# Development of Inquiry-Based Worksheets Assisted by PhET Simulations to Improve Students' Concept Mastery

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***Abstract*** *- Inquiry-based worksheets assisted by PhET simulations were developed to enhance students' concept mastery. Students' concept mastery is a variable that often becomes the focus in evaluating the effectiveness of learning aids. The purpose of this research is to develop inquiry-based worksheets assisted by PhET simulations to improve students' concept mastery. This research is a research and development (R&D) type, using the 4D development model (Define, Design, Develop, Disseminate), which in this study only involves three main stages: definition, design, and development. Data collection techniques include validation sheets, student response questionnaires, and concept mastery test instruments. The analysis results show that the worksheets are feasible with an average percentage of 75%. The student response questionnaire results show 83%, categorized as very feasible. The concept mastery test results show 80%, categorized as feasible. Thus, it can be concluded that the inquiry-based worksheets assisted by PhET simulations that were designed and developed are feasible and effective in improving students' concept mastery. This research provides an important contribution to the development of innovative and effective learning aids in the field of education.*

***Keywords****: Development; Student Worksheet, Inquiry, PhET Simulation, Concept Mastery*

## INTRODUCTION

In the 21st century, education continues to advance and develop, with various efforts being made to improve its quality. To enhance the quality of education, innovation and development in teaching and learning are essential (Ritonga, 2022). By implementing innovation and development in education, we can ensure that education provides optimal benefits for human resource development (Herlina & Hadiyanti, 2021). One subject that requires development and innovation in its teaching is physics.

Physics is one of the subjects that is difficult for students to understand and requires a deep understanding of concepts (Puri, 2023). In physics learning at school, students are expected not only to master the concepts of physics derived from theory, but until now, physics instruction still relies on textbooks as the sole teaching material. One alternative to address this issue is by improving the physics learning system through the development of teaching materials (Herayanti, 2021). One type of teaching material that is frequently used in the learning process is student worksheets. Student worksheets are a suitable alternative for student learning. According to Yusuf (2021), the development of student worksheets (LKS) is something that can support the teaching and learning process in education.

In teaching, it is also necessary to use the right teaching model to encourage students to actively engage in discovering concepts. One such approach is inquiry-based activities. According to Nurwahid (2021), the inquiry-based learning model is a model whose sequence of activities emphasizes critical and analytical thinking processes to find and discover answers to questions or problems independently. Inquiry-based learning, which focuses on discussion and experimentation, requires interactive media in the learning process.

The use of technology in education has become increasingly important in this digital era. One example is the PhET simulations developed by the University of Colorado Boulder. This tool has proven effective in helping students understand complex physics concepts through interactive simulations (Widyastuti, 2024). PhET provides various simulations that allow students to explore physical phenomena visually and interactively, which can help improve understanding and engagement in learning (Perkins et al., 2021). Additionally, research by Narulita (2024) shows that the use of PhET simulations can increase student motivation and provide a more in-depth and meaningful learning experience.

In addition to its effectiveness in improving concept mastery, the integration of PhET simulations in inquiry-based worksheets also supports a more modern and adaptive learning approach. According to Sugiyanto (2022), inquiry-based learning approaches supported by interactive media such as PhET can facilitate students in conducting virtual experiments that may be difficult to perform in school laboratories due to limitations in tools and materials. Therefore, the use of PhET not only helps explain abstract concepts but also enriches the student learning experience through safer and more controlled explorations and experiments (Herlina & Hadiyanti, 2021).

Besides PhET simulations, the use of digital technology in education also includes other learning applications and platforms that can enhance student engagement. According to Yulianti (2022), the use of technology-based learning applications can provide a more engaging and interactive learning experience, making it easier for students to understand difficult material. The implementation of this technology also enables teachers to monitor student progress more effectively and provide constructive feedback (Ramdani, 2023). Thus, technology not only facilitates learning but also strengthens the relationship between teachers and students.

The inquiry-based approach is also in line with the Merdeka Belajar curriculum introduced by the Indonesian Ministry of Education and Culture. This curriculum emphasizes student-centered learning, where students are encouraged to become active researchers in their learning process (Suryani, 2021). According to research by Lestari (2022), this approach can enhance students' critical and creative thinking abilities and encourage them to become more independent in their learning. Therefore, integrating inquiry-based worksheets with PhET simulations aligns with the goals of the Merdeka Belajar curriculum to create a more dynamic and participatory learning environment.

Previous studies also show that the use of inquiry-based worksheets can improve students' learning outcomes. For instance, research by Pratama (2023) found that students using inquiry-based worksheets showed significant improvements in concept mastery compared to students using conventional teaching methods. This indicates that inquiry-based worksheets are not only effective in improving concept mastery but also help students develop critical and analytical thinking skills. Therefore, the development of inquiry-based worksheets assisted by PhET simulations is expected to provide significant benefits in the physics learning process in schools.

