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Using PhET Simulations and Differentiated Instruction to Improve Ninth-Grade Students' Understanding of Physics Concepts

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ABSTRACT

This study aimed to analyze the effectiveness of integrating PhET simulation media with differentiated instruction in improving students' understanding of physics concepts among ninth-grade students at SMP Muhammadiyah 1 Gresik, focusing on dynamic electricity. The study was motivated by students' limited conceptual understanding resulting from the abstract nature of physics concepts and the lack of adaptive instructional strategies that accommodate diverse learning needs. A mixed-methods approach with a sequential explanatory design and a quasi-experimental one-group pretest–posttest design was employed. The participants consisted of 68 ninth-grade students in the 2025/2026 academic year. Quantitative data were collected through pretest and posttest assessments, whereas qualitative data were obtained from classroom observations and interviews. Quantitative data were analyzed using normalized gain (N-gain) and a paired-samples t-test, while qualitative data were analyzed through data reduction, data display, and conclusion drawing. The findings showed that the intervention effectively improved students' understanding of physics concepts. The mean score increased from 57.51 on the pretest to 77.18 on the posttest, with an average N-gain of 0.42, indicating moderate improvement. Most students achieved moderate to high learning gains, and qualitative findings revealed that integrating PhET simulations with differentiated instruction enhanced students' engagement, motivation, exploratory learning, and conceptual retention across different levels of prior ability. These findings suggest that integrating PhET simulations with differentiated instruction offers an adaptive, innovative approach to improving students' understanding of physics concepts.

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1. INTRODUCTION

Physics is one of the essential foundations of the natural sciences, studying natural phenomena and the principles underlying them. As a branch of Natural Science, physics also plays a fundamental role in understanding the universe [1]. However, the characteristics of physical concepts are often abstract and cannot be directly observed in everyday life [2]. Physics concepts such as electricity, magnetism, momentum, and mechanics require strong visualization and deep understanding, which often become obstacles for students. As a result, physics learning in schools, especially at the secondary level, faces significant challenges. Many students experience misconceptions and difficulties in connecting concepts and symbols in physics. These difficulties also impact students' scientific literacy, namely their ability to apply scientific concepts to understand natural phenomena and make decisions based on scientific data [3]. Therefore, more innovative learning approaches are needed to help students understand physics concepts more deeply.

Innovative learning approaches can be implemented through the use of technology in education. Technology serves as a tool for teachers to facilitate knowledge transfer, enabling students to understand physics concepts more easily. Interactive learning media in the form of digital simulations are among the many technologies increasingly used as strategies to address abstraction and misconceptions in physics learning. One of the most popular simulation platforms is PhET (Physics Education Technology) Simulations developed by the University of Colorado Boulder. PhET Simulations can help make difficult concepts easier to understand by demonstrating how objects move in realistic ways [4]. PhET Simulations offer entertaining, interactive computer simulations that can be used to improve students' understanding during learning. Recent empirical studies consistently show that the use of PhET simulations significantly improves students' conceptual understanding and learning outcomes in various physics topics, including electrical circuits, waves, and motion [5]. However, the effectiveness of PhET largely depends on how teachers design learning activities and provide exploratory guidance during the learning process.

On the other hand, the Merdeka Curriculum emphasizes that every child has different learning needs. As part of a differentiated learning approach, teachers must consider students' learning styles, interests, and talents to adjust learning experiences to their specific needs [6]. To fulfill these needs, differentiated instruction is required. Differentiated learning is a learning method that provides opportunities for students to develop their potential according to their readiness and learning interests [7]. By implementing differentiation, teachers can provide variations in content, process, product, or learning environment so that all students, both high-achieving and low-achieving, can still meet learning objectives. Empirical evidence shows that implementing differentiated instruction can have a significant positive impact on student learning outcomes, and various differentiation strategies, such as grouping students by ability, using technology, and modifying questions, have proven effective in creating more inclusive learning experiences tailored to individual student needs [8].

