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The effectiveness of arduino Uno-Based digital magnetic field demonstrators to improve high school students' understanding

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ABSTRACT

The study addresses the challenges often associated with the abstract nature and mathematical complexity of physics, particularly in relation to the concept of magnetic fields. To facilitate visual learning, the study aims to assess the efficacy of a teaching aid centered around a toroid, the researcher developed using Arduino Uno and Hall effect sensors. The research employs a quantitative one-group pretest-posttest design, measuring outcomes through test scores and student questionnaires. The N-Gain test indicates a moderate increase in student understanding concept. The results of the analysis of student responses through questionnaires had shown that students had found it easier to understand the magnetic field material when using Arduino-based magnetic field teaching aids, and the learning media used had made it easier for students to remember the magnetic field material. The findings support the effectiveness of the Arduino Uno-based digital magnetic field teaching aid in improving students' understanding of toroidal magnetic fields.

Keywords: Arduino Uno, Hall Effect Sensor, Magnetic Field, Toroid.

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INTRODUCTION

The learning process had always presented challenges in achieving goals. Teachers were expected to be creative in formulating learning activities and media used in delivering materials. Challenges in learning had been encountered when students experienced difficulties. Another study had also stated that students' difficulties in learning physics lay in their difficulties in calculating, understanding concepts, and understanding physics formulas (Nurmala, n.d.). From these two studies, it had turned out that students assumed that physics learning was only about formulas, memorization, and mathematical operations. While physics should have been more than that, containing its application in life, so that students realized that physics was close and around us. The physics knowledge received by students had still been abstract and could not be made clearer and contextual. Contextual learning had been closely related to learning methods and media. Learning media had been a solution to students' difficulties in understanding material that was difficult to imagine. With the material presented clearly and coherently and the simulation in the learning media, students had found it easier to understand physics material .Research conducted by (Mariasa et al., 2019) had also stated that learning media could effectively improve the mastery of physics concepts in grade XII high school students.

In addition, (Liza, 2021) had also stated that learning media could improve interest and learning outcomes in physics in grade XII students. One of the physics materials that had been considered abstract had been the magnetic field. The magnetic field could not be seen directly but had required the help of tools to visualize it. This had been in line with the results of observations carried out by (Astuti et al., 2021) at SMA Negeri 4 Semarang, which had stated that 74% of grade XII students had answered that the magnetic field had been the most difficult material to understand. Based on these problems, learning media had been needed that could help students understand the magnetic field material, especially to study the magnetic field around a circular wire with current, solenoids, and toroids. In this study, the development of a magnetic field learning media on a toroid had been carried out with the help of Arduino Uno. Toroids had been chosen because toroids had been one of the important components in several electronic devices, for example speakers and other loudspeakers. So it had been important to build students' understanding that had been appropriate, systematic, and good both physically and mathematically (Setyaningsih & Harijanto, 2018).

The understanding built by students had to be supported by the learning tools used by the teacher. Using practical and easy-to-use media had certainly also had a significant effect on the process of students understanding learning materials. In this study, we had used an Arduino Uno which had been directly connected to the LCD so that the detected magnetic field value would be read in microtesla units. Students had then found the relationship between variables that had influenced the magnetic field value. Research conducted by (Afa et al., 2023) had stated that the use of Arduino-based magnetic field meter learning media had effectively improved the physics learning outcomes of high school students. The tool used to detect magnetic fields had been a Hall Effect sensor. The Hall Effect Sensor had aimed to show the relationship between the strength of the magnetic field/magnetic induction (B) and the radius of the wire coil (a) and the number of wire coils (N) (Putri et al., 2022).

RESEARCH METHODS

The research design used in that study had been a one-group pretest posttest design. This research design had been a quantitative research design that was included in one of the pre-experimental methods. The pre-experimental research method with this type of design had been used to analyze the effect of independent variables on dependent variables. That study had involved one group of subjects without a control class, because the research test had been seen from the comparison of the results of the pre-test and post-test of the study. The pre-test (O1) had been a written test conducted before the experiment while the post-test (O2) had been a written test conducted after the experiment. The difference in results obtained between O1 and O2 had been considered the effect of treatment (experiment).

