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Assessing Student Performance in Designing Physics Teaching Aids and Experiments in Team-Based Project Learning for Instrumentation Courses

I Komang Werdhiana*[1], Haeruddin[1], Muhammad Jarnawi[1], Syamsuriwal[1]

[1]Department of Physics Education, Faculty of Teacher Training and Education, Universitas Tadulako, Palu, Indonesia.

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Corresponding Author:
I Komang Werdhiana*:
ikomangwerdhiana@yahoo.co.id

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Abstract: Performance assessment is an important part of learning that applies the team-based project method. This study aims to describe student performance in designing physics teaching aids and experiments in terms of active participation, understanding of the material, presentation skills and products. This study uses a descriptive method. Data were obtained through observation sheets and rubrics and assessment sheets. Data analysis for active participation, understanding of the material, and presentation skills was carried out by determining the number of students who obtained scores according to each category (very good, good, quite good, and less good) then expressed as a percentage. Data analysis for product assessment was carried out by determining the average score of each product and converting it to a score of 100. There were 29 students who were the sample of the study. The results of the study showed that students who participated actively were predominantly in the sufficient and less active categories. The percentage of students who understood the material was predominantly in the understand and understand enough categories. Students' presentation skills were predominantly in the good category. All the results of the teaching aid designs were in the very good category. There were three experimental design results in the very good category and three others in the good category. Based on the research results, it can be concluded that students are able to design physics demonstration tools and experiments in terms of active participation, understanding of the material, presentation and product skills, through team-based project learning.

Keywords: Assessment; Experiments; Performance; Teaching aids

Introduction

Project-based learning can develop teamwork skills, communication skills and solve real-life problems (Fider, 2017). This project-based learning is in line with what is expected in learning in higher education which provides opportunities for students to develop their creativity. Research conducted by Werdhiana et al. (2023) shows that through team-based project learning, students' abilities in designing project-based physics experiments can be improved. The assessment of this project is based on questionnaires filled out by High School Physics Teachers and Lecturers. The projects worked on by students have not been given product and process performance assessments. Therefore, it is important to assess student performance in working on projects.

Performance assessment is considered to have a better possibility to measure complex skills and communication, considered as important competencies

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and disciplinary knowledge needed in today's society (Palm, 2008). Several studies in the field of Physics Education, student performance is assessed based on their ability to complete certain tests (Krakeh et al., 2020; Agbele et al., 2020; Molin et al., 2021; Li & Singh, 2023; Lukita & Jayanagara, 2023). However, in this study, student performance was assessed based on their ability to design physics teaching aids and experiments using performance assessment instruments such as observation sheets and rubrics and product assessment sheets.

The use of performance assessment as a new method to measure physics learning planning skills in a standardized and authentic way (Schroder et al., 2020). The use of performance assessment instruments can improve students' psychomotor and cognitive abilities in science learning (Hartina et al., 2020) and the implementation of performance assessment through virtual laboratories can improve students' creative thinking skills (Sari et al., 2021). In addition, there is a relationship between comprehensive performance assessment in project-based learning and critical thinking (Sudirman et al., 2023).

Performance assessment integrated with web-based electronic modules to assess students' performance skills during laboratory practice is more comprehensive (Dhina et al., 2021). Experimental performance assessment instruments are effective in improving science process skills (Srirahayu & Arty, 2019) and performance assessment can improve students' science process skills in STEM-based biology learning (Farach et al., 2020). So that performance assessments related to skills or in working on certain projects need to be considered.

Student performance can be influenced by the learning process. The performance of students taught using the Polya heuristic method is better than students taught using project-based teaching and lecture methods (Thomas & Israel, 2013). Learning with PhET simulations makes students perform better than learning without PhET simulations (Tuyizere & Yadav, 2023) and the application of virtual laboratories is effective in improving students' academic performance in physics (Sabasales, 2018). Physics learning through a combination of face-to-face and online delivery that is utilized effectively can improve student performance and retention (Sivakumar & Selvakumar, 2019). In this study, we want to use the Team-based Project learning method to provide opportunities for students to show their performance in designing physics teaching aids and experiments.

Team-based project learning affects students' numeracy skills (Yustitia & Kusmaharti, 2022) and students' learning outcomes through the team-based project learning method are higher than without using the team-based project learning method (Wijaya et al., 2023).