Many studies have highlighted the effectiveness of either PhET simulations or differentiated instruction separately. However, most studies focus on only one aspect: either the use of PhET as interactive media without differentiation, or differentiation without integrating interactive media. In fact, the combination of both has the potential to create synergistic effects because digital visualization can strengthen adaptive learning tailored to students' needs. Previous studies also tended to report only posttest results immediately after the intervention, without assessing medium-term retention of conceptual understanding, even though this aspect is important for measuring the sustainability of learning outcomes. In addition, previous research rarely analyzed learning effects in relation to students' initial abilities, so the inclusivity potential of the approach has not been thoroughly explored.

Recent research indicates that combining interactive technology with instructional adjustment produces positive learning outcomes when supported by activity designs that promote exploration, formative assessment, and adaptive scaffolding [9]. Although initial findings are promising, differences in experimental designs and the lack of procedural descriptions in previous studies mean that the effectiveness of combining interactive technology and differentiated instruction cannot yet be generalized. This condition highlights the need for research with more standardized, well-documented designs to yield stronger empirical evidence.

Based on these considerations, this study seeks to focus on three main aspects: (1) explicitly integrating PhET simulations with systematically documented differentiated instruction procedures (group determination based on pretests, adaptive worksheets, assessment rubrics, and scaffolding), (2) analyzing the impact of the intervention on student subgroups based on initial ability levels, and (3) measuring medium-term retention of conceptual understanding after learning. Thus, this study is expected to provide theoretical, empirical, and practical contributions to efforts to improve the quality of adaptive and digital technology-based physics learning in Indonesia.

2. LITERATURE REVIEW

Learning Media

The term learning media derives from the words *media* and *learning*. Media are tools that transmit and receive messages and information [10]. Media is also often positioned as a channel or means of communication [11]. Based on these statements, media can be concluded as anything that serves as an intermediary or tool for disseminating information to society. Meanwhile, according to the Law of the Republic of Indonesia, learning is the process of interaction between students, teachers, and learning resources within a learning environment [12]. Therefore, learning media can be defined as tools or means for delivering information in the interaction process between teachers as educators and students within a learning environment.

PhET Simulation Media

PhET (Physics Educational Technology) Simulations are instructional tools that can support conceptual learning and skill development, and they are most effective when used in contexts that apply evidence-based and student-centered teaching and learning practices [13]. PhET (Physics Education Technology) provides useful simulations that can be accessed both online and offline through computers and Android-based devices. These simulations are designed for elementary to senior high school levels with content tailored to subjects that rely heavily on practical activities, such as Physics, Biology, and Chemistry.

Differentiated Instruction

Differentiated learning is a pedagogical approach that adjusts teaching methods, content, and learning environments to meet the unique needs of each student[8]. In addition, according to Rohmah Ainur [14], differentiated learning refers to efforts to adapt the teaching and learning process to meet students' needs, interests, and abilities. Thus, differentiated instruction can be concluded as a teaching approach that adjusts content, processes, products, and learning environments according to students' needs, interests, learning styles, and ability levels.

Understanding of Physics Concepts

According to Sujarwanto [15], the nature of physics consists of three dimensions: as a product, as a process, and as an attitude. Physics as a product refers to a body of knowledge consisting of facts, concepts, theories, principles, and models. Physics as a process refers to the skills scientists possess in producing scientific products, while physics as an attitude refers to behaviors grounded in the beliefs scientists hold as they produce scientific knowledge. Mardiyah and Ariaji [16] stated that conceptual understanding is the process of truly comprehending a design or an abstract idea, enabling someone to classify an object or event, and that it is obtained through the learning process.