Based on the brief overview above, the author is interested in developing inquiry-based worksheets assisted by PhET simulations to enhance students' concept mastery.

## RESEARCH METHODS

This research uses the 4D (Four D Models) development model, which consists of four stages: Define, Design, Develop, and Disseminate (Gogahu, 2020). The Define stage is conducted to identify the existing problems in the learning process. Therefore, the focus of this research is on the Design stage, which involves designing inquiry-based worksheets assisted by PhET simulations. The Develop stage includes the development of inquiry-based worksheets assisted by PhET simulations, product validation by expert validators, product revisions, and limited trials.

This research was conducted at SMAN 8 Mataram, during the second semester of the 2023/2024 academic year. The subjects of this study were 22 students from class XI MIPA. The data collection instruments used were validation sheets given to expert validators, student response questionnaires, and concept mastery test sheets. Data analysis was performed using a feasibility analysis of the worksheets using a Likert scale. Quantitative data were obtained from answer choices using the Likert scale, as shown in the following table.

**Table 1.** Category in Likert Scale

| Score | Description |
|---|---|
| 5 | Excellent/Strongly Agree |
| 4 | Good/Agree |
| 3 | Fairly Good |
| 2 | Not Good/Disagree |
| 1 | Strongly Disagree |

Source: (Sugiyono in Purwanti, 2021)

According to Arifin in Purwanti (2021), the formula for calculating the percentage of results can be determined using the following formula:

$$\text{Percentage (P)} = \frac{\sum R}{N} \times 100\% \quad (1)$$

Description:
P = percentage of student response
$\sum R$ = amount of validator's answer
N = Total Score/Ideal

The product feasibility categories are based on the following criteria.

**Table 2.** Product Feasibility Criteria

| Score | Criteria |
|---|---|
| 0% - 20% | Very Not Feasible |
| 21% - 40% | Not Feasible |
| 41% - 60% | Fairly Feasible |
| 61% - 80% | Feasible |
| 81% - 100% | Very Feasible |

Source: (Arikunto in Oktavia, 2020)

The practicality of the worksheets (LKS) is obtained from a student response questionnaire containing 15 questions with answer choices: strongly agree (SS), agree (S), neutral (R), disagree (TS), and strongly disagree (STS). These responses are analyzed using the Likert scale, and the practicality percentage according to Gulo (2022) can be calculated using the following formula:

$$P = \frac{\sum x}{\sum xi} \times 100\% \quad (2)$$

Description:
$P$ = percentage of students or teachers (%)
$\sum x$ = Total score of respondents
$\sum xi$ = Total ideal score

The practicality percentage result is then interpreted based on the following practicality criteria.

**Table 3.** Percentage Category Criteria

| Score Range | Description Qualification |
|---|---|
| $80\% < P \leq 100\%$ | Very practical |
| $60\% < P \leq 80\%$ | Practical |
| $40\% < P \leq 60\%$ | Moderately Practical |
| $20\% < P \leq 40\%$ | Not practical |
| $0\% < P \leq 20\%$ | Very impractical |

Source: (Gulo, 2022)

Analysis of effectiveness based on concept mastery test scores. The effectiveness analysis is derived from the concept mastery test scores, evaluated based on the percentage of classical mastery and referring to the Minimum Competency Criteria (KKM) established by the school. The score categories adhere to the Minimum

Competency Criteria (KKM) of SMAN 8 Mataram, which are as follows: scores ≥78 (categorized as "mastered") and scores ≤78 (categorized as "not yet mastered"). According to Astuti (2018), the percentage of students' classical learning mastery can be calculated using the following formula.

$$KB = \frac{NS}{N} \times 100\% \quad (3)$$

Description:
KB = Percentage of learning mastery
NS = Number of students achieving a score ≥78
N = Total number of students

## RESULTS AND DISCUSSION

**Design Stage:** This stage involves designing student worksheets (LKS) for the topic of mechanical wave characteristics. The product design consists of student worksheets that guide students through the inquiry process using PhET simulations. The worksheets are developed as printed materials in the Indonesian language, aligning with the mechanical wave characteristics content based on the 2013 curriculum.

A well-designed worksheet must consider various aspects, such as learning objectives, resource availability, and student needs (Trianto, 2013). In the context of physics learning, effective worksheets should facilitate concept mastery through interactive and meaningful activities. PhET simulations, as visual aids, help students connect theoretical concepts with real-world phenomena through virtual experiments (Perkins et al., 2021). Worksheets that integrate PhET not only provide concept visualization but also encourage students to think critically and analytically in solving given problems (Widyastuti, 2024).

