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Utilizing Smartphone Sensors for Simple Harmonic Motion on a Double Surfboard

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ABSTRACT

The aim of this research is to develop a simple harmonic motion experiment guide based on smartphone sensors for use on a double surfboard sports vehicle that is valid, practical, and effective. This study applies the Research and Development (R&D) method using the ADDIE development model, which includes five stages: (1) Analysis, (2) Design, (3) Development, (4) Implementation, and (5) Evaluation. The results show that the accelerometer sensor on a smartphone can effectively measure the period value in the double surfboard sports experiment. The experimental guidebook developed in this study demonstrates high validity, with an average score of 3.53 (88.33%) from media experts and 3.43 (85.75%) from material experts. Practicality testing, based on student responses, resulted in an average score of 3.48 (87.16%), indicating that the guide is highly suitable for use in the learning process. Furthermore, effectiveness testing through pretest and posttest assessments of 17 students showed an improvement in student understanding, with an n-gain value of 0.45, categorized as "medium." Consequently, this guidebook serves as an effective learning tool for enhancing students' comprehension of simple harmonic motion concepts.

Keywords :smartphone sensor; physics experiment; guidebook experiment; simple harmonic motion.

I. INTRODUCTION

Physics is a foundational science that underpins the development of science and technology [1]. Physics education is designed to emphasize scientific values, which are essential in experimental activities that students need to understand and perform [2], [3]. However, physics learning often remains confined to the classroom rather than taking place in laboratories, focusing mainly on curriculum-based content delivery [4.]. As a result, students frequently receive theoretical explanations without practical experience, even though understanding physics concepts requires direct observation and experimentation [5], [6], [7].

Physics experimental facilities and laboratory equipment in colleges, especially in 3T areas, are very limited. This lack of resources makes it challenging for students to gain practical experience and conduct physics experiments [8], [9]. Some colleges lack essential experimental tools for physics, such as acceleration and light sensors. Physics labs are also limited, making it difficult for students to access and use them independently.

Simple harmonic motion is one of the topics that can be explored through physics experiments. This topic involves measuring the swing period, determining the acceleration due to gravity, and examining relationships between variables, such as rope length and deviation. However, in the first-semester Department of Natural Science Education Universitas Pendidikan Muhammadiyah Sorong, experiments related to this topic are still limited. Much of the material is taught conceptually in class, making it challenging for students to draw conclusions about variable relationships in simple harmonic motion. This approach often leads to boredom and fatigue, reducing students' interest in studying physics at the college level.

To support physics learning through experimental methods, technology can be leveraged by using smartphone sensors with the Phyphox application [10]. Developed by Aachen University, this application enables scientific experiments directly on smartphones [11]. Phyphox utilizes the sensors already installed on smartphones, so no additional measuring instruments are needed. In physics learning, smartphones can serve as effective measuring tools. Modern smartphones are highly advanced, containing sensors that receive data from the surrounding environment [12]. These devices typically include a barometer, light sensor, magnetometer, gyroscope, accelerometer, and microphone. With such capabilities, smartphones can demonstrate the magnetic spectrum in real-time, gather data, measure distance through echo, and analyze the frequency and period of an oscillating spring [13], [14].

Given the problems and potential described above, the researchers are interested in developing a physics experiment guide on simple harmonic motion using smartphone sensors on a double surfboard sports vehicle. This study aims to create a valid, practical, and effective experimental guide for physics. The urgency of this research lies in providing a resource that enhances students' understanding and practical experience with physics experiments, particularly on simple harmonic motion. Additionally, this guide can serve as an alternative solution to the limited laboratory equipment at universities and connect students with natural phenomena around them.

Previous studies have explored smartphone sensor-based experimental guides for collision topics using the ADDIE development model, showing expert-validated results and positive user feedback on practicality [15]. Another study developed physics experiment guides in playgrounds, using video analysis on mechanics topics with the 4D development model, also yielding expert-validated and user-approved practical outcomes [16]. The novelty of this research lies in combining the strengths of both previous studies—using smartphone sensors and the ADDIE development model. Additionally, this study focuses on a new physics topic, simple harmonic motion, using a double surfboard sports vehicle as experimental media, and includes product effectiveness by conducting an n-gain analysis on pretest and posttest results.

II. METHOD

This study employs a research and development (R&D) approach to produce and assess the feasibility of a product [17]. The product developed is a guidebook for simple harmonic motion experiments using smartphone sensors, designed for conducting physics experiments on a double surfboard sports vehicle. The development model used in this study is ADDIE (Analysis, Design, Development, Implementation, and Evaluation), comprising five stages: analysis, design, development, implementation, and evaluation [18]. The ADDIE model is illustrated in Figure 1.