Research Hypotheses

a. Alternative Hypotheses (Ha)

1. The use of PhET simulations with differentiated instruction is effective in improving students' understanding of physics concepts in Grade IX.
2. There are differences in the effects of using PhET simulation media within differentiated instruction on students' understanding of physics concepts, depending on their initial abilities.
3. There are changes in students' retention of understanding of physics concepts after participating in learning using PhET simulation media that implement differentiated instruction.

b. Null Hypotheses (H0)

1. There is no significant difference in understanding physics concepts between students who learn using PhET simulations through differentiated instruction and those who do not.
2. There is no difference in the effects of using PhET simulation media with differentiated instruction on students' understanding of physics concepts, regardless of their initial abilities.
3. There is no change in students' retention of physics concepts after participating in learning using PhET simulations that implement differentiated instruction.

3. METHOD

Research Paradigm

This research paradigm uses a pragmatic paradigm, which focuses on solving real-world learning problems. This paradigm emphasizes selecting the most appropriate research method to address the research problem, rather than being tied to a specific approach [17]. In this research, the pragmatic paradigm was used to examine the effectiveness of using PhET simulations, combined with differentiated instruction strategies, in improving students' understanding of physics concepts.

This paradigm supports a mixed-methods approach, enabling researchers to obtain a more comprehensive picture of the effectiveness of media and learning strategies. The quantitative aspect focuses on improving learning outcomes through measuring pretest and posttest scores, while the qualitative aspect explores students' learning experiences, perceptions, and engagement during the learning process.

Research Approach

This research uses a mixed methods approach with a sequential explanatory design. According to Creswell (2003), this model begins with the collection and analysis of quantitative data, followed by the collection and analysis of qualitative data to explain or deepen the previous quantitative results.

The steps for this approach are as follows:

a. Quantitative Stage
   In this stage, the level of understanding of physics concepts among ninth-grade students was measured using pretests and posttests. The goal was to determine the improvement in learning outcomes following the implementation of PhET simulations with instructional differentiation strategies.
b. Qualitative Stage
   This stage was conducted through interviews and observations to deepen understanding of how the use of PhET media and the implementation of instructional differentiation affect student engagement, motivation, and learning experiences. The results of the qualitative analysis were used to explain the previously obtained quantitative data.

Type of Research

This research is a quasi-experimental study with a one-group pretest-posttest design. This design involves a single group receiving treatment without a control group [18]. In this design, students were given a pretest to assess their conceptual understanding before the treatment. They were then given instructions using PhET simulations with instructional differentiation, and a posttest was administered to determine improvements in learning outcomes.

Research Design

The following flowchart illustrates the research design:

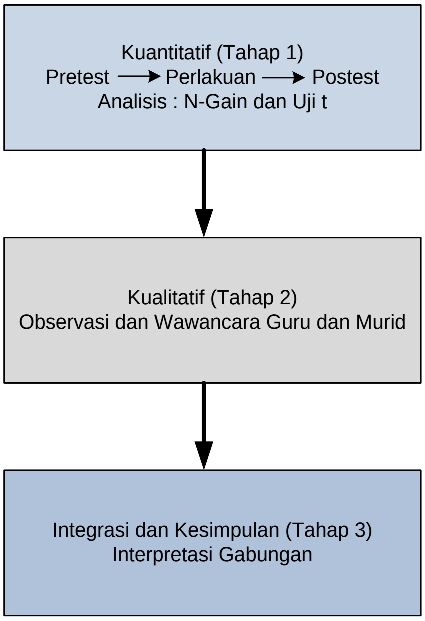

Figure 1. Research Design

Research Location and Time

The location used for this research was SMP Muhammadiyah 1 Gresik, Jl. KH Kholil No. 90, Gresik. We chose this location for several reasons, including the heterogeneity of students' cognitive abilities, learning styles, and socioeconomic backgrounds. The research was conducted in the even semester of the 2025/2026 academic year in January, with a duration of approximately four weeks covering one learning cycle on dynamic electricity.

