

# Design and Development of a Running Speed Timer Device Using a Microcontoller-Based Internet of Things (IoT) System for Elementary Schools

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Submitted : 17 Desember 2025

Accepted : 30 Desember 2025

Published : 30 Desember 2025

## Abstract

**Background :** *The rapid development of Internet of Things (IoT) technology offers new opportunities to improve learning assessment in physical education. In elementary schools, running speed is still commonly measured using manual stopwatches, which are prone to human error and inefficiency. This condition limits the objectivity and accuracy of performance evaluation in physical education learning..*

**Objectives:** *This study aimed to design and develop a microcontroller-based IoT running speed timer device that can measure running time automatically and in real time for use in elementary school physical education.*

**Methods :** *This study employed a Research and Development (R&D) approach using a procedural model, consisting of needs analysis, product design, expert validation, revisions, small-scale trials, and large-scale trials. Validation involved media experts, theory experts, and physical education teachers, while field trials were conducted with elementary school students. Data were collected using questionnaires and feasibility assessments and analyzed using descriptive statistics.*

**Results :** *The validation results showed that the device achieved a feasibility score of 86% from media experts and 78% from theory experts. Small-scale trials yielded feasibility scores ranging from 78% to 96%, while large-scale trials across multiple elementary schools showed feasibility levels between 82% and 100%. These results indicate that the device is effective, practical, and suitable for real-time running speed measurement.*

**Conclusion:** *The developed IoT-based running speed timer device is feasible and effective for use in elementary school physical education, supporting accurate, efficient, and objective assessment of students' running performance.*

**Keywords:** IoT, Microcontroller, Physical Education, Running, Timer Device.

## **INTRODUCTION**

Advances in science and technology (IPTEK) have driven various innovations in the field of sports, including in competitive sports that require technological support to improve the effectiveness of training and evaluate athlete performance (Rizal et al., 2018). In the Merdeka Curriculum, physical education plays an important role in developing students' character and skills through a project-based learning approach (Pratiwi, Marlina, & Kurniawan, 2023). One essential branch is athletics, particularly running events, which heavily rely on speed, strength, and coordination (Rifaldi, Dewi, & Gemael, 2023). However, the process of evaluating running speed in elementary schools still largely relies on manual stopwatches, which are considered inaccurate and prone to human error (Hidayat, Darajatun, Setiawan, & Fakhriani, 2019). This situation impacts the quality of learning and assessment in physical education. Additionally, physical education teachers generally lack practical, digitally integrated tools to support data-driven evaluation processes.

Furthermore, existing technology-based running speed measurement tools have rarely been specifically developed by considering the characteristics of elementary school physical education, such as ease of use, safety, portability, and alignment with learning objectives. As a result, physical education teachers still face difficulties in implementing objective, real-time, and technology-assisted assessments that are suitable for elementary school students. This condition indicates a clear research gap, namely the limited availability of feasible and effective IoT-based running speed evaluation tools that are specifically designed to support objective assessment in elementary school physical education. Addressing this gap is important to support data-driven and objective assessment practices in line with current curriculum demands and technological advancement. The integration of IoT-based measurement tools in physical education has the potential to enhance assessment accuracy, reduce subjectivity, and improve the efficiency of learning evaluation processes.

Based on this rationale, the objective of this study is to design and develop an IoT-based running speed timer device that is feasible, practical, and effective for use in elementary school physical education. Specifically, this study aims to develop a device capable of measuring running speed automatically and in real time, and to evaluate its feasibility and effectiveness through expert validation and field trials in elementary school settings. As a solution, Internet of Things (IoT) technology offers an automatic and accurate time measurement system that can minimize subjectivity and improve efficiency (Gathan & Afrianto, 2023). Therefore, this study

aims to design and build a running speed time detection tool based on a microcontroller and IoT to support more modern and data-based physical education learning.

### **Internet of Things (IoT) in Sports**

The Internet of Things (IoT) is one of the rapidly developing technologies that has been widely utilized in the field of sports to enhance measurement accuracy, training efficiency, and the evaluation of athletes' and students' performance (Pambudhi & Krisnadi, 2020). In sports such as running, IoT-based devices can automatically and in real-time measure time, speed, and movement patterns, providing more objective data for evaluation purposes (Gathan & Afrianto, 2023).