**Development Stage:** This stage involves developing the worksheets, including validation by two expert validators—media experts and subject matter experts—to obtain assessment scores and feedback or suggestions. Product revisions are made based on the feedback from the validators. Validation by media experts ensures that the developed worksheets are visually appealing and easy for students to understand (Sadiman, 2011). Meanwhile, validation by subject matter experts ensures that the content presented in the worksheets is accurate and aligns with the applicable curriculum standards (Prastowo, 2015).

The rigorous validation process is crucial to ensuring the quality of the worksheets (LKS) before their implementation in learning. According to research by Hermawan (2019), worksheets validated by experts tend to be more effective in improving student learning outcomes compared to those that are not validated. Moreover, feedback from validators plays a vital role in refining the final product to better align with student needs and learning objectives (Hake, 1999).

In this study, the results of the validation analysis for the worksheets, as obtained from media and subject matter expert validators, indicate that the worksheets are suitable for use with minor improvements, as shown in Table 4 below.

**Table 4.** The Result of Worksheet Validation

| | Validation Score (%) | Criteria |
|---|---|---|
| Validator 1 | 70% | Feasible |
| Validator 2 | 80% | Feasible |
| **Average** | **75%** | **Feasible** |

Based on the validation results conducted by both experts on the worksheets (LKS), the instrument was deemed valid and categorized as feasible. Validity is a crucial aspect of instructional material development because it ensures that the content aligns with learning objectives and established

standards (Nieveen, 2013). The validity assessment by media and subject matter experts ensures that the worksheets is not only academically accurate but also engaging and easy for students to use (Plomp & Nieveen, 2010). According to Hermawan (2019), high validity in teaching materials boosts teacher confidence in using them and positively influences student learning outcomes.

The practicality of the worksheet was determined through a student response questionnaire analyzed using a Likert scale. Student response questionnaires are essential tools for evaluating the practicality and effectiveness of teaching materials (Cohen, Manion, & Morrison, 2018). Based on 15 statements provided to students, the average percentage of student responses was 78%, categorized as practical. This practicality indicates that students found the worksheets comfortable and helpful, which positively impacted their learning process (Kemp & Dayton, 1985). Research by Prastowo (2015) also shows that practical worksheets facilitates active student engagement in the learning process, enhancing their motivation and understanding of the material studied.

This analysis is consistent with other studies demonstrating that using inquiry-based worksheets and interactive media such as PhET improves the practicality and effectiveness of learning (Yulianti, 2022). The PhET simulations integrated into the worksheets allow students to conduct safe and engaging virtual experiments, helping them better understand physics concepts (Perkins et al., 2021). Therefore, the developed worksheets is not only valid in terms of content but also practical and effective in improving the quality of physics learning in schools.

The effectiveness of the worksheets was measured using a concept mastery test conducted after the completion of learning activities using inquiry-based worksheets assisted by PhET simulations. The results of the students' concept mastery test are presented in the following table.

**Table 5.** Concept Mastery Test Results

| Aspect | Value |
|---|---|
| Lowest Score | 75 |
| Highest Score | 96 |
| Average Score | 82 |
| Number of Students Passed | 21 |
| Number of Students Not Passed | 1 |
| Class Average Percentage | 95% |

Based on the concept understanding test results, the student mastery percentage is 95%, categorized as "very good." This aligns with the findings of Hulu (2023), which revealed that inquiry-based learning can improve students' concept mastery. The inquiry-based approach encourages students to be more active in the learning process, ask questions, and seek answers through exploration and experimentation (Hake, 1999). This learning model is effective in enhancing concept mastery as it allows students to experience and comprehend concepts directly (Bybee et al., 2006).

Research by Suparman (2020) also indicates that students who learn using the inquiry model have a better concept mastery compared to those who learn through conventional methods. This is because inquiry-based learning places students at the center of the learning process, enabling them to develop critical and analytical thinking more deeply (Suparman, 2020). Therefore, the inquiry-based worksheets (LKS) developed in this study have proven effective in improving students' concept mastery abilities.

Moreover, Rahmawati (2021) found that using inquiry-based worksheets equipped with interactive media such as PhET simulations can further enhance students' concept mastery. PhET simulations

provide clear visualizations and allow students to conduct virtual experiments, which help them grasp abstract concepts more effectively (Perkins et al., 2021). Hence, the developed worksheets can be considered effective in terms of improving students' concept mastery, consistent with previous findings that emphasize the benefits of inquiry-based learning and interactive media.

## CONCLUSION

Based on the research results and discussion, the inquiry-based worksheets assisted by PhET simulations designed and developed is feasible, practical, and effective in improving students' concept mastery.

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