Through projects, students can be given the opportunity to conduct investigations (Wilcox & Lewandowski, 2016), develop communication skills (Fider, 2017) and provide opportunities for students to practice authentic writing (Hoehn & Lewandowski, 2020). Through project-based learning, students are actively involved (Ratna et al., 2025). Project-based learning can improve students' critical thinking skills (Aswan et al., 2024; Risamasu & Pieter, 2024), improve science process skills and critical thinking (Wulandari et al., 2024), improve students' metacognition and learning outcomes (Murisqa et al., 2024), improve students' creative thinking skills (Zakiah et al., 2020; Maysyaroh & Dwikoranto, 2021; Amalia et al., 2024; Anwar et al., 2024). The application of a project-based learning model assisted by PhET simulations can improve students' critical thinking and problem-solving skills (Puspita et al., 2024) and the integration of local cultural values in the project-based learning model can improve students' understanding and learning outcomes (Setiawan et al., 2024).

Projects that students work on need to be assessed. A suitable project assessment is a performance assessment. The performance referred to in this study is the performance of students in designing physics teaching aids and experiments reviewed from active participation, understanding of the material, presentation skills and products.

Method

The purpose of this study is to describe the performance of students in designing teaching aids and physics experiments in terms of active participation, understanding of the material, presentation skills and products. The study used a descriptive method. The students who became the research sample were students who took instrumentation courses. The number of students was 29 people. The research data was obtained through student performance assessments including understanding of the material, active participation, and presentation skills. as well as assessment of project results. Assessment of student performance for understanding the material, active participation, and presentation skills used observation sheets and rubrics. The rubric uses a scale of 4 with categories 1 = less good, 2 = quite good, 3 = good and 4 = very good.

Table 1. Project results assessment categories

Score interval	Category
≥ 82	Very good
$63 \leq X < 82$	Good

Score interval	Category
$44 \leq X < 63$	Good enough
$25 \leq X < 44$	Not good

The assessment of active student participation is based on the number of questions and answers submitted by each student. Understanding of the material is assessed based on the suitability with the physics concept, the accuracy and contextuality of the answers given by students to the questions given. Presentation skills are assessed based on fluency, structure, and creativity in conveying information according to the project being discussed.

The project results (products) are assessed by teachers and lecturers through Focus Group Discussion (FGD) using an assessment sheet. The Assessment Sheet uses a scale of 4. Data analysis for active participation, understanding of the material and presentation skills are expressed in the percentage of students for each category and presented in the form of a diagram. Data analysis for the assessment of project results is carried out by converting the scores obtained into a scale of 1-100. The conversion results are grouped into four categories as presented in Table 1.

Result and Discussion

Active participation of students is highly expected in lectures during discussion activities. In each lecture meeting, one to two groups present their project results and other students provide responses. Every time a student asks a question or provides an answer to a question asked by another student, it is considered active participation. Active student participation based on the categories of very active, active, quite active and less active is presented in Figure 1.