Research Population and Sample

a. Population

The population in this study was the ninth-grade students at SMP Muhammadiyah 1 Gresik in the 2025/2026 academic year.

b. Sample

The sample consisted of 68 ninth-grade students selected using purposive sampling. This sampling technique was chosen because participants were selected based on specific criteria relevant to the research objectives, rather than by random selection. The inclusion criteria were: (1) students enrolled in classes where physics instruction integrated PhET simulation media, (2) students participating in differentiated instruction during the intervention, and (3) classes representing diverse levels of prior academic ability. These criteria enabled the researcher to evaluate the effectiveness of integrating PhET simulations with differentiated instruction across students with varying learning needs.

Intervention Procedure

The intervention was conducted over four consecutive weeks during the second semester of the 2025/2026 academic year. During the first week, students completed a pretest to measure their initial conceptual understanding of dynamic electricity, and their prior abilities were mapped into low-, medium-, and high-achievement groups based on the pretest results.

During the second and third weeks, students participated in learning activities using the PhET Interactive Simulation on Circuit Construction Kit: DC, covering dynamic electricity topics including electric current, voltage, resistance, Ohm's Law, and simple series and parallel circuits. Learning activities followed the principles of differentiated instruction by adapting content, learning processes, teacher guidance, and feedback according to students' readiness levels.

Students with high prior ability were assigned inquiry-oriented tasks requiring independent exploration and analysis of electrical circuits. Students with medium prior ability completed guided investigation worksheets supported by teacher facilitation and collaborative discussions. Students with low prior ability received structured worksheets, additional scaffolding, step-by-step guidance, simplified experimental tasks, and more intensive feedback throughout the learning process.

At the end of the fourth week, students completed a posttest to evaluate improvements in conceptual understanding. Classroom observations and semi-structured interviews were subsequently conducted to explore students' learning experiences, engagement, and perceptions regarding the implementation of PhET simulations integrated with differentiated instruction.

Ethical Considerations

Prior to data collection, permission to conduct the research was obtained from the school administration and the physics teacher. Participation was voluntary, and all participants were informed of the study's objectives. To protect participants' privacy, all student data were anonymized during data analysis and reporting. Students' names and identification numbers were replaced with anonymous participant codes to maintain confidentiality throughout the research process.

4. RESULTS AND DISCUSSION

This study aims to test the effectiveness of using PhET simulations with differentiated instruction in improving understanding of physics concepts. The research used a mixed-methods, sequential, explanatory design with 68 ninth-grade students at SMP Muhammadiyah 1 Gresik. Quantitative data were obtained from pretest and posttest scores, while qualitative data were obtained from teacher and student interviews and from observations during the lesson.

Research Results

The study began with a pretest to determine the initial abilities of ninth-grade students. Student mapping was then conducted to determine low, medium, and high ability

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categories. Afterward, students engaged in learning using PhET simulation media with differentiated instruction. After completing the lesson, students took a posttest to assess their understanding of physics concepts.

The results of the study yielded the following pretest scores:

Table 1. Pretest scores of grade IX students at Muhammadiyah 1 Gresik Middle School

NO	STUDENT NAME	CLASS	PRETEST SCORE
1	AS	A	73
2	ASH	A	53
3	AZ	A	53
4	ADW	A	27
5	FAA	A	80
6	FLO	A	73
7	IR	A	67
8	JAA	A	80
9	MSZAH	A	53
10	MRAP	A	20
11	MRSA	A	73
12	MAM	A	60
13	MIM	A	27
14	MQO	A	67
15	MZZA	A	80
16	NA	A	33
17	PA	A	53
18	SCF	A	40
19	ZMA	A	53
20	AIP	A	80
21	ANA	A	67
22	MFRTR	A	60
23	KA	A	20
24	ACA	B	60
25	ANS	B	73
26	DAS	B	27
27	DM	B	60
28	FAR	B	47
29	GWW	B	60
30	JTD	B	87
31	MAHNP	B	73
32	MFA	B	33
33	DSP	B	60
34	MRHHD	B	60
35	MYA	B	67
36	MDAR	B	80
37	NRA	B	53
38	NSZ	B	53
39	NMA	B	67
40	RBS	B	80
41	SF	B	33
42	SSS	B	60
43	YXI	B	60
44	ZMA	B	73
45	SAA	B	27
46	AAR	B	80
47	ALA	C	60
48	AM	C	80
49	CSNA	C	33

