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# The Effect of an IoT-Based DC Power Measurement Instrument Utilizing Arduino NodeMCU on the Outcomes of Basic Physics Laboratory Practicum

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**Abstract:** In Basic Physics instruction, especially in laboratory experiments involving direct current (DC) circuits, accurate and efficient power measurement tools are essential. However, traditional instruments often lack the capability for real-time data analysis, leading to measurement inaccuracies and delays. This study aims to develop and implement an Internet of Things (IoT)-based power measurement tool using Arduino NodeMCU, which allows real-time data transmission and processing via Wi-Fi. By integrating current and voltage sensors, the tool enables more precise and accessible DC power measurements to support educational activities. Employing a one-group pretest-posttest quasi-experimental design with 12 students enrolled in a Basic Physics Laboratory course, the study assessed the effectiveness of the tool through pretest-posttest scores, student questionnaires, and observations. Normality tests (Shapiro-Wilk) confirmed a normal distribution for both pretest ($p = 0.262$) and posttest ($p = 0.284$) scores. A pair

**Keywords:** IoT; Arduino; Power Measurement; Physics Education; N-Gain.

## Introduction

Measuring electrical power in direct current (DC) circuits is a fundamental activity in Basic Physics laboratory sessions. However, this process often faces several challenges, especially due to the limitations of conventional measuring instruments. Manual tools not only require a relatively long time to operate but are also prone to reading errors, low precision, and delays in data recording (Permatasari et al., 2019). These issues reduce the accuracy of experimental results and can hinder students' understanding of the underlying physical concepts.

In response to these problems, the integration of Internet of Things (IoT) technology offers a promising solution. IoT enables the connection of hardware components such as current and voltage sensors to a microcontroller—specifically, the NodeMCU Arduino platform—equipped with Wi-Fi connectivity. This setup allows power measurements to be conducted automatically and in real time, with data transmitted directly to digital platforms for immediate analysis. Such innovation not only improves measurement efficiency and data accuracy but also supports technology-enhanced learning, which is increasingly emphasized in higher education curricula.

By developing an IoT-based DC power measuring device (Pertiwi et al., 2021), students are expected to focus more on grasping the core physics principles without being burdened by complicated measurement procedures. Moreover, the integration of modern digital tools into laboratory activities provides practical experiences that align with advancements in

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the industrial and technological sectors. This research is therefore significant, as it contributes to enhancing the quality of Basic Physics education and paves the way for further innovation in the development of adaptive and technology-driven measurement tools suitable for the demands of education in the digital era (Ummah, 2019).

## Method

### Type and Design of Research

This study is a quantitative research using a quasi-experimental design, specifically the One Group Pretest-Posttest Design. This design involves a single group of participants who are given a pretest before the intervention and a posttest after the intervention (Ardianti & Raida, 2022).
The aim is to determine any significant changes or improvements in students' understanding of the concepts after using the developed learning tool in the physics laboratory. The design is illustrated as follows:

$$\mathbf{O1 \rightarrow X \rightarrow O2} \quad \ldots\ldots\ldots \ (1)$$

Explanation:

- **O1** = Pretest (initial test to assess students' prior understanding)
- **X** = Treatment (use of the developed instructional tool in the physics practicum)
- **O2** = Posttest (final test to assess students' understanding after the treatment)

### Research Subjects

The subjects of this study are students enrolled in the Basic Physics Laboratory course at Physics education, FKIP, University of Muhammadiyah Mataram. The selection of participants uses purposive sampling based on the following criteria: Active students currently enrolled in the Basic Physics Laboratory course, Students who have not previously used the developed tool, Willingness to participate in all stages of the research. The number of participants is determined based on the available class size for the practicum session.

### Research Instruments

The instruments used in this study include:

**Pretest and Posttest**
These are multiple-choice or short-answer tests designed to assess students' conceptual understanding before and after using the tool. The test items are validated by subject matter experts.

**Student Response Questionnaire**
This questionnaire is used to gather students' feedback on the tool, particularly in terms of usability, conceptual clarity, and engagement during the practicum.

**Observation Sheet** (optional)
Used to record student engagement and behavior during the practicum, such as activeness, accuracy in using the tool, and group collaboration.

### Research Procedures

The research is conducted in the following stages:

**Preparation Stage**

- Development of research instruments (pretest, posttest, questionnaire, observation sheet).
- Instrument validation by experts and small-scale trial.
- Scheduling of the practicum sessions.

