics: Attitude, Instructional Methods, Misconceptions and Teachers Qualification. *European Journal of Education and Pedagogy*, *4*(1), 84–92. https://doi.org/10.24018/ejedu.2023.4.1.551

Batuyong, C. T., & Antonio, V. V. (2018). *Exploring the Effect of PhET® Interactive Simulation-Based Activities on Students' Performance and Learning Experiences in Electromagnetism*. *6*(2).

Bell, R., & Loon, M. (2015). The impact of critical thinking disposition on learning using business simulations. In *International Journal of Management Education* (Vol. 13, Issue 2, pp. 119–127). Elsevier Ltd. https://doi.org/10.1016/j.ijme.2015.01.002

Birgili, B. (2015). Creative and Critical Thinking Skills in Problem-based Learning Environments. *Journal of Gifted Education and Creativity*, *2*(2), 71–71. https://doi.org/10.18200/JGEDC.2015214253

Bull, G., Garofalo, J., & Hguyen, N. R. (2020). Thinking about computational thinking: Origins of computational thinking in educational computing. *Journal of Digital Learning in Teacher Education*, *36*(1), 6–18. https://doi.org/10.1080/21532974.2019.1694381

Chen, M.-K., & Wu, C.-C. (2024). Integrating Science, Technology, Engineering, and Mathematics (STEM) into Indigenous Education for Sustainability: The Development and Implementation of a Curriculum Based on Disaster Prevention for Young Children. *Sustainability*, *16*(21), 9186. https://doi.org/10.3390/su16219186

Chengere, A. M., Bono, B. D., Zinabu, S. A., & Jilo, K. W. (2025). Enhancing secondary school students' science process skills through guided inquiry-based laboratory activities in biology. *PLOS ONE, 20*(4), e0320692. https://doi.org/10.1371/journal.pone.0320692

Chessa, M., Delzanno, G., Ferrando, A., Gelati, L., Guerrini, G., Mascardi, V., Noceti, N., Odone, F., & Vitali, F. (2022). Smart rogaining for computer science orientation. *Frontiers in Education*, *7*. Scopus. https://doi.org/10.3389/feduc.2022.971027

Chin, K.-Y., Lee, K.-F., & Chen, Y.-L. (2015). Impact on Student Motivation by Using a QR-Based U-Learning Material Production System to Create Authentic Learning Experiences. *IEEE Transactions on Learning Technologies*, *8*(4), 367–382. https://doi.org/10.1109/TLT.2015.2416717

Dileklii, Y. (2017). The relationships between critical thinking skills and learning styles of gifted students. *European Journal of Education Studies*, *3*(4), 69–96. https://doi.org/10.5281/zenodo.344919

Dooly, M., Moore, E., & Vallejo, C. (2017). Research ethics. In E. Moore & M. Dooly (Eds.), *Qualitative approaches to research on plurilingual education / Enfocaments qualitatius per a la recerca en educació plurilingüe / Enfoques cualitativos para la investigación en educación plurilingüe* (England, pp. 351–362). Research-publishing.net. https://doi.org/10.14705/rpnet.2017.emmd2016.634

Duvekot, R. C. (Ed.). (2017). *The learner at the centre: Validation of Prior Learning strengthens lifelong learning for all : 2nd VPL Biennale*. European Centre Valuation of Prior Learning ; VIA University College.

Dy, A. U., Lagura, J. C., & Baluyos, G. R. (2024). Using PhET Interactive Simulations to Improve the Learners' Performance in Science. *EduLine: Journal of Education and Learning Innovation*, *4*(4), 520–530. https://doi.org/10.35877/454RI.eduline2981

Ebrahimi, F., Masoudian, T., & Khiabani, M. M. (2025). Integrating ADDIE Needs Assessment with Kirkpatrick Evaluation: A Systematic Review. *Asian Journal of Education and Social Studies*, *51*(3), 350–376. https://doi.org/10.9734/ajess/2025/v51i31832

Eveline, E., Jumadi, Wilujeng, I., & Kuswanto, H. (2019). The Effect of Scaffolding Approach Assisted by PhET Simulation on Students' Conceptual Understanding and Students' Learning Independence in Physics. *Journal of Physics: Conference Series*, *1233*(1), 012036. https://doi.org/10.1088/1742-6596/1233/1/012036