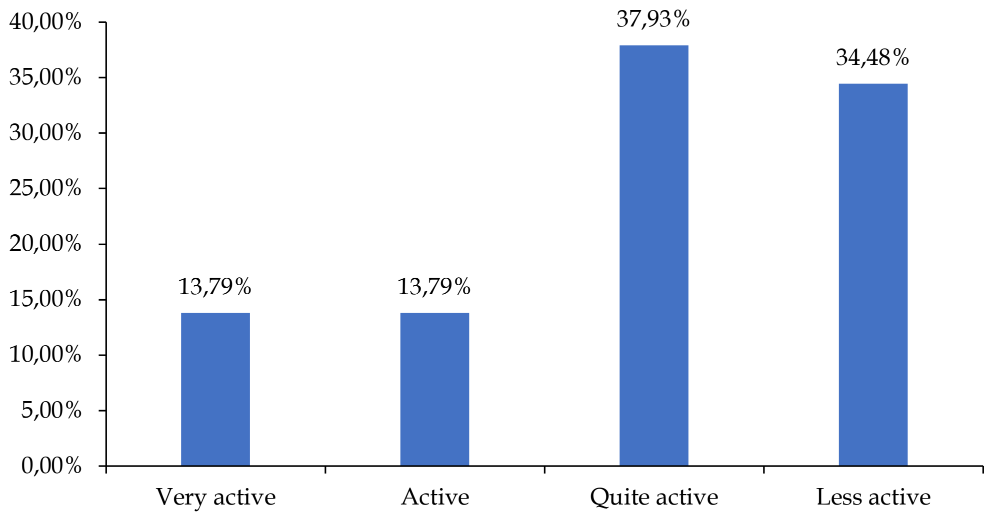

Figure 1. Percentage of students actively participating

Students who are very active and active are 13.79% each, those who are quite active are 37.93% and those who are less active are 34.48%. It seems that there are more students who are less active than those who are very active and active. Students who are active provide answers to questions from other students when acting as a group that presents the results of their project. Students who are very active, in addition to answering questions from other students, also ask questions and participate in answering even though they are not part of the group that presents the results of their project.

The lack of student activity due to focusing on their respective tasks, they tend to only answer questions addressed to their group. When not as presenters, only a few ask questions or provide responses or arguments regarding the results of the project being discussed. This is different from the findings of Rosmeli et al. (2023) that project-based learning can increase student participation in the learning process and the findings of Nurdiyanti et al. (2024) that project-based learning improves students' argumentation skills.

The implementation of Team based Project learning or project-based learning is expected to increase active student participation. Therefore, it is necessary to provide motivation to be able to increase student participation in discussions, for example by providing additional values for students who ask or answer questions. The additional values obtained are accumulated as an assessment that contributes to the final grade of the course.

Understanding of the material is assessed based on the quality of students' answers to questions asked by other students. Based on the assessment rubric, 20.69% were very knowledgeable, 44.83% were knowledgeable, and 34.48% were quite knowledgeable. Understanding of the material is related to understanding the physics concepts underlying the project being worked on and understanding the project being worked on.

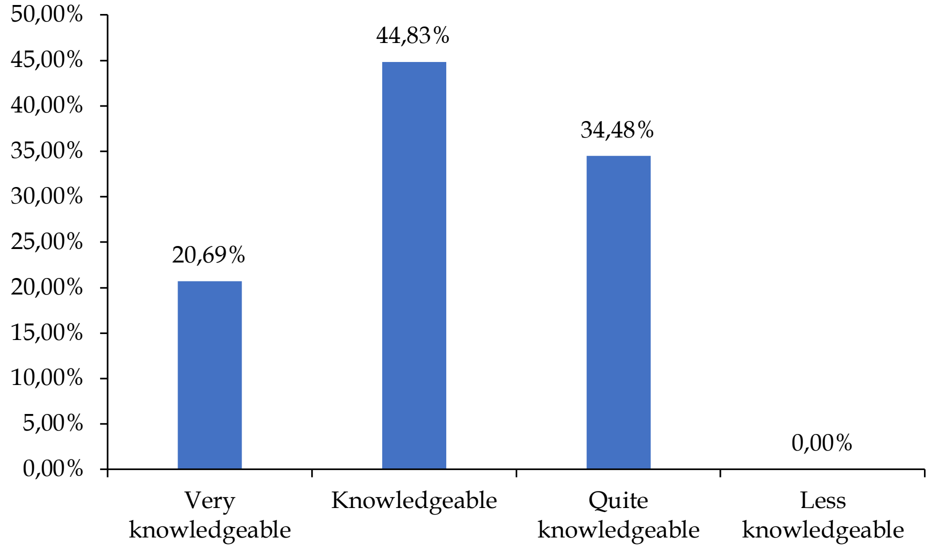

Figure 2. Percentage of students understanding the material

Based on Figure 2, students generally understand the material related to the project being worked on. This finding is in accordance with the findings of Pamenang et al. (2024) that project-based learning helps students understand the material in depth. This shows that students are serious about working on projects and trying to understand the physics concepts that underlie the props or experiments they design. There are a few students who do not understand the material related to the project being worked on. These students are generally less active in discussions and whose attendance in class is lacking. In addition, they participate less when designing assigned projects. Understanding the material will certainly affect presentation skills, in other words there is a relationship between presentation skills and understanding the material.