### **Running**

Running or sprinting is an event in track and field that emphasizes maximum speed from start to finish. According to Nopiyanto & Raibowo (2020), it includes distances of 100 m, 200 m, and 400 m. Each sprint category has different physical and technical demands, ranging from rapid acceleration to sustained speed. Basic running techniques consist of three main components: starting technique, running technique, and finishing technique (Yasriuddin & Poppy Elisano, 2024). Starting technique involves the use of starting blocks and signals to prepare the runner for the initial push. Running technique involves coordinating the support and swing phases with an efficient body posture, while finish technique aims to maximize time in the final seconds of the race

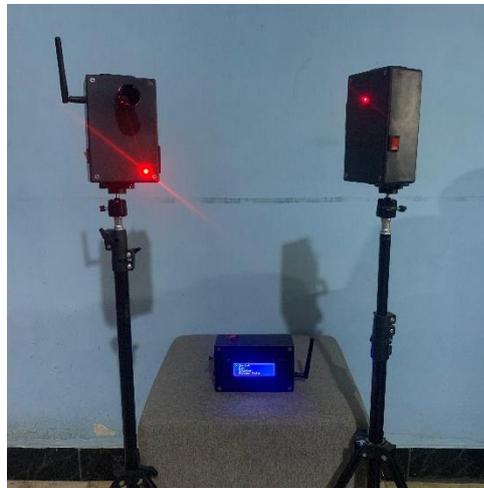
### **Time Measurement Systems in Sports**

Time measurement is a crucial aspect in sports, especially running, because the difference in results can be determined in milliseconds (Herman et al., 2021). Time measurement systems are divided into two main types, namely manual and automatic. Manual measurement uses a stopwatch operated by humans. This system is simple and cost-effective but prone to errors due to human subjectivity and reaction limitations. In contrast, automatic measurement uses technologies such as sensors, photo-finish cameras, and Internet of Things (IoT)-based systems. This system offers high accuracy, reduces human error, and can transmit and store data in real-time for performance evaluation (Hidayat et al., 2019). In this study, IoT is used to design an automatic time measurement system based on a microcontroller. The microcontroller plays a role in processing data from sensors, managing the IoT module, and regulating the entire system so that it can record running times accurately, efficiently, and in real-time.

## Product Specifications

This research developed a microcontroller-based running speed detector and Internet of Things (IoT) to support physical education evaluation in elementary schools. This device was designed using several main components, including:

1. 1.3-inch OLED LCD for displaying time information
2. A microcontroller as the system control center
3. Laser sensors and receivers to detect runners at the start and finish lines
4. An NRF24L01 wireless module for wireless data communication between components
5. An 18650 battery, charger module, and step-down converter for power supply
6. A module box and bracket as a protective casing.



**Figure 1.** Product Development of Running Speed Time Detection Device

The system's operation is based on an integrated wiring diagram and block diagram. The laser sensor captures the runner's movement signals, which are transmitted to the microcontroller for processing and real-time data transmission via the wireless module to the OLED display. The microcontroller also automatically controls the entire system, from data acquisition to measurement output. Calculations of the transmitter signal and sensor power indicate that the device can operate optimally up to a distance of 100 meters, and the laser sensor has an effective range of up to 6 km under ideal conditions.

The main issue in this study is the need to develop a more accurate, efficient, and relevant running speed detection tool for physical education in elementary schools. Therefore, the objective of this study is to develop a running speed time detection device based on microcontrollers and IoT technology that operates in real-time and is suitable for use in educational activities, particularly to support objective and data-driven assessment of student performance.

## METHODS

### Study Design

This study uses a Research and Development (R&D) design with a procedural model, in which the research stages are carried out in stages, starting from preliminary studies, product design, expert validation, revisions, limited trials, to more extensive field trials. This model was chosen because it is in line with the research objective of developing a valid, practical, and effective IoT-based running time detection tool for use in physical education in elementary schools.

The research was conducted at an elementary school in Pacitan Regency, in the subject of Physical Education, Sports, and Health (PJOK), during the period from April to June 2025.

### Research Subjects and Sample

#### 1. Expert Subjects

Comprising subject matter experts (PJOK teachers) and media experts (IoT/microcontroller technology practitioners) involved in validating the content and technical aspects of the tool.

#### 2. Test Subjects

Elementary school students actively participating in PJOK lessons and PJOK teachers. The sampling technique used was purposive sampling, with the criterion being the need for a real-time running evaluation tool.

### Research Instruments

The instruments used include:

1. Observation sheets to observe the needs and use of the tool in the field.
2. Expert and user validation questionnaires using a Likert scale with five rating categories.
3. Instruments designed to objectively measure the technical aspects, educational benefits, and operational ease of the tool.

