JPF | Volume 12 | Number 2 | 2024 | 109 - 120

p - ISSN: 2302-8939
e - ISSN: 2527-4015

Jurnal Pendidikan Fisika

https://journal.unismuh.ac.id/index.php/jpf

DOI: 10.26618/jpf.v12i2.12476

Development of Physics Digital Props Based on the Internet of Things (IoT) on the Material of Motion Dynamics

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Received: September 09, 2023; Accepted: March 27, 2024; Published: April 29, 2024

Abstract – *This research aims to create an Internet of Things (IoT)-based Newton's Law II physics practicum trainer. The developed props aim to make the students understand measure time, speed, and acceleration in Particle Dynamics Using IoT-based teaching aids. The design of teaching aids uses electronic components such as ESP32 WIFI-Bluetooth microcontrollers, obstacle Infrared Sensors, and LCDs as the main hardware components. The software for developing this teaching aid utilizes the Arduino IDE compiler based on C++. The development research method used is the ADDIE design development method. The ADDIE design development stages include Analyze, Development, Implementation, and Evaluation. The product feasibility test involved 35 SMAN 1 Montong Gading students. Expert validators in the media and material carry out the feasibility test. The feasibility test results in the media and material sector are 95%, with a very feasible category. The scores of the student's responses to the development are 77% with a practical. The results showed that the physics teaching aids developed were very valid and feasible to use.*

Keywords: *development; internet of things (iot); learning physics; props*

I. INTRODUCTION

The development of information technology today has entered the era of using the Internet of Things (IoT). Internet networks that connect various objects to exchange information quickly, easily, and efficiently. Internet has become a public necessity in all sectors of life, including education. The use of smartphones among students is not limited to communication, playing games, and streaming but is used to search for learning materials. Indirectly, students have utilized IoT facilities in learning (Muchlis et al., 2018).

Modern education and e-learning systems cannot ignore the role of IoT. The IoT model can connect physical things and examine how technology can affect e-learning

(Kumar & Al-Besher, 2022). The study Bayani et al. (2017) found that combining technical learning with IoT can improve e-learning outcomes. Mobile learning positively impacts learners' understanding (Muchlis et al., 2018; Samsudin et al., 2019; Saraswati, 2019). The usefulness of IoT in the learning process needs more attention from teachers.

Applying the scientific method in the physics learning process is essential, and the goal is to encourage and deepen students' understanding of the nature of science. The laboratory practicum process is the primary means of the scientific method (Noor et al., 2020).

Physics practicum provides a natural opportunity for students to learn to conduct an experiment and analyze the data obtained according to the experiment's purpose. One of the bridges so that students can think abstractly, conduct an experiment, and analyze physics is using teaching aids.

Teaching aids are defined as support education and teaching so that students can easily understand the concepts taught by the teacher and become a tool to keep the learning process by teachers or students (Adlan et al., 2021). In addition, teaching aids can be used as instruments to assess learner focus, are an essential component of learning evaluation, and can be used to measure learner engagement (Kumar & Al-Besher, 2022; Li et al., 2022; Malhotra et al., 2021).

The development of physical activity or practicum implementation in educational institutions is currently still limited lack of empowerment and development of teaching aids in physics learning (Radiyono et al., 2022). Physics learning methods implemented by subject teachers are lectures, demonstrations, and experiments, but the limited availability of teaching aids is an obstacle that hinders the creation of a practicum-based learning process (Lamanepa et al., 2022). The results of observations in one of the schools, found that physics practicum was carried out with conventional props/lab kits and was rarely done considering that the props could not be used, and 98.7% of students used smartphones at school.

Most of the researchers developed IoT-based teaching aids for physics learning, including the material of Newton's law 2 (Muchlis et al., 2018; Radiyono et al., 2022; Syahputra & Rosmayanti, 2022; Subhan & Sucahyo, 2020; Coletta et al., 2019), spring oscillation material (Irwandi et al., 2020), free-fall motion (Aisyah et al., 2022).

