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Effectiveness of Using Electromagnetic-Based Physical Pendulum Practical Tools Using Infrared Sensors in Basic Physics Practical 1

Armando Bachtiar[1], Imas Ratna Ermawati[2]
[1,2]Prof. Dr. HAMKA Muhammadiyah University, Indonesia

ABSTRACT: This study aims to determine the effectiveness of the electromagnetic-based physical pendulum practicum tool using infrared sensors in the Basic Physics Practicum 1 course. The research method used is Research and Development (R&D) with a descriptive quantitative approach using the 4D development model (Define, Design, Develop, Disseminate). The research subjects consisted of 15 students of the Physics Education Study Program, Muhammadiyah University of Prof. Dr. Hamka for small-scale tests and 30 students of the Physics Education Study Program, Tadulako University for large-scale tests. The research instrument was an effectiveness questionnaire with a Likert scale of 1-5 which included 15 questions in three aspects: construction, technical, and learning. The results showed that in the small-scale test, the percentage of effectiveness was 94% with the category "Very Good", while in the large-scale test, the percentage of effectiveness was 89% with the category "Very Good". Both results show that the electromagnetic-based physical pendulum practicum tool using infrared sensors is effective for use in learning Basic Physics Practicum 1. This tool is able to overcome the constraints of conventional practicums such as the difficulty of accurate time measurement, limited real-time data visualization, and minimal interaction with modern technology.

KEYWORDS: Effectiveness, Physical Pendulum, Electromagnetic, Infrared Sensor, Physics Lab

INTRODUCTION

The development of technological innovation in the digital era has brought significant transformation in various sectors of life, including in the field of education. The integration of modern technology in learning not only changes the way material is delivered, but also improves the quality of relationships between students and educators (Judijanto et al, 2025). This technological advancement opens up great opportunities to create more effective, interactive, and easy-to-understand learning methods, especially in learning that requires visualization and direct experimentation.

Learning that requires visualization and direct experimentation can be realized through practical activities. Practical work is an important component in the science learning process that allows students to directly experience scientific phenomena that are studied theoretically (Amirah Nuai & Silvi Nurkamiden, 2022). Through practicum, students can develop observation, analysis, and problem-solving skills that cannot be obtained only through theoretical learning. Practical activities play a vital role in helping students understand physics concepts that have abstract properties to be easier to understand.

One of the abstract physics concepts is the concept of a physical pendulum. A physical pendulum is a rigid object that can swing on an axis of rotation that does not pass through its center of mass (Syariffudin & Pratiwi, 2022). The material of physical pendulum covers various complex physics concepts such as simple harmonic motion, moment of inertia, torque, and period of oscillation. A deep understanding of this physical pendulum is very important because the concept in this material has wide applications in everyday life and of course becomes the basis for understanding more complex physics phenomena in the study of mechanics.

Mechanics studies involving pendulums often face challenges in terms of visualizing abstract concepts. Research conducted by Sa'adah & Prabowo (2021) regarding the lack of activeness and science skills possessed by students in the pendulum material. This shows that it is necessary to develop practical tools that can help students improve their science skills and activeness during the learning process through more interactive demonstrations in practical activities.

Conventional physical pendulum practical activities often face obstacles in terms of measurement accuracy, limited tools, and difficulties in visualizing abstract concepts (Yani et al, 2019). These constraints become difficulties in accurate time measurement, limitations in real-time data visualization, and minimal student interaction with modern technology such as Arduino and sensors in physics practicums. Therefore, innovation is needed in the development of practicum tools that can overcome these limitations through the integration of modern sensor technology.

Modern sensor technology, especially infrared sensors, has been proven to provide effective solutions to overcome conventional practical constraints. Research Subhan & Sucahyo (2020) about the use of infrared sensors in physics practicum activities shows that the use of infrared sensors provides an effectiveness value on the developed practicum tool of 95.7% which is included in the very effective category. The advantages of this infrared sensor technology allow data collection in real time, so that students can focus on data analysis and interpretation with the limitations of conventional measuring instruments, which can ultimately increase the effectiveness of learning.

The effectiveness of the physical pendulum practical tool can be measured by its ability to improve students' conceptual understanding (Andriani et al, 2020), ease of use and the ability to visualize the physical phenomena that occur. Effective lab tools must be able to provide meaningful learning experiences, motivate students to be active in learning, and help educators convey complex concepts in a way that is easier to understand in the context of technology-integrated learning.