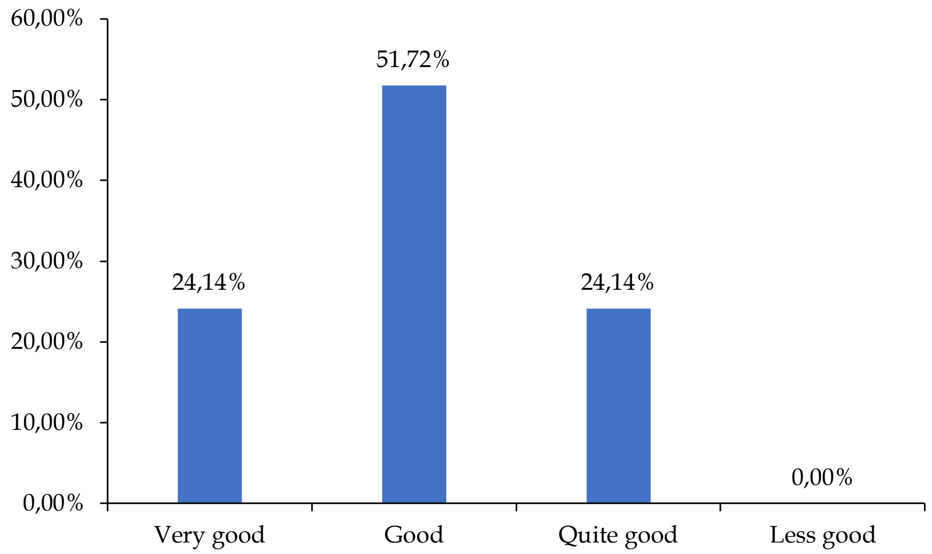

Figure 3. Distribution of students' presentation skills

The assessment of presentation skills is based on the ability to present information about the project being worked on smoothly and in a structured manner and creativity. Creativity is assessed based on the presentation of information on PowerPoint, while fluency and structure in delivering information are assessed based on answering questions and providing arguments in discussions. The distribution of students' presentation skills is as presented in Figure 3. Students' presentation skills are predominantly in the good category. So, it can be stated that in general students have presentation skills. Presentation skills are in line with understanding the material. It appears that between understanding the material and presentation skills for the less category the percentage is the same, which is 0%, likewise for the sufficient category between understanding the material and presentation skills only differs by about 10%. This means that there is a relationship between understanding the material and presentation skills. This is in accordance with the findings of Oktaviyanti (2019) that there is a correlation between presentation skills and answering tests orally.

Table 2. Average value of each aspect for each teaching aid

Aspects	Average value					
	AP1	AP2	AP3	AP4	AP5	AP6
Suitability of teaching aids with Physics concepts	3.58	3.50	3.33	3.42	3.83	3.50
This teaching aid makes it easier to understand physics concepts	3.75	3.50	3.42	3.42	3.92	3.50
Easy to use props	3.58	3.33	3.50	3.58	3.83	3.75
Teaching aids have elements of innovation	3.42	3.08	3.08	3.25	3.25	3.08
Easy to make props	3.58	3.67	3.50	3.50	3.58	3.50
Teaching Aids are safe to use	3.58	3.58	3.58	3.67	3.67	3.83
Teaching aids can be used as physics learning aids	3.50	3.42	3.42	3.42	3.67	3.50
Design interesting props	3.33	3.17	3.08	3.33	3.50	3.00
This teaching aid product reflects student creativity	3.50	3.17	3.17	3.33	3.50	3.17
Total	31.83	30.42	30.08	30.92	32.75	30.83

Description: AP1 = Orsted, AP2 = Mono polar motor, AP3 = Balloon rocket action reaction, AP4 = Hologram, AP5 = Hydraulic machine, and AP6 = Balloon car.