From the limited implementation of physics practicum in schools and the potential use of smartphones by students in schools, it is exciting to do physics practicum with the utilization of IoT technology as an innovation in the implementation of internship from conventional physics practicum to physics practicum based on technological development / IoT which can increase students' understanding and interest.

Thus, this research aims to develop IoT-based physics teaching aids to make the students understand on particle dynamics material and determine the level of validity and practicality of the designed teaching aids.

II. METHODS

In developing IoT-based teaching aids, researchers use R&D (Research and Development) development with ADDIE stages (Analyze, Design, Develop, Implement, and Evaluation).

The analysis stage is carried out by analyzing the independent learning curriculum, analyzing the needs of teaching aids in schools, and observing field conditions to discover the problems that occur to students. Then, at the design stage, initial design, material selection, and design of teaching aids are carried out. The flow of the development stages is in the figure below.

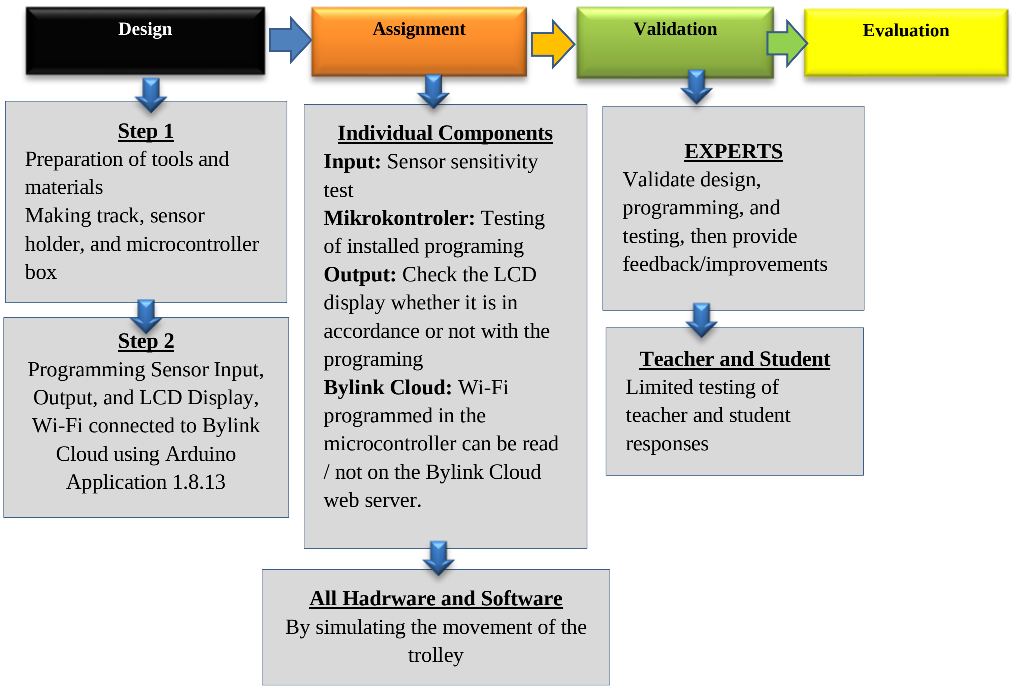

Figure 1. Workflow of tool development

In the development stage, a prototype of IoT-based physics teaching aids was produced. Media experts then validate the teaching aids—implementation of trial to students to test the validity and effectiveness.

In the final stage, the evaluation measures the feasibility of using IoT-based physics teaching aids. The feasibility of using IoT-based teaching aids is seen from three testing specs: validity, tool effectiveness, and tool practicality (Nurjannah & Sucahyo, 2022). This research is limited, as the subject of testing props to 35 students of class XI at SMAN Montong Gading.