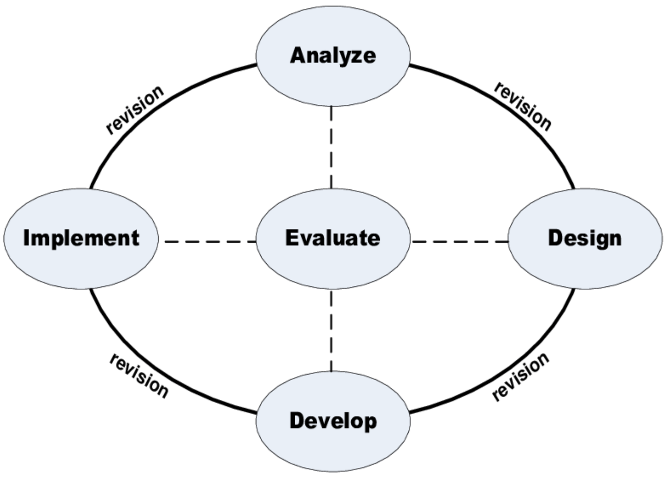

Figure 1. The ADDIE Model in the R&D Method

Using the ADDIE model, the development process begins with the analysis stage, which involves surveying students' needs and conducting initial trials of simple harmonic motion experiments with smartphone sensors on a double surfboard sports vehicle. In the design stage, the framework and content of the experimental guidebook were outlined. During the development stage, the guidebook was further refined and subjected to a validity test by two material experts and two media experts. At the implementation stage, a practicality test was conducted through a user response survey among students. Additionally, effectiveness testing was carried out in this stage by administering a pretest and posttest to the students. The evaluation stage took place throughout each phase, incorporating expert feedback and user responses to make necessary revisions.

Data processing in this study included both qualitative and quantitative methods. Qualitative data were derived from feedback and comments from validators and student responses, which guided revisions of the experimental guide. For quantitative data, assessments were conducted based on questionnaire responses, rated by experts and students. The average score from the questionnaire responses was calculated using the following formula:

$$\bar{x} = \frac{\sum x}{n} \quad (1)$$

where $\bar{x}$ represents the average score, $\sum x$ is the total score, and n is the number of questions.

The average score is then converted into a percentage using the following formula:

$$P = \frac{\bar{x}}{N} \times 100 \quad (2)$$

where P is the percentage, $\bar{x}$ is the average score, and N is the maximum score that can be achieved. The obtained percentage is then converted into a qualitative assessment based on the criteria in Table 1.

Table 1. Feasibility Level Criteria

Interval (P)	Feasibility Level Criteria
80% - 100%	Very feasible / Very good / Strongly agree
66% - 79%	Feasible / Good / Agree
56% - 65%	Less feasible / Less good / Less agree
0 - 55%	Not feasible / Not good / Disagree

This research is considered feasible if the percentage falls within the intervals of 80% - 100%, categorized as "very feasible," or 66% - 79%, categorized as "feasible."

To calculate the effectiveness of the product, the n-gain formula is used. The calculation for the effectiveness of the smartphone sensor-based physics experiment guide using the sports vehicle is:

$$g = \frac{posttest\ value - pretest\ value}{maximum\ value - pretest\ value} \quad (3)$$

The n-gain value is interpreted based on the following criteria: High, if g≥0.7; Moderate, if 0.7>g>0.30; Low, if g≤0 [19].

III. RESULTS AND DISCUSSION

The student needs survey revealed that experimental activities for science students at Muhammadiyah University of Education Sorong were not optimal during the learning process. Therefore, there is a need for a product that students can easily use to carry out practicums. This product is a smartphone sensor-based Physics experiment guide, supported by the Phypox application, and used with the double surfboard sports ride. The material covered in this experiment is simple harmonic motion, focusing on calculating the swing period. The double surfboard sports ride and data collection using a smartphone are shown in Figure 2 below:

Figure 2. Smartphone placed on a double surfboard sports vehicle

During the experimental trial of the double surfboard game, the period of acceleration generated by the accelerometer sensor on the z-axis was recorded. The data produced by the Phypox application is presented in the form of a graph showing the relationship between acceleration (a in m/s) and time (t in seconds), as shown in Figure 3.

Figure 3. Smartphone sensor data results showing oscillation period

Based on the previous analysis, the researcher designed the framework for the experimental guide as a procedure for conducting the experiments. The guidebook is systematically organized with detailed instructions and images to help students conduct the experiments more easily. The structure of the guidebook includes: 1) Cover; 2) Foreword; 3) Table of Contents; 4) Introduction; 5) Literature Review: Smartphone Sensors and Simple Harmonic Motion; 6) Experimental Objectives; 7) Tools and Materials; 8) Experimental Procedures; 9) Data Collection; 10) Data Analysis; 11) Conclusion; 12) Questions; and 13) Bibliography.

In the third stage, development, the experimental guidebook was arranged according to the framework design from the previous stage. The result of this development stage is the smartphone sensor-based Physics experiment guidebook, as shown in Figure 4.

