

# THE DEVELOPMENT OF PhET-BASED STUDENT WORKSHEETS TO IMPROVE STUDENTS' COGNITIVE LEARNING OUTCOMES AT MTS NUR HADI MUARA JAWA

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## ABSTRACT

This study aims to develop PhET-based student worksheets (LKPD) and examine their effectiveness in improving students' cognitive learning outcomes at MTs Nur Hadi Muara Jawa. The research employed a research and development (R&D) design using the ADDIE model, consisting of analysis, design, development, implementation, and evaluation stages. The subjects of the study were MTs students selected through purposive sampling. Data were collected using expert validation sheets, student response questionnaires, and cognitive achievement tests administered before and after the implementation of the worksheets. The data were analyzed using descriptive statistics and inferential analysis to measure learning gains. The findings indicate that the PhET-based LKPD are valid, practical, and effective in enhancing students' cognitive performance, particularly in understanding abstract scientific concepts. The integration of interactive simulations encourages active learning, inquiry processes, and conceptual understanding. Therefore, PhET-based student worksheets can serve as an effective instructional material to support digital-based science learning in secondary education.

**Keywords:** Development, PhET, Worksheets, Cognitive, Learning Outcomes.

## INTRODUCTION

The rapid advancement of digital technology has significantly transformed educational practices, particularly in the development of instructional materials that promote active and meaningful learning. In the context of science education, the integration of digital learning resources is increasingly emphasized to enhance students' conceptual understanding and cognitive achievement (Mayer, 2020; OECD, 2021). However, many classrooms, especially in Islamic junior high

schools (Madrasah Tsanawiyah), still rely heavily on conventional teaching methods and printed worksheets that are predominantly procedural and lack interactive elements.

Student Worksheets (Lembar Kerja Peserta Didik/LKPD) play a crucial role in guiding students' learning activities, facilitating inquiry, and reinforcing conceptual understanding (Prastowo, 2019). Ideally, LKPD should encourage students to actively explore concepts, analyze phenomena, and

construct knowledge independently. Nevertheless, previous studies have reported that many LKPD used in schools are limited to mechanical exercises and fail to stimulate higher-order cognitive processes such as analysis, evaluation, and problem-solving (Sari & Wahyudi, 2021; Widodo et al., 2022).

One of the promising digital tools to address this issue is **PhET Interactive Simulations**, developed by the University of Colorado Boulder. PhET simulations provide interactive, inquiry-based learning environments that allow students to visualize abstract scientific concepts through dynamic representations (Perkins et al., 2019). Research has shown that PhET simulations can significantly improve students' conceptual understanding, engagement, and cognitive learning outcomes when appropriately integrated into classroom instruction (Wieman et al., 2020; Finkelstein et al., 2021).

Despite the proven effectiveness of PhET simulations, their integration into structured learning materials such as LKPD remains limited, particularly in madrasah contexts. Teachers often use PhET simulations as supplementary tools without systematic

guidance, which reduces their instructional impact (Putri et al., 2022). Therefore, there is a critical need to develop PhET-based LKPD that align with curriculum objectives and support guided inquiry learning.

At MTs Nur Hadi Muara Jawa, preliminary observations indicated that students' cognitive learning outcomes in science subjects were relatively low, especially in understanding abstract concepts. Learning activities were predominantly teacher-centered, and existing worksheets did not utilize digital simulations. This condition highlights a research gap between the availability of interactive digital tools and their effective integration into instructional materials.

Based on these considerations, this study aims to develop PhET-based student worksheets and examine their effectiveness in improving students' cognitive learning outcomes at MTs Nur Hadi Muara Jawa. The study is expected to contribute to the development of innovative instructional materials and provide empirical evidence for the integration of digital simulations in madrasah science education.

## **.METHODS**

### **2.1 Research Design**

This study employed a **Research and Development (R&D)** approach using the **ADDIE model**, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009). The ADDIE model was selected due to its systematic and flexible framework for developing instructional products and evaluating their effectiveness.

### **2.2 Analysis Stage**

The analysis stage involved identifying learning problems, students' needs, curriculum requirements, and existing instructional materials. Data were collected through classroom observations, interviews with science teachers, and analysis of existing LKPD used at MTs Nur Hadi Muara Jawa. The findings revealed that students experienced difficulties in understanding abstract scientific concepts and required more interactive and inquiry-oriented learning materials.