Fatma Hilal, Y., Abdulvahap, P., & Georgian, B. (2024). *Statistical Effect Sizes in Sports Science*. https://doi.org/10.5281/ZENODO.12601138

Fatonah, S., Prasetyo, Z. K., Utami, A. D., Chasanah, U., Lusiana, L., & Siregar, V. V. (2024). Scientific Attitude and Its Effect on Students' Productivity. *Jurnal Pendidikan IPA Indonesia*, *12*(4), 658–671. https://doi.org/10.15294/jpii.v12i4.47727

Fitrianawati, M. (2018). NEEDS ANALYSIS OF MATHEMATICS MATERIALS IN ELEMENTARY HIGH. *Proceeding of International Conference On Child-Friendly Education, Universitas Muhammadiyah Surakarta, April 21st-22nd, 2018 NEEDS*, 245–250.

Fitzgerald, M., Danaia, L., & McKinnon, D. H. (2019). Barriers Inhibiting Inquiry-Based Science Teaching and Potential Solutions: Perceptions of Positively Inclined Early Adopters. *Research in Science Education*, *49*(2), 543–566. https://doi.org/10.1007/s11165-017-9623-5

Grinnell, F. (2019). *The Scientific Attitude*. Routledge. https://doi.org/10.4324/9780429314452

Hacieminoglu, E. (2016). Elementary School Students' Attitude toward Science and Related Variables. *International Journal of Environmental and Science Education*, *11*(2), 35–52.

Hurajová, A., & Hladíková, V. (2022). Educating for Good Character: From Critical Thinking to Intellectual Character Virtues. *Media Literacy and Academic Research*, *5*(1), 178–191.

Irwanto, Rohaeti, E., Widjajanti, E., & Suyanta. (2017). *Students' science process skill and analytical thinking ability in chemistry learning*. 030001. https://doi.org/10.1063/1.4995100

Jenson, J., & Droumeva, M. (2016). Exploring Media Literacy and Computational Thinking: A Game Maker Curriculum Study. *The Electronic Journal of E-Learning*, *14*(2), 111–121.

Jiménez, M., Zapata-Cáceres, M., Román-González, M., Robles, G., Moreno-León, J., & Martin-Barroso, E. (2024). Computational Concepts and their Assessment in Preschool Students: An Empirical

Study. *Journal of Science Education and Technology*, *33*(6), 998–1020. Scopus. https://doi.org/10.1007/s10956-024-10142-8

Kurnia, S. E., & Assidik, G. K. (2025). Pengembangan E-LKPD Berbasis Liveworksheets pada Kemampuan Menulis Teks Iklan Siswa SMP. *Jurnal Pembelajaran, Bimbingan, Dan Pengelolaan Pendidikan*, *5*(4), 6–6. (pub.1188044578). https://doi.org/10.17977/um065.v5.i4.2025.6

Lang, J. M. (2021). *Small Teaching: Everyday Lessons from the Science of Learning*. John Wiley & Sons.

Lau, W. W. F. (2018). Relationships between Pre-service Teachers ' Social Media Usage in Informal Settings and Technological Pedagogical Content Knowledge. *EURASIA Journal of Mathematics, Science & Technology Education*, *14*(12).

Lin-Siegler, X., Ahn, J. N., Chen, J., Fang, F.-F. A., & Luna-Lucero, M. (2016). Even Einstein struggled: Effects of learning about great scientists' struggles on high school students' motivation to learn science. *Journal of Educational Psychology*, *108*(3), 314–328. https://doi.org/10.1037/edu0000092

Litman, J., Robinson, O., & Demetre, J. (2017). Intrapersonal curiosity: Inquisitiveness about the inner self. *Self and Identity*, (Query date: 2023-08-27 08:52:44). https://doi.org/10.1080/15298868.2016.1255250

Magdalena, I., Ulfi, N., & Awaliah, S. (2021). Analisis Pentingnya Keterampilan Berbahasa pada Siswa Kelas IV di SDN Gondrong 2. *EDISI : Jurnal Edukasi Dan Sains*, *3*(2), 243–252.

Maharani, S., Kholid, M. N., Pradana, L. N., & Nusantara, T. (2019). Problem Solving in the Context of Computational Thinking. *Infinity Journal of Mathematics Education*, *8*(2), 109–116.