The research product in the form of IoT-based teaching aids was tested with three aspects of assessment, namely the validation of teaching aids, the practicality of teaching aids, and the effectiveness of teaching aids. Furthermore, researchers did data collection with two different methods: observation, questionnaires, and interviews. Before testing on students, media and material validation has been carried out on five expert lecturers.

Props are validated by expert lecturers who validate the assessment instrument by marking each criterion with the state of the props. The criteria for selecting validators are based on lecturers majoring in physics education and mastering particle dynamics material (Nurjannah & Sucahyo, 2022). The instrument used is a rating scale with the highest score of 4 and the lowest score of 1. It can be said whether or not a teaching aid is valid based on the suitability of the validation results by lecturers with a range of criteria in Table 1.

Table 1. Criteria for validation of props

Average score 5 validators	Rating category	Category description
0,00% –0,20%	Invalid	cannot be used
0,21% – 0,405	Not Valid	Revision required
0,41% – 0,60%	Quite Valid	Recommended not to use; major revision required
0,61% – 0,80%	Valid	It is usable but requires minor revision
0,81% – 1,00%	Very Valid	Usable without revision

To calculate the percentage of validity and learner response, use the following equation:

$$V = \frac{\text{r - lo}}{n\,(c-1)} \qquad (1)$$ (Crocker, 2015)

Description:

V: Agreement Index

r: Choice category score

lo: Lowest score in the assessment category

n: Number of experts

c: The number of categories

Then, to find out the percentage of students' responses, use the criteria for the percentage of students' response scores in Table 2 as follows,

Table 2. Percentage score of learner response

Average score	Criteria	Information
0,00% –0,20%	Invalid	Not Practical
0,21% – 0,40%	Not Valid	Not Practical
0,41% – 0,60%	Quite Valid	Less practical
0,61% – 0,80%	Valid	Practical
0,81% – 1,00%	Very Valid	Very Practical

III. RESULTS AND DISCUSSION

In developing this IoT-based physics teaching aid, researchers used the research and development method using the ADDIE design.

Analyze

At this stage, before developing IoT-based teaching aids, researchers analyze what students need to support learning in the classroom. The needs analysis includes (1) Problem Analysis, a review of curriculum needs for using media in the form of practical aids and student problems in learning physics; (2) Analysis of the needs for IoT-based teaching aids.

The problem analysis to review curriculum needs on using teaching aids in the learning process. Based on the National Education System Law No. 20 of 2003 concerning the National Education System Article 1, education is a conscious and planned effort to create a learning atmosphere and learning process so that students actively develop their potential to have religious, spiritual strength, self-control, personality, intelligence, noble character, and skills needed by themselves, society, nation and state (Khodam et al., 2022).

The survey results show that science practice tools and materials in SMA/MA are only used with the demonstration method or only demonstrated for some conceptual topics. The conditions described above make high school science laboratories and other tools and facilities less effective and ultimately cannot used as a learning resource that supports improving the quality of education in schools (Kemdikbud, 2017).

Advances in science and technology have produced various electronic devices that help develop teaching aids. Some essential electronic devices in learning media development include control devices such as microcontrollers, detector devices or sensors, display devices or LCDs (Aisyah et al., 2022). With a variety of existing electronic devices, the design of the resulting teaching aids is more effective and efficient and has better accuracy of measurement and visualization results. With these electronic components, students have a great interest in learning, which can increase their ability to innovation and creativity.

Design

The design stage begins with designing the initial design of the props, called Phyiscs Digital Props. The following illustrates the design of IoT-based physics practicum props, shown in Figure 3 below.

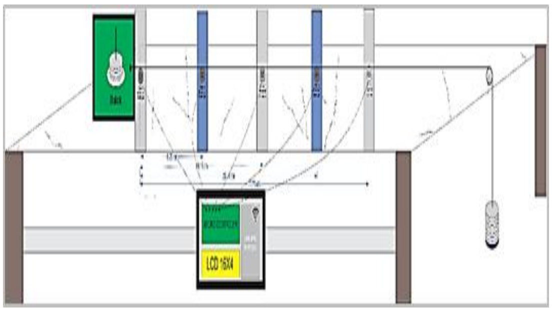

Figure 3. IoT-based props design

Illustration of the IoT-based props development architecture, shown in Figure 4 below.