NO	STUDENT NAME	CLASS	PRETEST SCORE
50	EAN	C	60
51	FTMS	C	80
52	FFFU	C	53
53	FGNF	C	47
54	HRA	C	73
55	KAB	C	80
56	KAT	C	73
57	MRFSP	C	80
58	MHBS	C	27
59	MH	C	20
60	MNAR	C	73
61	MRK	C	20
62	MIA	C	60
63	NR	C	47
64	RWH	C	67
65	RMAS	C	53
66	THH	C	80
67	VMAA	C	33
68	ZANK	C	47

The pretest results above were then processed to map student abilities. Student abilities were divided into three categories: high, medium, and low. According to Arikunto [19], student mapping was conducted using the mean and standard deviation to determine high, medium, and low categories. The standard deviation formula and category format are as follows:

$$SD = \sqrt{\frac{\sum(x-\bar{x})^2}{N}}$$

Where:

SD	:	Standard deviation
x	:	student score
$\bar{x}$	:	average score
N	:	total student

According to Malik [20], the category format is as follows:

Table 2. Student Mapping Category Format

Equation	Category
$x + SD$	High
$(x - SD) \leq x \leq (x + SD)$	Moderate
$x - SD$	Low

Based on the above categories and the results of the standard deviation (SD) formula calculation, the average value obtained is $\bar{x} = 57.51$ and the standard deviation value $SD = 18{,}76$, so the mapping results are as follows:

Table 3. Mapping results of class IX students at Muhammadiyah 1 Gresik Middle School

NO	STUDENT NAME	CLASS	PRETEST SCORE (X)	X - Xaverage2	(X - Xaverage)^2	Category
1	AS	A	73	15.49	239.79	moderate
2	ASH	A	53	-4.51	20.38	moderate
3	AZ	A	53	-4.51	20.38	moderate
4	ADW	A	27	-30.51	931.15	low
5	FAA	A	80	22.49	505.59	high
6	FLO	A	73	15.49	239.79	moderate
7	IR	A	67	9.49	89.97	moderate
8	JAA	A	80	22.49	505.59	high
9	MSZAH	A	53	-4.51	20.38	moderate
10	MRAP	A	20	-37.51	1407.35	low
11	MRSA	A	73	15.49	239.79	moderate
12	MAM	A	60	2.49	6.18	moderate
13	MIM	A	27	-30.51	931.15	low
14	MQO	A	67	9.49	89.97	moderate
15	MZZA	A	80	22.49	505.59	high
16	NA	A	33	-24.51	600.97	low
17	PA	A	53	-4.51	20.38	moderate
18	SCF	A	40	-17.51	306.76	moderate
19	ZMA	A	53	-4.51	20.38	moderate
20	AIP	A	80	22.49	505.59	high
21	ANA	A	67	9.49	89.97	moderate
22	MFRTR	A	60	2.49	6.18	moderate
23	KA	A	20	-37.51	1407.35	low
24	ACA	B	60	2.49	6.18	moderate
25	ANS	B	73	15.49	239.79	moderate
26	DAS	B	27	-30.51	931.15	rendah
27	DM	B	60	2.49	6.18	moderate
28	FAR	B	47	-10.51	110.56	moderate
29	GWW	B	60	2.49	6.18	moderate
30	JTD	B	87	29.49	869.38	high
31	MAHNP	B	73	15.49	239.79	moderate
32	MFA	B	33	-24.51	600.97	low
33	DSP	B	60	2.49	6.18	moderate
34	MRHHD	B	60	2.49	6.18	moderate
35	MYA	B	67	9.49	89.97	moderate
36	MDAR	B	80	22.49	505.59	high
37	NRA	B	53	-4.51	20.38	moderate
38	NSZ	B	53	-4.51	20.38	moderate
39	NMA	B	67	9.49	89.97	moderate
40	RBS	B	80	22.49	505.59	low
41	SF	B	33	-24.51	600.97	moderate
42	SSS	B	60	2.49	6.18	moderate
43	YXI	B	60	2.49	6.18	moderate
44	ZMA	B	73	15.49	239.79	moderate
45	SAA	B	27	-30.51	931.15	low
46	AAR	B	80	22.49	505.59	high
47	ALA	C	60	2.49	6.18	moderate
48	AM	C	80	22.49	505.59	high
49	CSNA	C	33	-24.51	600.97	low
50	EAN	C	60	2.49	6.18	moderate
51	FTMS	C	80	22.49	505.59	high
52	FFFU	C	53	-4.51	20.38	moderate
53	FGNF	C	47	-10.51	110.56	moderate
54	HRA	C	73	15.49	239.79	moderate