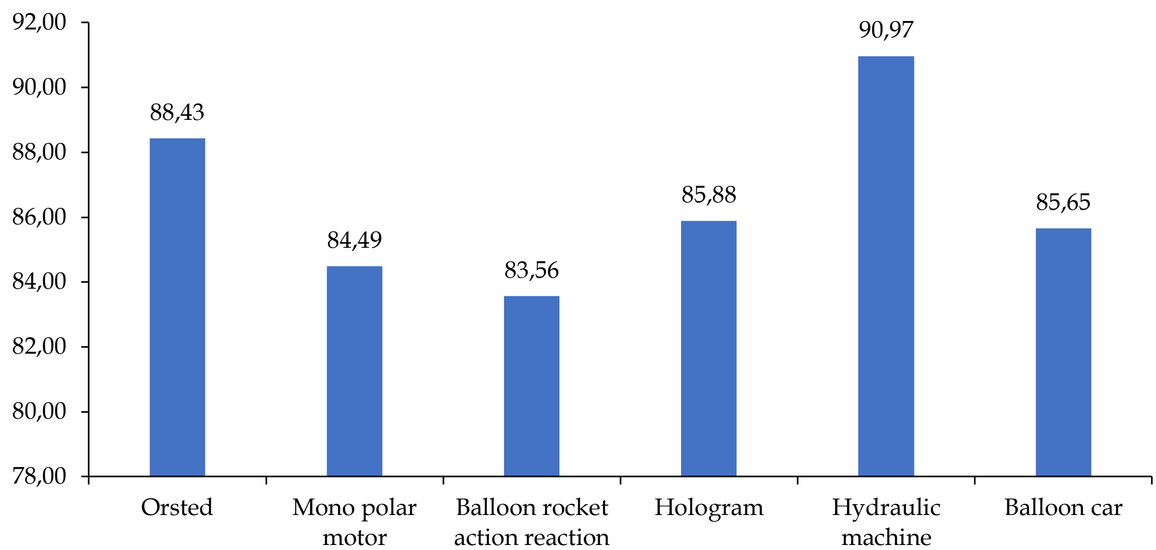

Figure 4. Average value of teaching aid products

Presentation skills are also related to the products produced, students can present their products well when the results of their project work are good. The average assessment results for each aspect for each teaching aid presented in Table 4.1 show very good results for all teaching aid products. This means that through team-based project learning, students are able to design physics teaching aids. This finding is in accordance with the findings of Lia (2018) that through project-based learning, students are able to make physics teaching aids well.

The teaching aid (AP) that obtained the highest average score was the hydraulic machine. This teaching aid has the best design and is easy to operate. Only the balloon car teaching aid received a score of 3 on the design aspect of the tool and the others were above 3. Because the design that was made still used simple materials and the equipment used to add air to the balloon was incomplete. For follow-up so that the design is more attractive, it needs to be designed more seriously and use better materials. The results of the teaching aid project show student creativity and the products produced can be used in schools as a physics learning aid. This can be explained that the assessment given to the aspect of teaching aids can be used as a physics learning aid > 3 and comments from Physics Teachers stated that the designed tool can be applied in physics learning. Because this teaching aid is easy to bring to class and easy to use.

Table 3. Average value of each aspect for each experiment

Aspects	Average value					
	EX1	EX2	EX3	EX4	EX5	EX6
Completeness of tools and materials	3.58	3.50	3.17	3.73	3.50	3.50
Clarity of experimental procedures	3.67	3.42	3.17	3.50	3.17	3.25
Conformity of experiments with Physics concepts	3.67	3.42	3.00	3.42	3.33	2.92
The experiments conducted make it easier to understand physics concepts	3.50	3.33	3.25	3.42	3.08	2.92
Experimental design has elements of innovation	3.25	3.25	3.17	3.17	3.25	3.17
Easy to do experiment	3.67	3.58	3.33	3.25	3.42	3.58
Experimental tools and materials are safe to use	3.42	3.67	3.42	3.25	3.33	3.58
The results of the Experimental Design are interesting in terms of design	3.17	3.17	3.08	3.25	3.00	2.92
Experimental design can support Physics learning	3.50	3.33	3.17	3.42	3.25	3.25
The results of this experimental design reflect student creativity	3.33	3.25	3.10	3.09	3.00	3.17
Total	34.75	33.92	31.85	33.48	32.33	32.25

Description: EX1 = Photometry, EX2 = Magnetic field measurement, EX3 = Free fall motion, EX4 = Standing waves, EX5 = Simple pendolum, and EX6 = Organ pipe.