Integrated learning with digital technology has shown a significant positive impact in improving the quality of physics practicums. Research conducted by Andarias et al. (2025) shows that the use of practical tools equipped with digital technology can increase students' learning motivation compared to conventional tools. The integration of technology in practical tools can not only improve measurement accuracy, but also enable students to develop digital literacy which is very necessary in the era of the industrial revolution 4.0 and supports the achievement of more comprehensive learning objectives.

Achieving comprehensive learning objectives requires a systematic evaluation of the effectiveness of the developed practical tools. According to research Sagita & Hartini (2025) evaluation of the effectiveness of physics lab tools must include construction, technical, and learning aspects. This approach ensures that the developed lab tools are not only technically functional, but also have a positive impact on achieving physics learning objectives in the context of modernizing higher education.

Modernization of higher education in the field of physics requires adaptation to the latest technological developments in practical activities. Research conducted by Fauziah & Sulisworo (2022) regarding the use of technology in physics learning shows that with the application of technology can make students more motivated in learning physics concepts especially during practical activities. However, there is still a gap between the availability of technology and effective implementation in learning, so further research is needed to measure the effectiveness of the implementation of the technology in the context of basic physics learning, especially in the development of physical pendulum practical tools.

This research continues from research conducted by Bachtiar & Ermawati (2025) entitled "Development of Electromagnetic-Based Physical Pendulum Practical Tools Using Infrared Sensors" in which the research produces data up to the validation test conducted by the validator, while this research refers more to the effectiveness of the tool obtained from the results of the questionnaire filled out by respondents in this case students.

Based on the description, the researcher conducted a study entitled "Effectiveness of Electromagnetic-Based Physical Pendulum Practical Tools Using Infrared Sensors in Basic Physics Practical 1". This study aims to determine the effectiveness of the tool based on the responses of respondents regarding the practical tools that have been developed.

METHOD

This study applies the Research and Development (R&D) approach which aims to determine the effectiveness of the product that has been produced. The product that is the object of evaluation is a physical pendulum practicum tool based on electromagnetics using infrared sensors that have passed a feasibility test and are intended for students of the Physics Education Study Program, Muhammadiyah University of Prof. Dr. Hamka. The research method applied is a descriptive quantitative method, where information collected from the results of the questionnaire regarding the effectiveness of the practicum tool and respondents' responses is processed in a structured manner, then analyzed and interpreted to produce an objective description of the level of effectiveness of the practicum tool that has been developed.

The development framework implemented in this study refers to the 4D model introduced by Thiagarajan in 1994 (Cahyati et al, 2023). The 4D model consists of four main stages, namely Define, Design, Develop, and Disseminate. The define phase includes identifying the needs of respondents, the design phase contains the preparation of effectiveness evaluation instruments, the develop phase develops practical tools according to the needs of respondents, while the disseminate phase integrates the stages of small-scale trials and large-scale trials to analyze the level of effectiveness of the tools that have been produced.

The implementation of this research started from September 2024 to February 2025. The location of the research was carried out at Muhammadiyah Prof. Dr. Hamka University and Tadulako University. The target respondents of the research were active students of the Physics Education study program who had taken the Basic Physics Practicum 1 course.

To measure the effectiveness level of the electromagnetic-based physical pendulum practicum tool using infrared sensors, researchers applied data analysis techniques using the Likert scale. The Likert scale is a measurement instrument used to assess respondents' attitudes, opinions, and views on certain objects.

The effectiveness instrument was constructed using a Likert scale with five response options, namely:

Table 1. Value Criteria

Achievement Level	Interpretation
Very Effective	5
Effective	4
Quite Effective	3
Less Effective	2
Ineffective	1

To calculate the percentage of effectiveness of the practical tools, the following formula is applied:

$$NP = \frac{R}{SM} \times 100\%$$

Information:

NP = Targeted effectiveness percentage value

R = Actual score obtained

SM = Maximum score

The results of the percentage of effectiveness obtained are then interpreted using product effectiveness standards based on(Judge, 2021)as follows:

Table 2. Interpretation of Values

Value Range	Predicate	Information
81 – 100	A	Very Effective
61 – 80	B	Effective
41 – 60	C	Quite Effective
21 – 40	D	Less Effective
0 – 20	E	Ineffective

The physical pendulum practical tool based on electromagnetics using infrared sensors is categorized as effective if the results of the effectiveness questionnaire evaluation reach a minimum percentage of 61% with the classification "Effective" or higher based on the responses of students who have used the practical tool in physical pendulum practical activities.

RESULTS AND DISCUSSION

The research on the effectiveness of the electromagnetic-based physical pendulum practicum tool with infrared sensors was carried out through the 4D model stages consisting of the Define, Design, Develop, and Disseminate phases. Each stage contributes to producing comprehensive effectiveness data.