NO	STUDENT NAME	CLASS	PRETEST SCORE (X)	X - Xaverage2	(X - Xaverage)^2	Category
55	KAB	C	80	22.49	505.59	high
56	KAT	C	73	15.49	239.79	moderate
57	MRFSP	C	80	22.49	505.59	high
58	MHBS	C	27	-30.51	931.15	low
59	MH	C	20	-37.51	1407.35	rendah
60	MNAR	C	73	15.49	239.79	moderate
61	MRK	C	20	-37.51	1407.35	low
62	MIA	C	60	2.49	6.18	moderate
63	NR	C	47	-10.51	110.56	moderate
64	RWH	C	67	9.49	89.97	moderate
65	RMAS	C	53	-4.51	20.38	moderate
66	THH	C	80	22.49	505.59	high
67	VMAA	C	33	-24.51	600.97	low
68	ZANK	C	47	-10.51	110.56	moderate

After being given treatment in the form of learning using PhET simulation media with instructional differentiation within a certain period of time, a posttest was conducted, and the following results were obtained:

Table 4. Posttest scores of grade IX students at Muhammadiyah 1 Gresik Middle School

NO	STUDENT NAME	CLASS	POSTES SCORE
1	AS	A	80
2	ASH	A	73
3	AZ	A	73
4	ADW	A	80
5	FAA	A	87
6	FLO	A	87
7	IR	A	67
8	JAA	A	87
9	MSZAH	A	73
10	MRAP	A	80
11	MRSA	A	87
12	MAM	A	80
13	MIM	A	80
14	MQO	A	87
15	MZZA	A	87
16	NA	A	73
17	PA	A	73
18	SCF	A	67
19	ZMA	A	80
20	AIP	A	87
21	ANA	A	67
22	MFRTR	A	73
23	KA	A	60
24	ACA	B	87
25	ANS	B	80
26	DAS	B	67
27	DM	B	80
28	FAR	B	67
29	GWW	B	73
30	JTD	B	93
31	MAHNP	B	73
32	MFA	B	60
33	DSP	B	80

NO	STUDENT NAME	CLASS	POSTES SCORE
34	MRHHD	B	87
35	MYA	B	67
36	MDAR	B	87
37	NRA	B	67
38	NSZ	B	73
39	NMA	B	80
40	RBS	B	87
41	SF	B	67
42	SSS	B	80
43	YXI	B	73
44	ZMA	B	80
45	SAA	B	53
46	AAR	B	87
47	ALA	C	73
48	AM	C	80
49	CSNA	C	73
50	EAN	C	67
51	FTMS	C	93
52	FFFU	C	93
53	FGNF	C	87
54	HRA	C	67
55	KAB	C	87
56	KAT	C	80
57	MRFSP	C	93
58	MHBS	C	60
59	MH	C	73
60	MNAR	C	87
61	MRK	C	60
62	MIA	C	80
63	NR	C	73
64	RWH	C	80
65	RMAS	C	73
66	THH	C	87
67	VMAA	C	73
68	ZANK	C	73

