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The Influence of the Use of PhET Simulation and Online Practical Flexibility on Physics Learning Outcomes of Students at MTs Baiturrahman NW Pemepek in the Digital Era

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Abstract— *This study aims to describe the initial stages of a study on the effect of the use of PhET simulation media and the flexibility of online practicums on physics learning outcomes of students at MTs Baiturrahman NW Pemepek in the digital era. The background of this study is based on the need to integrate simulation-based learning technology into the physics teaching and learning process to make it more interactive and effective. This study uses a quantitative approach with a quasi-experimental method involving two groups of students as research subjects. This article specifically reports the initial or baseline phase of the study, which focuses on instrument development and the identification of students' prior knowledge before the implementation of the treatment. In this phase, research activities were directed at developing valid and reliable instruments and collecting initial data through five multiple-choice questions to measure students' initial abilities before being given treatment using PhET simulation media. The data obtained were analyzed descriptively to describe students' initial level of understanding of physics material. Preliminary results show variations in the level of concept mastery among students, which serve as baseline data for the next stage of the study involving the implementation of PhET simulations and flexible online practicums. These findings provide an empirical foundation for refining the research design and optimizing digital learning strategies in the madrasah environment.*

Keywords— PhET simulation media, Physics learning outcomes, Initial data collection.
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1. Introduction

The digital era has transformed the landscape of education, including physics learning, where students require interactive tools to understand abstract concepts such as motion, energy, and electricity [1]. The main challenge in physics education lies in students' difficulty in visualizing physical phenomena that cannot be directly observed, thus necessitating the use of effective simulation media [2]. PhET (Physics Education Technology) simulations have been proven to enhance students' conceptual understanding through interactive exploration [3]. In addition, the flexibility of online practicums allows students to learn according to their own schedules, which is essential in today's digital era [4].

Despite these developments, a key problem in madrasah-based physics education is the limited availability of validated instruments capable of accurately measuring students' conceptual understanding within digital learning environments. In many madrasah contexts, including MTs Baiturrahman NW Pemepek, the integration of simulation media and online practicums has not been systematically accompanied by the development of standardized assessment tools. Therefore, this study aims to develop and validate a physics learning outcome test instrument as a foundational step for examining the influence of PhET simulation use and the flexibility of online practicums on students' learning outcomes. The significance of this study lies in providing a valid and reliable measurement tool that supports evidence-based implementation of digital learning strategies in madrasah-based physics education.

This study aims to develop a physics learning outcome test instrument as an initial step in analyzing the influence of PhET

simulation use and the flexibility of online practicums on students' physics learning outcomes at MTs Baiturrahman NW Pemepek. The research background is based on the need for valid and reliable instruments to measure students' conceptual understanding in the context of digital technology, where PhET simulations provide a safe and interactive virtual laboratory experience, while flexible online practicums enable access anytime and anywhere [5]. This is consistent with findings that simulation media can enhance students' motivation and learning outcomes [6].

Previous studies have shown that PhET simulations are effective in improving students' understanding of physics concepts [7], [8]. Furthermore, flexibility in online practicums supports independent and adaptive learning [9]. However, the development of appropriate test instruments to measure these impacts has not been widely explored in the context of junior secondary schools in Indonesia [10]. Therefore, this research is important to provide a valid instrument as a foundation for full-scale experimental studies.

2. Method

This research was conducted in the 2025/2026 academic year, specifically in September during the odd semester at MTs Baiturrahman NW Pemepek. Conceptually, the study is part of a broader quasi-experimental research plan designed to examine the effect of PhET simulation media and the flexibility of online practicums on students' physics learning outcomes. However, the present article reports only the initial phase of the research, which focuses on baseline data collection and instrument preparation. Therefore, although the overall project adopts a quasi-experimental framework, this stage employs a quantitative descriptive design to obtain an initial overview of students' physics learning outcomes prior to the implementation of treatment.

The population of the study included students from grades VII to IX. Nevertheless, data collection was conducted in Grade VIII. The selection of Grade VIII students was based on curriculum relevance and cognitive readiness, as the physics topics assessed in the instrument—such as speed, acceleration, force, and distance—are formally taught at this level according to the junior secondary curriculum. In addition, Grade VIII students are considered to have sufficient conceptual foundation and abstract reasoning ability to respond meaningfully to the test items and to participate in subsequent simulation-based learning interventions. A total of 21 students were selected using purposive sampling, with the assumption that they had already received instruction related to the tested material. The research site was chosen because the madrasah has begun implementing limited digital technology-based learning and shows potential for further development of PhET simulation-based instruction.