### Data Analysis

The data was analyzed quantitatively using the percentage formula:

$$\text{Percentage of response} = \frac{\sum \text{Score of data obtained} \times 100\%}{\sum \text{Total score}}$$

Next, the percentage results are categorized based on eligibility criteria, as follows:

**Table 1.** Category Percentage of Suitability

No	Achievment Level	Qualification	Information
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1.	81-100%	Very good	Very suitable
2.	61-80%	Good	Suitable
3.	41-60%	Quite good	Less suitable
4.	21-40%	Not so good	Unsuitable
5.	<20%	Very poor	Very unsuitable

## RESULTS

This study was conducted in 12 elementary schools in Pacitan Regency, including SDN 1 Tambakrejo, SDN 2 Tambakrejo, SDN Ponggok, SDN Banjarsari, SDN Purworejo, SDN Menadi, SDN Mentoro, SDN Bangunsari, SDN Widoro, SD Integral Hajar Aswad, SDN 1 Ploso, and MI GUPPI Jatimalang to develop a microcontroller- and IoT-based running speed detection tool. The main problem found in the field was that physical education teachers still used manual stopwatches, which were prone to human error and ineffective in evaluating student performance. The development procedure followed the R&D research stages, including needs analysis, planning, prototyping, expert validation, and small- and large-scale trials. The device integrates a laser sensor, microcontroller, and wireless IoT module that can automatically record running times in real time.

### Media Expert Assessment

The tool was validated by media expert Mr. Tika Dedy Prastyo, M.Kom., a lecturer at STKIP PGRI Pacitan who specializes in microcontroller technology and IoT. The media expert assessment table is as follows.

**Table 2.** Media Expert Assessment Data Tabulation

No	Statement	Very Good	Good	Quite Good	Not So Good	Very Poor	Total
1	This tool helps coaches measure running speed more accurately.	v					5
2	This tool can replace the use of manual stopwatches in training sessions.	v					5
3	The tool's reaction time (finish) is tailored to running needs.		v				4
4	The time data generated can be used to evaluate athlete performance.	v					5
5	This tool is easy to use in open fields by coaches and beginner athletes.		v				4
6	The design and shape of the tool are practical and safe to use in routine training sessions.	v					5

No	Statement	Very Good	Good	Quite Good	Not So Good	Very Poor	Total
7	This device can support ongoing athlete development programs	v					5
8	The device can be used in various sprint events (100m, 200m, etc.) without interference	v					5
9	The measurement results from this device make it easier for coaches to analyze athletes' progress	v					5
10	Coaches can quickly understand how the device works and the procedures for operating it	v					5
<b>Total Scores Obtained</b>							43
<b>Total Scores</b>							50
<b>Percentage of Responses</b>							86%

*Source: Primary Data*

Based on the assessment results of 10 indicators of effectiveness, efficiency, practicality, and technical feasibility, the tool scored 43 out of 50, or 86%, with a rating of “Highly Feasible.” Experts assessed that the tool is functionally and visually sound, capable of replacing manual stopwatches, easy to use, and supports digital and efficient physical education learning. This validation reinforces that the tool is suitable for further testing and development as a technology-based learning innovation in elementary schools.

### **Theory Expert Assessment**

The assessment was conducted by Bripka Gatot Dwi Ananto, S.H., Chairman of PASI Pacitan Regency and athletics coach. Based on an evaluation of 10 indicators, the running speed detection device scored 39 out of 50 or 78%, with a rating of “Suitable.” The device was deemed sufficiently effective, efficient, and practical for use in physical education training and learning. However, further improvements are still needed to optimize the device's performance and functionality in supporting the evaluation of running speed.

### **Media Expert Assessment**

After the running speed detector was assembled, it underwent a validation process by subject matter experts, namely experienced physical education teachers at the elementary school level. The validation used a questionnaire that had been approved by two expert lecturers, covering indicators of functionality, usability, and feasibility.