Discussion

Effectiveness of Using PhET Simulation Media with Differentiated Instruction

The improvement in students' conceptual understanding can be explained by the characteristics of PhET simulations, which enable students to visualize abstract concepts through interactive experimentation. Rather than passively receiving concepts, students actively manipulated circuit variables and immediately observed their effects, facilitating conceptual change and reducing misconceptions. This finding supports constructivist learning theory, which emphasizes that conceptual understanding develops through active knowledge construction. From the pretest data above (Table 2), the average pretest score was 57.51. The maximum and minimum scores were 80 and 20, respectively. The resulting standard deviation was 18.76. According to Sudjana (2022), the coefficient of variation, formulated as $KV = \frac{SD}{\bar{x}}.100\%$, for an average score of 57.51 and a standard deviation of 18.76, yields a coefficient of variation of 32.6%, which is in the moderate category. This indicates that students have heterogeneous ability backgrounds with a fairly high level of variation in ability. Meanwhile, the pretest and posttest results were analyzed using the N-Gain test, resulting in the following results:

Table 5. Pretest, posttest scores and N-Gain calculation results

NO	STUDENT NAME	CLASS	PRETES SCORE	POSTES SCORE	N-Gain
1	AS	A	73	80	0.3
2	ASH	A	53	73	0.4
3	AZ	A	53	73	0.4
4	ADW	A	27	80	0.7
5	FAA	A	80	87	0.4
6	FLO	A	73	87	0.5
7	IR	A	67	67	0.0
8	JAA	A	80	87	0.4
9	MSZAH	A	53	73	0.4
10	MRAP	A	20	80	0.8
11	MRSA	A	73	87	0.5
12	MAM	A	60	80	0.5
13	MIM	A	27	80	0.7
14	MQO	A	67	87	0.6
15	MZZA	A	80	87	0.4
16	NA	A	33	73	0.6
17	PA	A	53	73	0.4
18	SCF	A	40	67	0.5
19	ZMA	A	53	80	0.6
20	AIP	A	80	87	0.4
21	ANA	A	67	67	0.0
22	MFRTR	A	60	73	0.3
23	KA	A	20	60	0.5
24	ACA	B	60	87	0.7
25	ANS	B	73	80	0.3
26	DAS	B	27	67	0.5
27	DM	B	60	80	0.5
28	FAR	B	47	67	0.4
29	GWW	B	60	73	0.3
30	JTD	B	87	93	0.5
31	MAHNP	B	73	73	0.0
32	MFA	B	33	60	0.4
33	DSP	B	60	80	0.5
34	MRHHD	B	60	87	0.7
35	MYA	B	67	67	0.0
36	MDAR	B	80	87	0.4
37	NRA	B	53	67	0.3
38	NSZ	B	53	73	0.4
39	NMA	B	67	80	0.4
40	RBS	B	80	87	0.4
41	SF	B	33	67	0.5
42	SSS	B	60	80	0.5
43	YXI	B	60	73	0.3
44	ZMA	B	73	80	0.3
45	SAA	B	27	53	0.4
46	AAR	B	80	87	0.4
47	ALA	C	60	73	0.3
48	AM	C	80	80	0.0
49	CSNA	C	33	73	0.6
50	EAN	C	60	67	0.2
51	FTMS	C	80	93	0.7
52	FFFU	C	53	93	0.9
53	FGNF	C	47	87	0.8