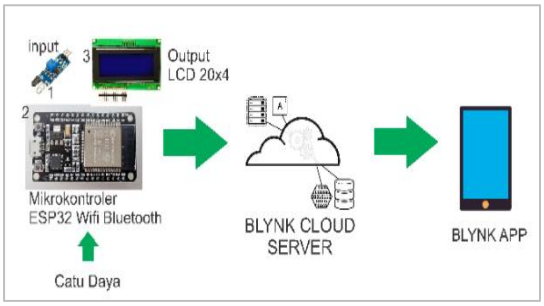

Figure 4. Architecture of IoT

The hardware consists of input in the form of an obstacle course infrared sensor, ESP32 Wi-Fi Bluetooth Microcontroller as the CPU programming the entire physics props system, and 20x4 LCD as the output display of infrared sensor readings. At the same time, the software itself is a Blynk cloud server as part of the output that reads the Wi-Fi ID sent by the EPS32 Microcontroller.

The next stage is sensor testing, ESP32 microcontroller programming, and testing the bylink app installed on the smartphone, shown in Figures 5, 6, and 7 below.

Figure 5. Obstacle sensor testing

Figure 6. Microcontroller programming

Figure 7. Testing bylink app installed on smartphones

The picture above shows the stages' results before the development and validation of teaching aids by media and material experts, teachers, and students.

Development

The development stage consists of two stages: the development stage and the validity test of teaching aids by media and material experts. The development stage, shown in the results of IoT-based teaching aids in Figure 8, follows.

Figure 8. Physics digital props

The stage of testing the validity of teaching aids by media and material experts involved five physics education lecturer experts. The following are the results of the media and material experts assessment, as shown below.