Pretest	**Treatment**	**Posttest**
O_1	X	O_2

Figure 1. Research one-group pretest posttest design

Description:

O1 = Pre-test (initial test) before treatment is given

O2 = Post-test (final test) after treatment is given

X = treatment for the experimental group, namely by implementing target games in physical education learning

RESULT AND DISCUSSION

The magnetic field measuring instrument around the toroid had been designed using an Arduino circuit to make it easier for students in the learning process. The results that appeared were digital numbers so that students could immediately find out the magnetic field strength value by reading. With the existence of digital-based teaching aids like this, it had reduced students' perceptions about the difficulty of calculations in learning physics as stated by (Rizti Yovan & Kholiq, 2021) that the facts in the field showed that learning physics is still considered difficult.

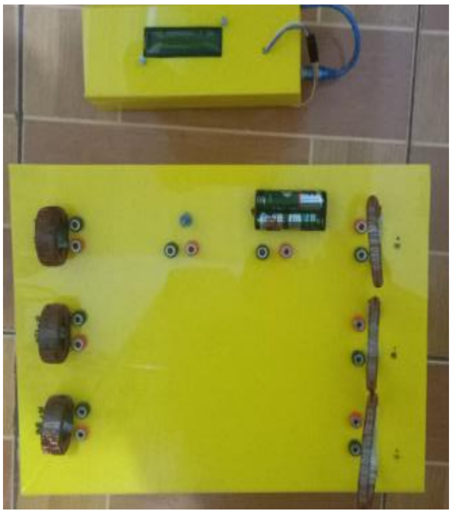

Figure 2. Arduino Uno-Based Magnetic Field Demonstration Tool

The magnetic field prop around the toroid had been tested on 12th-grade students at a high school located in West Bandung Regency with 28 participants. Learning had been carried out using the discovery learning model, starting with providing stimulus then the process of finding relationships between variables through experiments, until students were able to draw conclusions about the relationship between these variables.

Table 1. Summary result of *Pre-Test* and *Post-Test*

Tes	N	Nilai Min.	Nilai Max.	Mean	Std. Deviation	N-Gain	Interpretation
Pre-Test	28	0	65	12,68	14	0,3	Medium
Post-Test	28	10	80	37,50	17		

After the normality test, it had been known that the 28 data were normally distributed based on the results of the Komogorov-Smirnov test using SPSS.

One-Sample Kolmogorov-Smirnov Test

		PreTest	PostTest
N		28	28
Normal Parameters[a,b]	Mean	12.68	37.14
	Std. Deviation	14.239	18.024
Most Extreme Differences	Absolute	.360	.134
	Positive	.360	.116
	Negative	-.187	-.134
Test Statistic		.360	.134
Asymp. Sig. (2-tailed)		.000[c]	.200[c,d]

a. Test distribution is Normal.

b. Calculated from data.

c. Lilliefors Significance Correction.

d. This is a lower bound of the true significance.

Figure 3. Normality Test Results

After it had been known that the data were normally distributed, hypothesis testing had been carried out to determine whether there was an increase in student understanding of magnetic field material after being given learning using these teaching aids. The results of the hypothesis test can be seen in the Figureure below

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PreTest	12.68	28	14.239	2.691
	PostTest	37.14	28	18.024	3.406

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	PreTest & PostTest	28	.594	.001

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	PreTest - PostTest	-24.464	14.928	2.821	-30.253	-18.676	-8.672	27	.000

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NPAR TESTS
  /K-S(NORMAL)=Pretest Postest
  /STATISTICS DESCRIPTIVES
  /MISSING ANALYSIS.
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Figure 4. Hypothesis Test Results

The Figureure above shows the results of a difference test using a significance level of 5%. The null hypothesis (H0) stated that there had been no improvement in students' understanding before and after the learning process, while the alternative hypothesis (Ha) stated that there had been an improvement in students' understanding before and after the learning process. The significance value obtained from the Figureure had been 0.000, which was smaller than the significance level of 0.05; therefore, in accordance with the t-test rules, H0 had been rejected, and Ha had been accepted. This result indicated that there had been an improvement in students' understanding after being provided with instruction using magnetic field teaching aids around an Arduino-based toroid.

The improvement in students' understanding at this stage had been measured using the N-Gain test. The results, as shown in Table 1 above, had indicated an increase in the pretest scores compared to the posttest scores, with a value of 0.3, which fell within the medium category. Based on the analysis of students' responses, with this moderate improvement in understanding, students had already been able to identify the variables that affected the strength of the magnetic field around the toroid. Additionally, students had also been able to analyze the relationships between these variables. However, the area where improvement had still been low was in graph analysis. The test results had shown that most students had not yet been able to analyze the presented graphs.