### **2.3 Design Stage**

At this stage, the structure and content of the PhET-based LKPD were designed. The worksheets were aligned with the national curriculum and learning objectives. Each LKPD consisted of learning objectives, guided inquiry questions, PhET simulation activities, data analysis tasks, and reflection questions aimed at higher-order thinking skills. The

design emphasized student-centered learning and cognitive engagement.

### **2.4 Development Stage**

The LKPD were developed by integrating selected PhET simulations relevant to the learning topics. The draft LKPD were then validated by two experts in science education and one instructional media expert. Validation focused on content accuracy, instructional design, language clarity, and media integration. Revisions were made based on expert feedback to improve the quality of the worksheets.

### **2.5 Implementation Stage**

The implementation was conducted at MTs Nur Hadi Muara Jawa with one class consisting of **30 students** as the research sample. The PhET-based LKPD were used during science lessons over four instructional meetings. Teachers facilitated learning activities while students worked collaboratively using the worksheets and simulations.

### **2.6 Evaluation Stage**

Evaluation was carried out to assess the effectiveness of the developed LKPD. A **pre-test and post-test** design was used to measure students' cognitive learning outcomes. The test items were developed based on Bloom's taxonomy, covering cognitive levels from understanding to analyzing. Data were analyzed using descriptive statistics and

paired-sample t-tests to determine significant differences between pre-test and post-test scores.

## RESULTS AND DISCUSSION

The results of expert validation indicated that the PhET-based LKPD were highly valid in terms of content, instructional design, and media integration. The average validation score was categorized as “very valid,” indicating that the worksheets were suitable for classroom implementation.

The analysis of students’ cognitive learning outcomes showed a significant improvement after the implementation of the PhET-based LKPD. The mean pre-test score was **62.4**, while the mean post-test score increased to **82.7**. The paired-sample t-test revealed a statistically significant difference ( $p < 0.05$ ), indicating that the use of PhET-based LKPD had a positive effect on students’ cognitive achievement.

Additionally, classroom observations showed increased student engagement and active participation during learning activities. Students demonstrated better understanding of concepts, were able to explain phenomena using scientific reasoning, and actively discussed simulation results with peers.

The findings of this study indicate that the PhET-based student worksheets significantly improved students’ cognitive learning outcomes at MTs Nur Hadi Muara

Jawa. The statistically significant increase in post-test scores confirms that integrating interactive simulations into structured learning materials is an effective approach to enhancing students’ conceptual understanding. This result is consistent with previous studies reporting that simulation-based learning environments positively affect students’ cognitive achievement when combined with guided instructional support (Wieman et al., 2020; Cheng et al., 2022).

One of the primary factors contributing to this improvement is the visualization capability of PhET simulations. Science concepts at the junior secondary level often involve abstract processes that are difficult for students to comprehend through verbal explanation alone. PhET simulations enable learners to observe invisible phenomena, manipulate variables, and immediately see the consequences of their actions. According to Mayer’s multimedia learning theory, meaningful learning occurs when learners actively integrate verbal and visual information (Mayer, 2020). The PhET-based LKPD developed in this study facilitated such integration by guiding students to interact with

simulations while responding to structured inquiry questions.

In addition, the guided inquiry design embedded within the LKPD played a crucial role in supporting students' cognitive development. Rather than allowing unguided exploration, the worksheets provided systematic scaffolding through prediction activities, observation tasks, data interpretation, and reflective questions. This approach aligns with constructivist learning theory, which emphasizes that knowledge is actively constructed through interaction with learning environments and guided reflection (Jonassen, 2018). As a result, students were able to build conceptual understanding progressively rather than relying on rote memorization.

The effectiveness of the PhET-based LKPD also supports prior research suggesting that simulations are most impactful when integrated into well-designed instructional materials. Smetana and Bell (2019) argue that simulations alone do not guarantee learning gains unless accompanied by pedagogical structures that guide students' cognitive processes. In this study, the LKPD functioned as a cognitive organizer that directed students' attention to key concepts, supported hypothesis testing, and encouraged analytical thinking. This structured integration transformed PhET simulations from supplementary media into core learning tools.