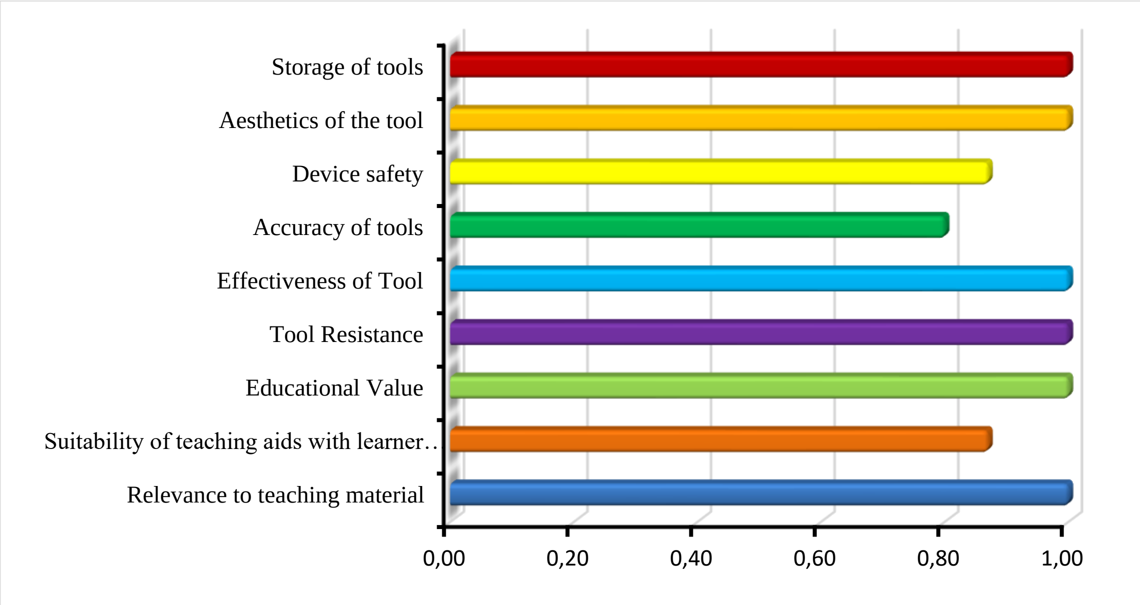

Figure 9. Aspects of expert validation assessment

Based on the graph above, when averaged, the validation results of IoT-based physics teaching aids are at 0.95 in the very valid category. The aspects rated 1 in the very valid category include aspects of relevance to teaching materials, the educational value of the props developed, the durability of tools, the effectiveness of tools, the aesthetics of tools, and the storage of tools. These results are also supported by previous research, which says that aspects of relevance to teaching materials, educational value, and effectiveness of teaching aids have a very valid media validation value (Nurjannah & Sucahyo, 2022; Oktafiani et al., 2017).

The assessment aspect of the accuracy of IoT-based props obtained a value of 0.80 in the valid category. The results obtained are caused by constraints on the sensitivity of the obstacle sensor readings during testing by the validator. The light intensity strongly influences the sensitivity of this sensor in the room where the test was conducted, supported by previous research conducted by Mukhlis in 2018, which states that the biggest obstacle using infrared sensors is when the signal is dark and bright, which will affect the sensitivity of the sensor (Subhan & Sucahyo, 2020; Muchlis et al., 2018; Pérez-Padillo et al., 2020). From the results of the validation carried out by this expert, the researcher then made improvements according to the input from the validator regarding sensor sensitivity. One of the actions researchers took was to change the sensor before testing it on students and teachers.

The suitability of teaching aids with the development of students is at a value of 0.87, with a very valid category. The results of this validation are supported by an initial analysis of the demands of the curriculum and an analysis of the needs of teaching aids conducted by researchers. While in the aspect of device security with a value of 0.87 in the category of highly valid. In the safety aspect of this device, the researcher re-designed the props to adjust to the safety level of the props designed. The re-design was carried out on the sensor holder model, which was originally integrated with the track and could not be disassembled so the holder could be disassembled. The purpose of re-designing the sensor holder model is to secure users (students) and facilitate the storage of props after use.

Implementation

At this stage, the researchers implemented the teaching aids that had been developed using the distribution of questionnaires to teachers and students. This implementation process consists of several stages, namely, the stage of introducing the specifications of the props developed, the stage of introducing the physics concepts used by the props, namely the physics concept of Newton's second law, the stage of testing by students and teachers, and giving questionnaires for the responses of students and teachers.

Figure 10. Stage of the introduction of props

Figure 11. Props trial

Evaluation

At this stage, researchers analyzed the results of the props trial from three aspects: validity, effectiveness, and practicality. To find out, distribute teacher and learner response questionnaires. The results of the teacher response recapitulation can be seen in the following figure,