**Implementation Stage**

- Students take the **pretest** to assess their initial understanding.
- Students carry out the **practicum using the developed tool**.
- Students complete the **posttest** to assess their conceptual improvement.
- Students fill out the **questionnaire** to provide feedback on the use of the tool.

**Data Analysis Stage**

- Processing and analyzing the pretest and posttest results.
- Calculating normalized gain (N-Gain) scores to evaluate learning improvement.
- Descriptive analysis of the questionnaire and observation data.

### Data Analysis Techniques

The collected data are analyzed using the following techniques:

**Normality Test**
To determine whether the pretest and posttest scores are normally distributed (e.g., using the Shapiro-Wilk test).

**Paired Sample t-Test** (Ayu Permata Sari et al., 2023)**/ Wilcoxon Test** If data are normally distributed: a **paired sample t-test** is used to examine the significance of the difference between pretest and posttest scores, If data are not normally distributed: a **Wilcoxon signed-rank test** is used as a non-parametric alternative.

**Normalized Gain (N-Gain) Calculation**
To determine the effectiveness of the intervention, N-Gain is calculated using the formula:

$$\text{N-Gain} = \frac{\text{Posttest score} - \text{Pretest score}}{\text{Maximum score} - \text{Pretest score}}$$

Interpretation of N-Gain values:

- N-Gain < 0.3: Low
- 0.3 ≤ N-Gain ≤ 0.7: Medium
- N-Gain > 0.7: High

Descriptive Analysis of Questionnaire Data
Questionnaire responses are analyzed descriptively to capture students' perceptions regarding the

effectiveness of the developed tool in enhancing their learning.

## Result and Discussion

The use of learning aids in the Basic Physics practicum led to measurable improvements in students' conceptual understanding. The following table summarizes the core findings:

| Indicator | Result |
|---|---|
| Average Pretest Score | 47.8 |
| Average Posttest Score | 73.9 |
| Average N-Gain Score | 0.565 (medium category) |
| Number of Students with High N-Gain | 3 students |
| Average Student Response Score | 84.5 (positive response) |

Table 1. presents the complete data on pretest scores, posttest scores, N-Gain values, N-Gain categories, and students' response scores

| No | Student Name | Pretest | Posttest | N-Gain | N-Gain Category | Response |
|---|---|---|---|---|---|---|
| 1 | Suratman Azuardi | 65 | 80 | 0.429 | Medium | 86 |
| 2 | Alfarizi | 70 | 90 | 0.667 | Medium | 92 |
| 3 | Tirta Wati | 55 | 75 | 0.444 | Medium | 85 |
| 4 | Hardianti | 60 | 85 | 0.625 | Medium | 87 |
| 5 | Erik Mulandas | 70 | 80 | 0.333 | Medium | 96 |
| 6 | Putri Dewi | 65 | 90 | 0.714 | High | 82 |
| 7 | Rifal Sucisno Saputra | 55 | 80 | 0.556 | Medium | 84 |
| 8 | Syamsul Pahmi | 50 | 95 | 0.900 | High | 87 |
| 9 | Anis | 65 | 80 | 0.429 | Medium | 80 |
| 10 | Widiawati | 50 | 90 | 0.800 | High | 80 |
| 11 | Ririn Arianti | 60 | 85 | 0.625 | Medium | 82 |
| 12 | M. Sahid | 55 | 75 | 0.444 | Medium | 83 |

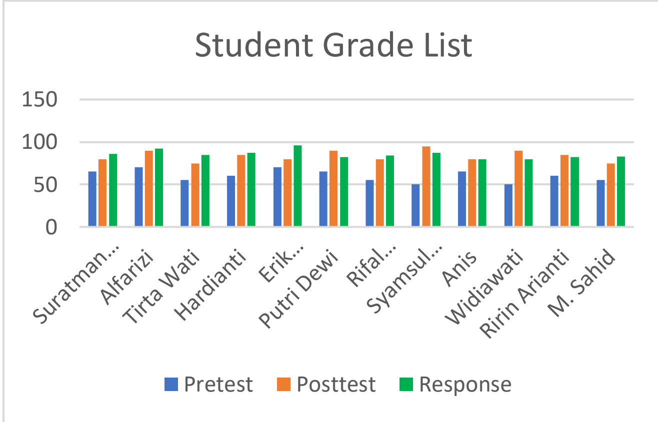


Figure 1. Students Grade List

### N-Gain Analysis

The N-Gain value was used to measure the improvement in students' conceptual understanding after the learning intervention. It is calculated using the formula:

$$\text{N-Gain} = \frac{\text{Posttest score} - \text{Pretest score}}{\text{Maximum score} - \text{Pretest score}}$$

are as follows:

- N-Gain < 0.3: Low
- 0.3 ≤ N-Gain ≤ 0.7: Medium
- N-Gain > 0.7: High

Based on the results:

- Number of students with High N-Gain: 3 (25%)
- Number of students with Medium N-Gain: 9 (75%)
- No students with Low N-Gain

The average N-Gain score for all participants is: 0.565
This value indicates that, on average, the improvement in conceptual understanding is within the **medium** category.

### Student Response Analysis

As part of the evaluation instruments, students were asked to fill out a response questionnaire regarding the use of the practicum learning aid (Verawati et al., 2022). Response scores ranged from 80 to 96. The average response score is calculated as:
Average=84.5
This average indicates that students gave a **positive** response to the learning aid used. The highest response was given by Erik Mulandas (96), while the lowest was shared by Anis and Widiawati (80).

### Discussion

The improvement in students' understanding, indicated by a medium average N-Gain score of 0.565, suggests that the learning aids significantly contributed to conceptual change. Hake (1998) emphasized that a medium N-Gain (0.3 < g < 0.7) reflects effective learning outcomes in physics education, particularly when active learning strategies are utilized. The consistent rise in posttest scores for all participants implies that the intervention provided meaningful conceptual scaffolding.

Notably, three students—Putri Dewi, Syamsul Pahmi, and Widiawati—achieved high N-Gain scores. This finding is significant because these students initially had low pretest scores, indicating that the learning aids were especially beneficial in supporting struggling learners. This aligns with Vygotsky's (1978)(Ummah, 2019) theory of the Zone of Proximal Development (ZPD), which argues that students can reach higher levels of understanding with appropriate guidance and tools.

Student perception, as captured in a response score averaging 84.5, also supports the effectiveness of the learning aid. Students found the aids engaging, clear, and easy to use. Mayer (2005) (Mulyaningsih & Saraswati, 2017) stated that multimedia learning materials that integrate visuals, interactivity, and relevant content tend to promote deeper understanding and retention. These features were embedded in the designed learning aids, likely contributing to students' positive feedback.

The hands-on and contextual nature of the practicum also played a key role. According to Piaget (1972)(Ummah, 2019), students learn best through active exploration and experience. In this study, students were encouraged to make predictions, test hypotheses, and analyze results, which provided a meaningful connection between theory and practice. This finding is supported by Novak and Gowin (1984) (Hes & Reider, 1985), who emphasized that concept mapping and hands-on tools can significantly enhance science learning.

Moreover, the results of this study are in line with (Islahudin et al., 2021) and (Isnaini et al., 2022), who found that innovative learning tools in science education increase student motivation and engagement. Motivation is a key factor in learning success, and students who are more involved are more likely to persevere in understanding complex concepts. Similarly, (Ardianti & Raida, 2022) reported that practical-based and student-centered learning models can strengthen students' problem-solving and critical thinking abilities—skills that are essential in physics learning.

## Conclusion

Based on the results and discussions of this study, the following conclusions can be drawn: 1) The use of instructional tools in the Basic Physics practicum has been proven effective in enhancing students' conceptual understanding. This is evidenced by the increase in posttest scores compared to pretest scores for all participants; 2) The average N-Gain value of 0.565 indicates a moderate level of improvement in conceptual understanding. A total of 75% of students achieved a moderate N-Gain category, while the remaining 25% reached the high N-Gain category; 3) Student responses to the practicum learning tool were highly positive, with an average response score of 84.5. This suggests that students found the tool helpful, clear, and engaging during the learning process; 4) The developed instructional tool provided an interactive and contextual learning experience, encouraged active student participation, and supported a constructivist approach to science education; 5) Specifically, the integration of Internet of Things (IoT) technology in the instructional tool effectively addressed the problems related to time, accuracy, and precision in measuring direct current (DC) electric current. The IoT-based system enabled real-time monitoring, minimized human error, and improved the reliability of measurement data during the practicum.
Therefore, the IoT-based instructional tool is suitable for broader implementation in Basic Physics practicum sessions and serves as an innovative and effective alternative to enhance students' conceptual understanding in physics.

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