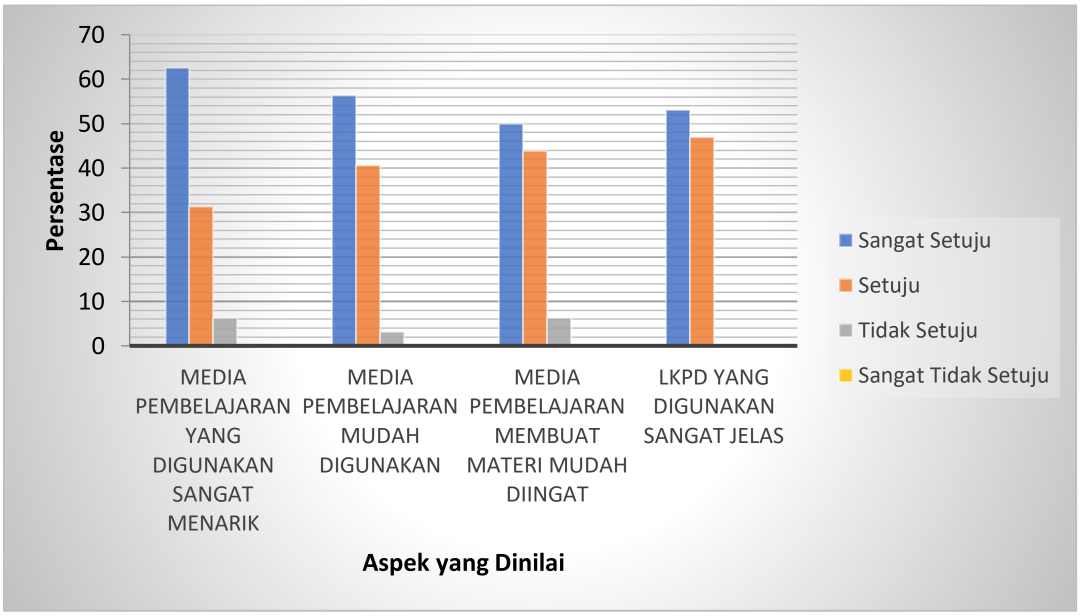

Figure 5. Students' Response Questionnaire Results

In addition to being measured qualitatively using a test instrument, the researcher had also administered a questionnaire to assess students' interest in learning after being taught using the teaching aids. Based on the analysis of students' responses to the questionnaire, more than 50% had strongly agreed that the instructional media used had been very engaging. The use of digital systems in the teaching aids had made the learning process easier for students, as supported by 56.3% of students who had strongly agreed that the learning media had been easy to use. The minimal mathematical calculations in this lesson had made the material less challenging for students, allowing it to be more easily remembered, as reflected in the questionnaire results where 50% had strongly agreed that the learning media had made the material easier to recall. This achievement had not been separated from the teaching tools, including the Student Activity Sheets (LKPD) that had been used. All students had responded that the LKPD provided had been clear.

The use of instructional media has been able to assist students in understanding the material. However, aside from that, the magnetic field teaching aids had not only helped students comprehend the basic concept of the magnetic field but had also assisted in demonstrating the existence of a magnetic field around a current-carrying wire (Harijanto Alex et al., 2023). Nonetheless, the media that had been developed still had limitations and drawbacks. The magnetic field teaching aids around the toroid had been designed using a Hall effect sensor, with the results displayed in digital form. The Earth's magnetic field strength had influenced the actual value of the magnetic field generated by the toroid, so during data collection, the recorded values had needed to be adjusted by subtracting the Earth's magnetic field strength in that location. Moreover, its use had required a stable sensor to produce accurate results.

CONCLUSION

Based on the results of the trial on grade 12 students at one of the high schools in West Bandung Regency, it could have been concluded that the Arduino-based magnetic field props around the toroid had improved students' understanding and interest in learning. Quantitatively, students' understanding had increased in the moderate category. Based on the results of the student response questionnaire analysis, almost all students had had a positive response to the props used. So the magnetic field props around the toroid had been effective for use in high school physics learning, especially for grade 12. In general, that study had aimed to test the effectiveness of the magnetic field props around the toroid with the help of Arduino Uno in improving high school students' understanding. The implications of that study had been, first, that Arduino Uno-based magnetic field props were digital props that could have made it easier for students to understand the material regardless of the fairly complicated mathematical derivation. Second, the use of those props could have increased students' interest in learning, especially in the field of physics. The use of Arduino Uno and sensors had required a high level of accuracy in the programming process, so for further researchers, it had been recommended to create a simpler coding code by including the calibration code. Magnetic fields could have been influenced by many things, so they needed to have been considered in selecting the sensor to be used.

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