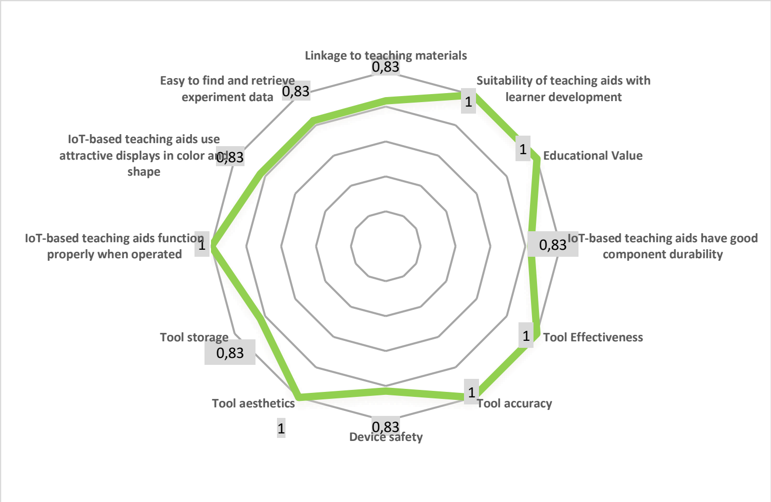

Figure 12. Recapitulation of teacher response

The figure above provides information on the teacher's response to the aspects of the props trial. Aspects with a very valid category include aspects of the suitability of teaching aids with the development of students, the educational value of teaching aids, the effectiveness of teaching aids, the accuracy of teaching aids when tested, the aesthetics of teaching aids, and teaching aids functioning when tested. During an interview with Nanik Yuliani, M.Pd (Physics Teacher) stated: "Several aspects stand out in this teaching aid, especially how the props developed can provide solutions to the limitations of conventional practicum props in constructing understanding in Newton's Law 2 material. Besides that, the props also attract students to operate them".

The results of students' responses to IoT-based physics practicum aids are presented in the following table.

Table 3. Recapitulation of students' response to props

No	Question	Value	Criteria
1	I am interested in learning physics using IoT-based teaching aids	0.75	Valid
2	Learning physics with props using IoT-based props is interesting and not boring	0.83	Very Valid
3	Learning with IoT-based teaching aids makes it easier for me to remember physics material and formulas.	0.72	Valid

No	Question	Value	Criteria
4	Learning with IoT-based teaching aids makes me more active and skilful.	0.67	Valid
5	Learning with IoT-based props gave me the experience of being an inventor like the scientists before me.	0.72	Valid
6	This IoT-based teaching aid is easy to maintain	0.68	Valid
7	IoT-based teaching aids function when operated	0.83	Very Valid
8	IoT-based teaching aids use attractive displays in colour and shape	0.86	Very Valid
9	IoT-based teaching aids have good component durability	0.89	Very Valid
10	Through IoT-based props, I find it easy to find and retrieve experimental data	0.78	Valid
	Average	**0.77**	**Valid**

Based on the table above, the average learner response to teaching aids is 0.77 in the valid category. The aspects of durability, attractive appearance, and props operate well and have very valid criteria with a value of 0.83. These results correspond to the advantages of IoT-based physics teaching aids, namely, the results of automatic time measurement and data from demonstration results can be observed directly, are durable, and the shape and colour are attractive (Muchlis et al., 2018). The aspect of learning physics with teaching aids makes learning interesting and not boring and has very valid criteria with a value of 0.83. This result is clarified by the advantages of IoT-based teaching aids that can present concepts (not complicate understanding) following learning concepts, and demonstrations aim to be the basis for the growth of students' conceptual thinking (Muchlis et al., 2018; Samsudin et al., 2019).

IoT-based physics teaching aids on particle dynamics material sub-concept of newton's law 2 are very feasible to use in the learning process and based on the results of teacher responses of 92% in the very practical category and student responses of 77% in the practical category used in teaching the concept of newton's law II. The results obtained are supported by similar previous research such as (Muchlis et al., 2018; Radiyono et al., 2022; Syahputra et al., 2022; Subhan & Sucahyo, 2020; Coletta et al., 2019) stated that the use of IoT-based physics practicum aids is feasible to use as physics practicum aids for newton's law 2 material.

IV. CONCLUSION AND SUGGESTION

Based on the calculations and research results, developing IoT-based physics practicum props based on the validation of props and instruments is feasible overall to use as a learning medium for particle dynamics physics material, especially Newton's Law 2.

Some suggestions that can be given for further development include: IoT-based teaching aids need to be supported by modules/guidebooks for the use of tools and practical modules, the ability of tools needs to be improved to be able to measure the concept of regular straight motion.

ACKNOWLEDGMENTS

Thank you to Universitas Islam Negeri Mataram, especially the Institute for Research and Community Service (LP2M), for providing research funding from BOPTN DIPA UIN Mataram.

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