The research instruments consisted of a questionnaire and a physics learning outcome test. The questionnaire covered two aspects: (1) the use of PhET simulations and (2) the flexibility of online practicums. It was constructed using a five-point Likert scale ranging from "Strongly Disagree" (1) to "Strongly Agree" (5). In this initial phase, the questionnaire data function as supporting information to describe students' perceptions of digital-based learning and will be analyzed more comprehensively in subsequent stages of the quasi-experimental study. The physics learning outcome test consisted of five multiple-choice questions designed to measure students' understanding of basic physics concepts. Each item had one correct answer, and scores were converted to a scale of 0–100. Regarding instrument quality, this phase focused on initial development; content validity through expert judgment and reliability testing are planned to be conducted and reported in the next stage of the research to ensure that the instrument meets established psychometric standards.

Data were collected through the administration of the learning outcome test, and the results were tabulated for each student. The data were analyzed using descriptive statistics, including the mean score, highest score, lowest score, and percentage of learning mastery. The mean score was calculated using the standard statistical formula:

$$\bar{X} = \frac{\sum X}{N}$$

where $\bar{X}$ represents the mean score, $\sum X$ is the total of all individual student scores, and N is the number of students. This descriptive analysis aims to provide a clear baseline profile of students' learning achievement before the implementation of PhET simulation-based instruction and flexible online practicums in the subsequent experimental phase.

3. Result and Discussion

The results of the baseline physics learning achievement test reveal that students' conceptual mastery of fundamental topics remains considerably below the expected standard. From a total of 21 Grade VIII students, the mean score obtained was 37.14 on a scale of 0–100, indicating that, on average, students answered fewer than half of the items correctly. The highest score achieved was 80, while the lowest score was 0, demonstrating a wide variation in individual performance. However, despite this variation, only one student met the established minimum mastery criterion, resulting in a mastery percentage of 4.76%. This extremely low level of mastery suggests that the majority of students have not yet developed an adequate understanding of essential physics concepts, particularly those related to speed, acceleration, force, and distance. To strengthen data presentation and analytical clarity, these findings should be supported by a detailed descriptive statistics table and a graphical representation—such as a bar chart showing score distribution or mastery levels—so that patterns of performance and the concentration of low scores can be more clearly visualized.

The low average score and minimal mastery level indicate that students face difficulties in interpreting and applying conceptual knowledge to problem-solving situations. Many students appear to rely on memorization rather than conceptual reasoning, which limits their ability to analyze relationships between physical variables. From a constructivist perspective, meaningful learning occurs when students actively construct knowledge through interaction and cognitive engagement. The current findings suggest that traditional instructional approaches, which tend to emphasize verbal explanation and textbook-based exercises, may not sufficiently facilitate the visualization of abstract physical phenomena. Concepts such as acceleration or force interactions require dynamic representation to help students connect mathematical expressions with observable phenomena.

In this context, interactive digital simulations offer strong pedagogical potential. Simulation-based environments enable learners to manipulate variables, observe cause-and-effect relationships, and receive immediate visual feedback, thereby supporting inquiry-based and experiential learning processes. Such environments align with cognitive theory, which emphasizes the importance of dual coding (verbal and visual representation) in strengthening conceptual understanding. Furthermore, the integration of flexible online practicum activities supports principles of self-regulated learning by allowing students to revisit materials, adjust learning pace, and engage in repeated experimentation without the constraints of time and physical laboratory limitations. This flexibility is particularly relevant in the madrasah context, where access to complete laboratory facilities may be limited.

Although the present study reports only the baseline phase without direct implementation of simulation-based instruction, the results carry significant implications. The substantial gap between students' current achievement and expected mastery levels highlights the urgent need for instructional innovation in madrasah-based physics education. These baseline data provide empirical justification for proceeding to the next phase of the broader quasi-experimental research design, in which PhET simulation media and flexible online practicum models will be systematically implemented and evaluated. The comparison between baseline and post-intervention outcomes will allow for a clearer assessment of the effectiveness of digital-based learning strategies in improving students' conceptual mastery and overall learning achievement.

4. Conclusion

The findings of this baseline study show that students' physics learning outcomes are still low, with a mean score of 37.14 and a mastery rate of 4.76%. This indicates that most students have not yet achieved adequate understanding of fundamental physics concepts, suggesting that conventional instructional approaches may be insufficient to support conceptual learning. Pedagogically, these results highlight the need to integrate interactive digital tools, such as PhET simulations, and flexible online practicum activities to enhance visualization, engagement, and conceptual understanding. For future research, a quasi-experimental design with pretest–posttest comparison is recommended to examine the effectiveness of simulation-based learning more rigorously. Thus, this study provides an important baseline for subsequent experimental implementation in madrasah-based physics education.

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