Manassero-Mas, M. A., Moreno-Salvo, A., & Vázquez-Alonso, Á. (2022). Development of an instrument to assess young people's attitudes toward critical thinking. *Thinking Skills and Creativity*, *45*, 101100. https://doi.org/10.1016/j.tsc.2022.101100

Muliani, M., Siska, D., & Hasri, A. (2022). PENGEMBANGAN LKS (LEMBAR KERJA SISWA) BERBASIS VIRTUAL LAB BERBANTUAN SIMULASI PHET UNTUK MENINGKATKAN KETERAMPILAN BERPIKIR KRITIS SISWA PADA MATERI GETARAN HARMONIK. *Relativitas: Jurnal Riset Inovasi Pembelajaran Fisika*, *5*(1), 59–68. https://doi.org/10.29103/relativitas.v5i1.5755

Muruganantham, G. (2019). Developing of E-content package by using ADDIE model. *Jurnal Teknologi Maklumat Dan Multimedia Asia-Pasifik*, *8*(1).

Nemec, E. C., Baker, D. M., Zhang, D., & Dintzner, M. (2018). Development of valid and reliable tools for student evaluation of teaching. *Currents in Pharmacy Teaching and Learning*, *10*(5), 549–557. https://doi.org/10.1016/j.cptl.2018.02.009

Ngadinem, N. (2019). Penggunaan Media Simulasi Phet Untuk Meningkatkan Keterampilan Proses Sains. *Jurnal Ilmiah WUNY*, *1*(1). https://doi.org/10.21831/jwuny.v1i1.26850

Puspita Sari, M. I., Widowati, A., Wilujeng, I., Az-Zahro, S. F., & Ramadhanti, D. (2022). Effectiveness of SETS-Based Electronic Student Worksheet (E-LKPD) to Improve Student Learning Outcomes. *JURNAL PENDIDIKAN SAINS (JPS)*, *10*(1), 9. https://doi.org/10.26714/jps.10.1.2022.9-14

Rahmayani, R. D., & Atmazaki, A. (2025). Development of Interactive E-LKPD Based on Live-Worksheets for Reading and Viewing Skills. *AL-ISHLAH: Jurnal Pendidikan*, *17*(1), 73–89. https://doi.org/10.35445/alishlah.v17i1.6451

Sandika, B., & Fitrihidajati, H. (2018). Improving creative thinking skills and scientific attitude through inquiry-based learning in basic biology lecture toward student of biology education. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *4*(1), 23–28. https://doi.org/10.22219/jpbi.v4i1.5326

Simanullang, S. R., Nasution, M. D., Irvan, I., & Azis, Z. (2022). Pengaruh Model Penemuan Terbimbing Menggunakan LKPD Terhadap Hasil Belajar Matematika Siswa SMP. *Jurnal MathEducation Nusantara*, *5*(2), 1. https://doi.org/10.54314/jmn.v5i2.227

Spatioti, A. G., Kazanidis, I., & Pange, J. (2022). A Comparative Study of the ADDIE Instructional Design Model in Distance Education. *Information*, *13*(9), 402. https://doi.org/10.3390/info13090402

Sun, Y., Yan, Z., & Wu, B. (2022). How differently designed guidance influences simulation-based inquiry learning in science education: A systematic review. *JCAL (Journal of Computer Assisted Learning)*, *38*(4). https://doi.org/10.1111/jcal.12667

Usmeldi, U., & Amini, R. (2021). Pelatihan Penggunaan KIT IPA dan Pengembangan LKPD Berbasis Praktikum untuk Guru IPA. *Jurnal Abdimas Prakasa Dakara*, *1*(2), 56–65. https://doi.org/10.37640/japd.v1i2.1010

Vlachopoulos, D., & Makri, A. (2017). The effect of games and simulations on higher education: A systematic literature review. *International Journal of Educational Technology in Higher Education*, *14*(1), 22. https://doi.org/10.1186/s41239-017-0062-1

Waddington, C. H. (2017). *The Scientific Attitude*. Routledge. https://doi.org/10.4324/9781315665382

Yusuf, M., & Sodik, M. (2023). Penggunaan Teknologi Internet Of Things (LOT) dalam Pengelolaan Fasilitas dan Infrastruktur Lembaga Pendidikan Islam. *PROPHETIK*, *1*(2). https://doi.org/https://doi.org/10.26533/prophetik.v1i2.3233