#### 1. Small-Scale Trial

**Table 3.** Tabulation of Data Assessment of Material Experts on a Small Scale

No	Statement	Small-Scale Tool Trial			
		SD N 1 Tambakrejo	SD N 2 Tambakrejo	SD N Ponggok	SD N Banjarsari
1	This tool is relevant to the physical education learning objectives in elementary schools.	5	5	4	5
2	The tool can improve the effectiveness of evaluating students' running speed.	4	4	5	4
3	The tool helps teachers record running speed times more accurately.	4	3	5	5
4	Using this tool simplifies the process of recording running speed times compared to a manual stopwatch.	3	4	5	5
5	The design of the tool is suitable for the characteristics of elementary school students.	3	3	5	4
6	This tool supports the implementation of the Merdeka Curriculum in Physical Education.	5	5	5	4
7	The tool supports innovative, engaging, and contextual learning in physical education.	5	5	4	5
8	This tool can be used for both practice sessions and practical running exams.	4	3	5	5
9	The instructions for using the tool are clear and easy to understand for Physical Education teachers.	4	4	5	4
10	This tool is suitable for widespread implementation in elementary schools as part of the learning evaluation process.	3	3	5	4
<b>Total Scores Obtained</b>		40	39	48	45
<b>Total Score</b>		50	50	50	50
<b>Response Percentage</b>		80%	78%	96%	90%
<b>Criteria</b>		<b>Suitable</b>	<b>Suitable</b>	<b>Very Suitable</b>	<b>Very Suitable</b>

Source: Primary Data

The small-scale trial was conducted in four elementary schools: SDN 1 Tambakrejo, SDN 2 Tambakrejo, SDN Ponggok, and SDN Banjarsari. The assessment results showed that the tool was rated as acceptable to very acceptable, with response rates ranging from 78% to 96%. The highest score was given by SDN Ponggok (96%). Some indicators that need improvement are the design of the tool, the clarity of the instructions for use, and the feasibility of widespread implementation.

## 2. Large-Scale Trial

**Table 4.** Tabulation of Data Assessment of Material Experts on a Large Scale

No	Statement	Large-Scale Equipment Testing							
		SD N Purworejo	SD N Menadi	SD N Mentoro	SD N Bangunsari	SD N Widoro	SD Integral Hajar Aswat	SD N 1 Ploso	MI GUPPI Jatimalang
1	This tool is relevant to the physical education learning objectives in elementary schools.	5	5	5	5	5	5	5	5
2	The tool can improve the effectiveness of evaluating students' running speed.	4	4	4	5	4	4	5	5
3	The tool helps teachers record running speed times more accurately.	4	4	4	4	4	4	5	4
4	Using this tool simplifies the process of recording running speed times compared to a manual stopwatch.	5	5	4	4	4	5	5	4
5	The design of the tool is suitable for the characteristics of elementary school students.	4	4	3	5	5	4	5	4
6	This tool supports the implementation of the	4	4	4	5	4	5	5	4

		<b>Large-Scale Equipment Testing</b>							
<b>No</b>	<b>Statement</b>	<b>SD N Purworejo</b>	<b>SD N Menadi</b>	<b>SD N Mentoro</b>	<b>SD N Bangunsari</b>	<b>SD N Widoro</b>	<b>SD Integral Hajar Aswat</b>	<b>SD N 1 Ploso</b>	<b>MI GUPPI Jatimalang</b>
	Merdeka Curriculum in Physical Education.								
7	The tool supports innovative, engaging, and contextual learning in physical education.	5	5	4	5	4	5	5	4
8	This tool can be used for both practice sessions and practical running exams.	5	5	4	4	4	4	5	4
9	The instructions for using the tool are clear and easy to understand for Physical Education teachers.	4	4	5	5	5	5	5	4
10	This tool is suitable for widespread implementation in elementary schools as part of the learning evaluation process.	5	5	4	4	4	5	5	4
<b>Total Scores Obtained</b>		45	45	41	46	43	46	50	42
<b>Total Score</b>		50	50	50	50	50	50	50	50
<b>Response Percentage</b>		90%	90%	82%	92%	86%	92%	100%	84%

		<b>Large-Scale Equipment Testing</b>							
<b>No</b>	<b>Statement</b>	<b>SD N Purworejo</b>	<b>SD N Menadi</b>	<b>SD N Mentoro</b>	<b>SD N Bangunsari</b>	<b>SD N Widoro</b>	<b>SD Integral Hajar Aswat</b>	<b>SD N 1 Ploso</b>	<b>MI GUPPI Jatimalang</b>
<b>Criteria</b>		<b>Very Suitable</b>	<b>Very Suitable</b>	<b>Very Suitable</b>	<b>Very Suitable</b>	<b>Very Suitable</b>	<b>Very Suitable</b>	<b>Very Suitable</b>	<b>Very Suitable</b>

*Source: Primary Data*

The Large-Scale Trial was conducted in eight elementary schools: SDN Purworejo, SDN Menadi, SDN Mentoro, SDN Bangunsari, SDN Widoro, SD Integral Hajar Aswat, SDN 1 Ploso, and MI GUPPI Jatimalang. The results showed that all schools scored above 80%, with a percentage range of 82%–100%. SDN 1 Ploso achieved a perfect score of 100%, indicating that all indicators were rated very good. All schools stated that the tool is highly suitable for use in PJOK evaluation.