Furthermore, the results demonstrate that PhET-based LKPD support higher-order cognitive skills, particularly analysis and

reasoning. The assessment instruments were designed based on Bloom's taxonomy, and the improvement in post-test scores indicates that students were able to move beyond basic comprehension toward analytical thinking. Students were required to interpret simulation outcomes, identify patterns, and draw conclusions, which are essential components of scientific reasoning. This finding is in line with Widodo et al. (2022), who reported that inquiry-based digital learning materials effectively enhance higher-order thinking skills.

Classroom observations also revealed increased student engagement during the implementation of the PhET-based LKPD. Students showed enthusiasm, actively participated in discussions, and collaborated with peers to solve problems presented in the worksheets. Engagement is a critical factor in cognitive learning, as motivated learners tend to invest greater effort in understanding complex concepts (OECD, 2021). The interactive nature of PhET simulations, combined with inquiry-oriented tasks, created a learning environment that sustained students' attention and curiosity.

The collaborative learning process facilitated by the LKPD further contributed to improved learning outcomes. Students worked in small groups to explore simulations, compare findings, and discuss interpretations. Social interaction allowed learners to articulate their understanding, confront misconceptions, and refine their ideas through dialogue. From a social constructivist perspective, learning is

enhanced through interaction and shared meaning-making (Vygotsky, as cited in Jonassen, 2018). This study provides empirical evidence that digital-assisted collaborative learning can effectively support cognitive development in science education.

In the context of madrasah education, the successful implementation of PhET-based LKPD carries important implications. Madrasah Tsanawiyah often face challenges related to limited learning resources and reliance on traditional teaching methods. However, this study demonstrates that freely accessible digital tools such as PhET simulations can be effectively utilized when supported by appropriate instructional design. This finding aligns with Putri et al. (2022), who emphasized that digital innovation in schools depends more on pedagogical planning than on advanced technological infrastructure.

The role of teachers also shifted during the implementation of the PhET-based LKPD. Teachers acted primarily as facilitators, guiding inquiry, encouraging discussion, and providing feedback rather than delivering direct explanations. This instructional role supports student-centered learning and aligns with contemporary educational paradigms that emphasize active learning and learner autonomy (Branch, 2009). Teacher facilitation was essential in helping students interpret simulation results correctly and connect them with scientific principles.

Despite the positive outcomes, several limitations should be considered. First, the

study involved a relatively small sample from a single madrasah, which may limit the generalizability of the findings. Second, the duration of implementation was limited to specific topics, and long-term retention of cognitive gains was not examined. Future research should involve larger and more diverse samples, extend the implementation period, and explore the long-term effects of PhET-based LKPD on learning outcomes.

Another limitation concerns the focus of assessment, which primarily measured cognitive achievement through test scores. While cognitive improvement is a critical indicator of learning effectiveness, future studies should also examine affective and metacognitive variables such as learning motivation, self-regulated learning, and critical thinking skills. Qualitative data from interviews or reflective journals could provide deeper insights into students' learning experiences when using PhET-based worksheets.

Nevertheless, the findings of this study contribute significantly to the literature on simulation-based learning and instructional material development. The PhET-based LKPD demonstrate that effective learning innovation lies in the thoughtful integration of digital tools with sound pedagogical principles. Well-designed worksheets that guide inquiry, reflection, and analysis can maximize the educational potential of interactive simulations (Perkins et al., 2019; Wieman et al., 2020).

In summary, this discussion highlights that PhET-based student worksheets effectively

enhance students' cognitive learning outcomes through visualization, guided inquiry, engagement, and collaboration. The study reinforces the importance of aligning digital simulations with instructional design to support

meaningful learning. These findings provide practical implications for teachers, curriculum developers, and policymakers seeking to improve the quality of science education, particularly in madrasah contexts.

## CONCLUSIONS

This study concludes that the development of PhET-based student worksheets is effective in improving students' cognitive learning outcomes at MTs Nur Hadi Muara Jawa. The integration of interactive simulations into structured worksheets enhances students' conceptual understanding, engagement, and higher-order thinking skills.

The PhET-based LKPD developed through the ADDIE model proved to be valid, practical, and effective for classroom implementation. These findings highlight the importance of integrating digital simulations into instructional materials to support student-centered and inquiry-based learning.

Future research is recommended to involve larger samples, apply the worksheets to different topics and educational levels, and examine additional variables such as learning motivation and critical thinking skills. The broader implementation of PhET-based LKPD is expected to contribute significantly to the improvement of science education quality in madrasah contexts.

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