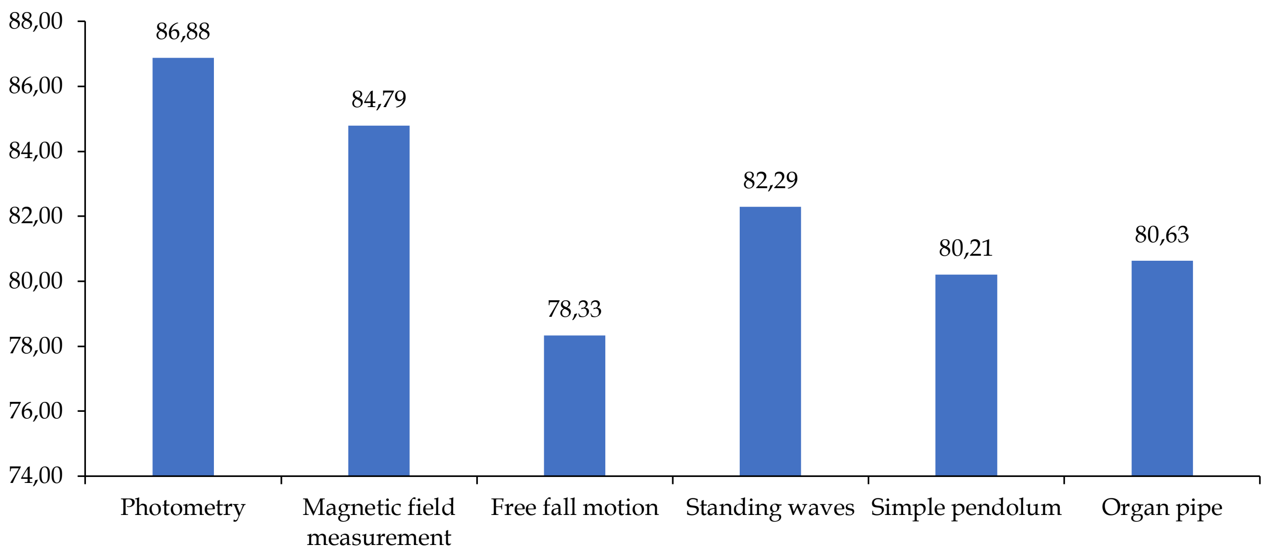

Figure 5. Average value of experimental products

The experimental designs made by students are all android-based. The assessment of the experimental design (EX) presented in Table 3 shows that for organ pipe products there are three aspects that get an assessment below 3, namely: the suitability of the experiment to the Physics concept; the experiments carried out make it easier to understand the physics concept; and the results of the experimental design are interesting in terms of design.

The organ pipe that was made could not present the results of the experiment well because the design had not been assembled properly, so that when conducting the experiment it was difficult and the results were less accurate. The organ pipe design had not been assembled properly, because students felt that the pipe could be held by one person and then the cellphone (HP) was held by another. This method made it difficult for students to adjust the position of the cellphone and operate it.

Other experimental products received a score of >3 for all aspects. When viewed from the lowest average value, the free fall experimental design was and the highest average value was the photometry experimental design. Photometry experiments are the easiest to do and can help to understand physics concepts. Based on the results of the experimental design assessment, it can be stated that students are able to produce experimental designs through teamwork. This means that through team-based project learning, students are able to design experiments (Werdhiana et al., 2023). The ability to design experiments is very important for prospective physics teachers. When they work in remote areas, they can still carry out experiments because they already have the ability to design simple experimental equipment.

The implications of the experimental design produced by students can be applied in schools to support learning that uses experimental methods or inquiry-oriented learning. Through laboratory experience, inquiry can improve the ability to design and carry out experiments independently (Perl-Nussbaum & Yerushalmi, 2022). In addition, the projects worked on by students can be used as provisions for working on final assignment research.

Conclusion

Based on the results of the study, students are able to design teaching aids and experiments in terms of active participation, understanding of the material, presentation skills and products. Students' presentation skills through team-based project learning are good, but there are some people who need to improve their presentation skills. Most students understand the material, but quite a few only understand it well. Therefore, a better strategy is needed in implementing team-based project learning so that all students can understand the material well. Overall, students do not participate actively enough. Therefore, to increase active participation of students in implementing team-based projects, it is necessary to involve assessments that can motivate students to participate actively. The results of the project in the form of teaching aids and physics experiments can be applied in schools in physics learning. Teaching aids and experiments produced by students are easy to use and easy to bring into the classroom. Through teaching aids and experiments, physics learning becomes more interesting and students can conduct experiments.

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Author Contributions

Conceptualization, writing—original draft, methodology, I.K.W. and H.; validation, H. and M.J.; formal analysis, resources, writing—review and editing, I.K.W., H., M.J., and S.; investigation, visualization, M.J. and S.; data curation, I.K.W., H., and M.J. All authors have read and approved the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest. The funders did not participate in the study design, data collection, analysis, interpretation, writing of the manuscript, or decision to publish the results.

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