## **DISCUSSION**

The results of this study indicate that the developed IoT-based running speed timer device is feasible and effective for use in elementary school physical education learning. Expert validation and field trials demonstrate that the device is capable of measuring running speed automatically, accurately, and in real time, thereby addressing key limitations associated with manual stopwatch-based assessment. These findings support previous studies that emphasize the superiority of technology-assisted measurement tools in improving accuracy and reducing human error in sports performance evaluation. Several earlier studies have reported the development of automatic running speed measurement devices using microcontrollers, sensors, or laser-based systems. However, most of these tools were designed for competitive sports contexts, laboratory testing, or higher education environments, which limits their direct applicability in elementary school settings. Compared to these previous tools, the product developed in this study offers a more pedagogically relevant design by prioritizing simplicity, portability, safety, and ease of use, which are critical factors in elementary school PJOK learning. This distinction confirms the innovative value of the product, as it bridges the gap between technological sophistication and classroom practicality.

From the perspective of PJOK learning evaluation theory, effective assessment should be objective, valid, reliable, and efficient, while also supporting formative learning processes. Manual stopwatch measurement often fails to meet these criteria due to its dependence on teacher reaction time and subjective judgment. The IoT-based timer device developed in this study aligns with contemporary evaluation principles by providing objective and consistent measurement results that can be used as reliable performance data. This supports the theory that technology integration in assessment enhances measurement validity and strengthens evidence-based decision-making in physical education. The pedagogical implications of this innovation are significant. By using an automated and real-time measurement system, teachers can focus more on observing movement quality and providing instructional feedback rather than on

technical timekeeping. This shift supports formative assessment practices, where evaluation is not only used to measure outcomes but also to guide learning and skill development. Furthermore, the availability of accurate performance data allows teachers to monitor student progress over time, supporting individualized learning and differentiated instruction.

In addition, the integration of IoT technology into PJOK learning promotes digital literacy and introduces students to technology-enhanced learning environments at an early age. This aligns with current curriculum directions that emphasize the integration of technology and data-driven learning. Compared to similar tools reported in previous studies, the product developed in this research demonstrates innovative advantages in terms of real-time data transmission, operational efficiency, and adaptability to school conditions, thereby strengthening its contribution to both educational practice and sports technology development. Overall, this study confirms that the developed IoT-based running speed timer device is not only technically feasible but also pedagogically meaningful. By linking physical performance measurement with evaluation theory and classroom needs, the product contributes to the advancement of objective, efficient, and innovative assessment practices in elementary school physical education.

The microcontroller- and IoT-based running speed detection device was found to be effective in recording the running times of elementary school students. Small-scale and large-scale trials, as well as expert validation of the material and media, showed that this device is suitable for use in physical education classes. Physical education teachers assessed that this device helps reduce manual recording errors and improves evaluation efficiency. This study aligns with Hidayat et al. (2019), who developed an automatic running speed measurement device based on Arduino Uno and ultrasonic sensors, and Rahmat et al. (2016), who used phototransistors and lasers connected to a PC. Compared to these two studies, this tool is superior in terms of portability and ease of use because it is integrated with IoT, making it more suitable for elementary school environments.

## **CONCLUSION**

This study aims to develop a microcontroller-based running speed detection tool using Internet of Things (IoT) technology as a solution to the limitations of manual measurement using a stopwatch in physical education at elementary schools. This tool is designed to automatically and instantly (real-time) record running times, thereby improving accuracy, efficiency, and reducing subjective errors by teachers during the evaluation process. Based on

validation results from media experts (86%), theoretical experts (78%), and subject matter experts through small-scale trials (78%–96%) and large-scale trials (82%–100%), the device was deemed suitable to highly suitable for use in physical education instruction at elementary schools. This tool can automatically record time in real-time, support a more objective evaluation process, and has the potential for widespread application in elementary education institutions. These results indicate that the IoT-based running speed time detection tool has significant potential for widespread use in physical education learning at the elementary school level.

### ACKNOWLEDGMENTS

The author would like to express gratitude to his beloved parents and family for their prayers and support, their beloved partner who assisted in this research, their academic advisor for their guidance and direction, the school administration for facilitating this research, as well as their friends and classmates from the Physical Education, Health, and Recreation program, Class B, 2021, for their enthusiasm and camaraderie, which made it possible for this research to be successfully completed.

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