Figure 4. The compiled guidebook

After compiling the guidebook, the product's validity was evaluated by two subject matter experts and two media experts using a questionnaire with 15 questions across three assessment indicators. The validation results from the media experts are shown in Table 2 below:

Table 2. Media Expert Validation Results

Assessment Indicator	Score	Percentage	Conclusion
Visual design	3.5	87%	Very Feasible
Ease of use	3.5	87%	Very Feasible
Instruction accuracy	3.6	91%	Very Feasible
Average	3.53	88.33%	Very Feasible

Based on the data in Table 2, the average score from the two media experts was 3.53, which corresponds to a percentage of 88.33%. This result indicates that the guidebook product is considered very feasible for use from a media perspective.

Following this, a validity test was conducted to evaluate the content quality by two material experts, using a questionnaire with 15 questions across three assessment indicators. The validation results from the material experts are presented in Table 3 below:

Table 3. Validation Results from Material Experts

Assessment Indicator	Score	Percentage	Conclusion
Content suitability with curriculum	3	77%	Very Feasible
Material depth	4	100%	Very Feasible
Relevance to daily life	3.3	88%	Very Feasible
Average	3.43	85.75%	Very Feasible

Based on the table above, the average score from the two material experts was 3.43, equating to 85.75%. This indicates that the guidebook product is highly suitable for use from a content perspective.

Combining the assessments of media and material experts, it can be concluded that the developed product is indeed suitable for educational use. Additionally, expert suggestions were incorporated to enhance the guidebook, as shown in Table 4 below:

Table 4. Expert Suggestions for Product Improvement

No.	Expert Suggestions	Improvement
1	Improve the instructions by providing a more detailed explanation of the experimental steps, including visuals such as pictures or diagrams to facilitate student understanding.	Revised as per suggestions
2	Ensure that the experiment guide includes clear information on integrating smartphone sensors into physics experiments, explaining relevant application features and sensor usage.	Revised as per suggestions
3	Add interactive elements such as reflection questions or challenges at the end of the experiment to foster critical thinking and deepen concept understanding.	Revised as per suggestions

In the fourth stage, the implementation phase, a practicality test was conducted by gathering student responses on the developed guidebook. The results from 10 students, based on 15 questions in three assessment indicators, are shown in Table 5:

Table 5. Student Response Test Results

Assessment Indicator	Score	Percentage	Conclusion
Ease of Understanding	3.34	83.5%	Very Good
Experiment Implementation	3.45	86.25%	Very Good
Learning Benefits	3.67	91.75%	Very Good
Average	3.48	87.16%	Very Good

The table above shows an average score of 3.48, equating to an 87.16% practicality rating, suggesting the guidebook is very effective for student use.

At this stage, an effectiveness test was also conducted to measure students' understanding of simple harmonic motion, before and after using the practicum guidebook. This test involved 17 first-semester Science Education students enrolled in a Basic Physics course. The experiment was conducted at Alun-Alun Aimas, Sorong Regency, using the double surfboard sports facility, as illustrated in Figure 5.

Figure 5. Simple Harmonic Motion Experiment on the Double Surfboard Facility

The pretest and posttest results from the practical test on 17 students are shown in **Table 6**:

Table 6. N-Gain Test Results

	Pretest	Postest	N-Gain Score	N-Gain Score (%)
Average	50.01	72.55	0.45	45.1%

The table indicates an improvement in average scores from pretest to posttest. The effectiveness of the guidebook, as measured by an n-gain value of 0.45, falls within the "moderate" category. This suggests that the experimental guidebook has a moderate level of effectiveness in enhancing students' understanding of simple harmonic motion.

In conclusion, this study successfully developed a smartphone sensor-based physics experiment guidebook on simple harmonic motion that is valid, practical, and effective. Validation by media and material experts shows that this guidebook is highly suitable, achieving an average score above 3.4. Student responses also indicate the guidebook is user-friendly, facilitating comprehension of physics concepts, experiment feasibility, and learning benefits. The pretest and posttest results demonstrate a significant improvement in students' understanding, with an n-gain value of 0.45 indicating moderate effectiveness.

This research supports the theory that integrating technology, particularly smartphone sensors, can enhance physics education by providing practical, in-depth learning experiences[20], [21]. These findings align with other studies emphasizing the importance of technology in science education and hands-on learning in physics [22], [23], [24]. The developed guidebook shows promising potential for further application of technology in science education, particularly in physics experiments that incorporate real-world contexts.

IV. CONCLUSION

A simple harmonic motion experiment guidebook based on smartphone sensors and using a double surfboard sports vehicle has been developed, demonstrating strong validity, practicality, and effectiveness. Media experts rated the guidebook with an average score of 3.53 (88.33%), and material experts with an average score of 3.43 (85.75%), both indicating a high level of validity. The practicality test, based on student responses, yielded an average score of 3.48 (87.16%), signifying that the guidebook is highly suitable for classroom use. Additionally, an effectiveness test conducted through pretest and posttest assessments with 17 students revealed an improvement in understanding, with an n-gain value of 0.45, categorizing it as "moderate." Therefore, this guidebook proves to be an effective educational tool for enhancing students' comprehension of simple harmonic motion.

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