Define Stage

Based on the literature study conducted, it was found that the use of conventional laboratory tools in learning physical pendulums faces several obstacles to effectiveness, including: 1) difficulties in accurate time measurement, 2) limitations in real-time data visualization, and 3) minimal student interaction with modern technology such as Arduino and Sensors in physics laboratory. This needs analysis is the basis for evaluating the extent to which electromagnetic-based physical pendulum laboratory tools using infrared sensors can overcome these obstacles.

Design Stage

At this stage, the effectiveness instrument was designed in the form of numbers with a Likert scale of 1-5 consisting of 15 questions covering seven effectiveness indicators. Each indicator is represented by 2-3 questions that have gone through a validation process by experts. The effectiveness test scenario was designed in two stages, namely a small-scale test with 15 students and a large-scale test with 30 students. The test began with an introduction to the practical tools, demonstration of use, independent practicum, discussion of results, and filling out the effectiveness questionnaire.

Development Stage

At this stage, the researcher begins the process of making the tool based on the results of the needs analysis. The researcher develops a physical pendulum practicum tool based on electromagnetics using infrared sensors through several stages, namely preparing the main material in the form of acrylic, creating a circuit schematic, assembling components, uploading program codes, until reaching the final stage where the tool is ready to be operated. The following is a picture of a physical pendulum practicum tool based on electromagnetics using infrared sensors that have been developed through several stages that have been mentioned.

Figure 1. Electromagnetic-Based Physical Pendulum Practical Tools Using Infrared Sensors

Researchers hope that by developing a physical pendulum practical tool based on electromagnetics using infrared sensors, it will make it easier for students to collect data and understand the concept of physical pendulums and how to apply them in everyday life.

Disseminate Stage

At this stage, small-scale and large-scale tests were conducted to determine the effectiveness of the developed tool. The first assessment was a small-scale test assessment of 15 students of the Physics Education Study Program at Muhammadiyah University Prof. Dr. Hamka who had taken the Basic Physics 1 practical course and had taken part in practical activities entitled physical pendulum. Students were asked to fill out a questionnaire in the form of a google form containing a test of the effectiveness of the physical pendulum practical tool based on electromagnetics using infrared sensors. The assessment related to this effectiveness test is divided into three aspects, namely the construction aspect, the technical aspect, and the learning aspect. The following are the results of the small-scale test assessment

Table 3. Small Scale Test Results

No	Aspect	*ΣSM*	*ΣR*	*NP%*	Predicate
1	Construction Aspects	225	207	92	Very good
2	Technical Aspects	300	285	95	Very good
3	Learning Aspects	600	574	95	Very good
Average Percentage				94	Very good

The graph of the results of the small-scale test of the development of the physical pendulum practical tool is as follows.

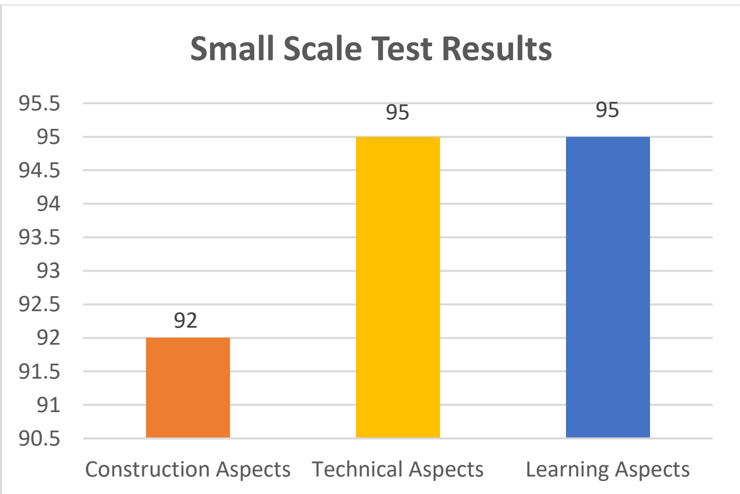

Figure 2. Small Scale Test Graph

Based on the graph of the results of the small-scale test above, it was found that the average percentage value of all aspects was 94%. The value is included in the predicate with a very good category. This can state that the physical pendulum practicum tool based on electromagnetics using infrared sensors is said to be effective for use in the Basic Physics 1 Practicum course.

The next stage of assessment is a large-scale test assessment. At this stage, a large-scale test assessment was carried out on 30 students of the Physics Education Study Program at Tadulako University who had taken the Basic Physics 1 practical course and had taken part in practical activities entitled physical pendulum. Students were asked to fill out a questionnaire in the form of a google form containing a test of the effectiveness of the physical pendulum practical tool based on electromagnetics using infrared sensors. The assessment related to this effectiveness test is divided into three aspects, namely the construction aspect, the technical aspect, and the learning aspect. The following are the results of the large-scale test assessment.

Table 4. Large Scale Test Results

No	Aspect	ΣSM	ΣR	NP%	Predicate
1	Construction Aspects	450	404	90	Very good
2	Technical Aspects	600	530	88	Very good
3	Learning Aspects	1200	1082	90	Very good
Average Percentage				89	Very good

The graph of the results of large-scale tests of the development of physical pendulum practical tools is as follows.

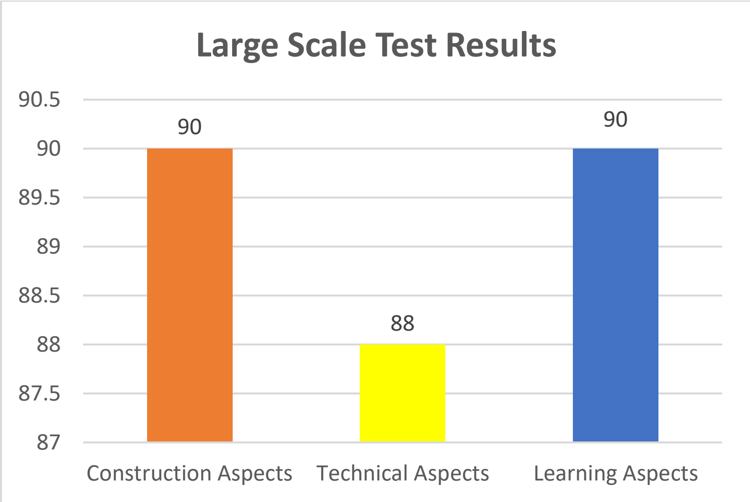

Figure 3. Large Scale Test Graph

Based on the graph of the large-scale test results above, it was found that the average percentage value of all aspects was 89%. The value is included in the predicate with a very good category. This can state that the physical pendulum practicum tool based on electromagnetics using infrared sensors is said to be effective for use in the Basic Physics 1 Practicum course.

As for the results of the effectiveness test that has been carried out through two stages, namely a small-scale test conducted at Muhammadiyah University Prof. Dr. Hamka and a large-scale test conducted at Tadulako University, it is said that the electromagnetic-based physical pendulum practicum tool using infrared sensors is effective for use as a physical pendulum practicum tool in the Basic Physics Practicum 1 course.

This is in line with research conducted by Hartini et al. (2022) with the title Effectiveness of Virtual Laboratory in Integrated Prophetic Electronics Practical Learning received a value with validation results of 79.2 which is included in the very good category. In addition, research conducted by Rahmadani (2022) with the title Effectiveness of Practical Instructions Based on Jigsaw Type Cooperative Learning with a Probing Approach to Critical Thinking Skills obtained a score with an N-Gain result of 0.70 which is included in the high or very effective category.

CONCLUSIONS

Based on the results of the research and discussion that has been carried out, it can be concluded that:

1. The electromagnetic-based physical pendulum practical tool using infrared sensors has been successfully developed through the 4D model stages (Define, Design, Develop, Disseminate) and has been proven effective for use in the Basic Physics Practical 1 course.

2. The results of the effectiveness test on a small scale with 15 students of the Physics Education Study Program, Prof. Dr. Hamka Muhammadiyah University showed an effectiveness percentage of 94% with the category "Very Good" covering construction aspects (92%), technical aspects (95%), and learning aspects (95%).
3. The results of a large-scale effectiveness test with 30 students of the Physics Education Study Program at Tadulako University showed an effectiveness percentage of 89% with the category "Very Good" covering construction aspects (90%), technical aspects (88%), and learning aspects (90%).
4. The developed practical tools are able to overcome the constraints of conventional physical pendulum practicals, namely difficulties in accurate time measurement, limitations in real-time data visualization, and minimal student interaction with modern technology such as Arduino and sensors in physics practicals.
5. The use of electromagnetic-based physical pendulum lab tools using infrared sensors can make it easier for students to collect data and understand the concept of physical pendulums and their applications in everyday life. Thus, electromagnetic-based physical pendulum lab tools using infrared sensors are feasible and effective to be implemented in basic physics lab activities, especially on physical pendulum materials.

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