NO	STUDENT NAME	CLASS	PRETES SCORE	POSTES SCORE	N-Gain
54	HRA	C	73	67	-0.2
55	KAB	C	80	87	0.4
56	KAT	C	73	80	0.3
57	MRFSP	C	80	93	0.7
58	MHBS	C	27	60	0.5
59	MH	C	20	73	0.7
60	MNAR	C	73	87	0.5
61	MRK	C	20	60	0.5
62	MIA	C	60	80	0.5
63	NR	C	47	73	0.5
64	RWH	C	67	80	0.4
65	RMAS	C	53	73	0.4
66	THH	C	80	87	0.4
67	VMAA	C	33	73	0.6
68	ZANK	C	47	73	0.5
	Total Score		3911	5248	28.8
	Average Score		57.5	77.2	0.42

Comparison of pretest and posttest scores

Table 6. Comparison of average pretest and posttest N-Gain scores

Pretest Average Score	57.51
Postest Average Score	77.18
Increase in Average Score	19.67

Summary of N-Gain Values

Table 7. Summary of N-Gain Values

Low	7
Moderate	51
High	10

The data analysis above shows that most students achieved moderate to high N-Gain scores. This indicates that the learning process helped students understand physics concepts better than conventional learning. This is also consistent with observations during the learning process, which showed high student activity, characterized by: a) students actively exploring the simulation; b) students actively discussing with their peers; and c) students being able to draw conclusions from the simulation results. These findings are reinforced by teacher interviews, which stated that the use of PhET made students more enthusiastic and easier to understand abstract concepts because they could conduct experiments directly through simulations. Theoretically, the results of this study also align with those of Muhsin and Harijanto [5], who found that PhET significantly improved conceptual understanding. Meanwhile, Pande et al. [9] also suggested that technology integration can improve learning quality, and Wieman [13] stated that research-based simulations are effective for conceptual learning. From the explanation above, it can be concluded that the use of PhET simulations with differentiated instruction is effective in learning because it visualizes concepts, provides direct learning experiences, and adapts to student needs.

The Difference in the Effects of Using PhET Simulation Media and Differentiated Instruction on Improving Physics Concept Understanding Based on Students' Initial Ability

The research data show a difference in conceptual understanding based on students' initial ability. This can be seen from the N-Gain calculation in Table 6, where high ability is 10, medium ability is 51, and low ability is 7. High-ability students demonstrate faster understanding and exploration. Meanwhile, students with medium ability show improvement through discussions with peers and the teacher. Meanwhile, students with low ability are supported by scaffolding and teacher guidance.

Observations indicate that learning with PhET simulations, accompanied by teachers providing graded assignments, differentiated guidance, and feedback tailored to students' abilities, improves students' understanding of the concepts being learned. This also aligns with teacher interviews, which confirmed that differentiation is implemented by grouping students based on ability and providing different approaches. Interviews with students indicate that they are more confident, learning is easier to understand, and they become more active in discussions. This also aligns with existing research, including Caro's [22] study, which found that differentiation increases student engagement and learning outcomes. Aprima and Sari's [6] research also suggests that differentiated learning can improve learning effectiveness. Similarly, Sobirin [8] research found that defensibility creates inclusive learning. Therefore, learning using PhET simulation media with differentiated instruction has been proven to accommodate individual differences, improve equity in learning, and maximize learning outcomes for all groups, including students with low, medium, and high abilities.

Retention Rate of Students' Understanding of Physics Concepts

This study was conducted over four weeks, beginning with a pretest and mapping of student abilities. Then, learning using PhET simulations with differentiated instruction was implemented from weeks 2 to 3. The learning implementation was aligned with the teacher-prepared Learning Plan. A posttest was administered in week 4 to measure students' conceptual understanding after the learning. The results showed a significant difference between pretest and posttest scores, as measured by the percentage of learning completion. The learning completion score for Physics at Muhammadiyah 1 Gresik Middle School is 70, with a total of 68 students, and the research shows the following results:

Table 8. Recapitulation of Student Learning Outcomes

Decision	Before learning (pretest)	After learning (postest)	Percentage
Not Completed	46	15	-46 %
Completed	22	53	46 %

 https://doi.org/10.58421/gehu.v5i4.1638

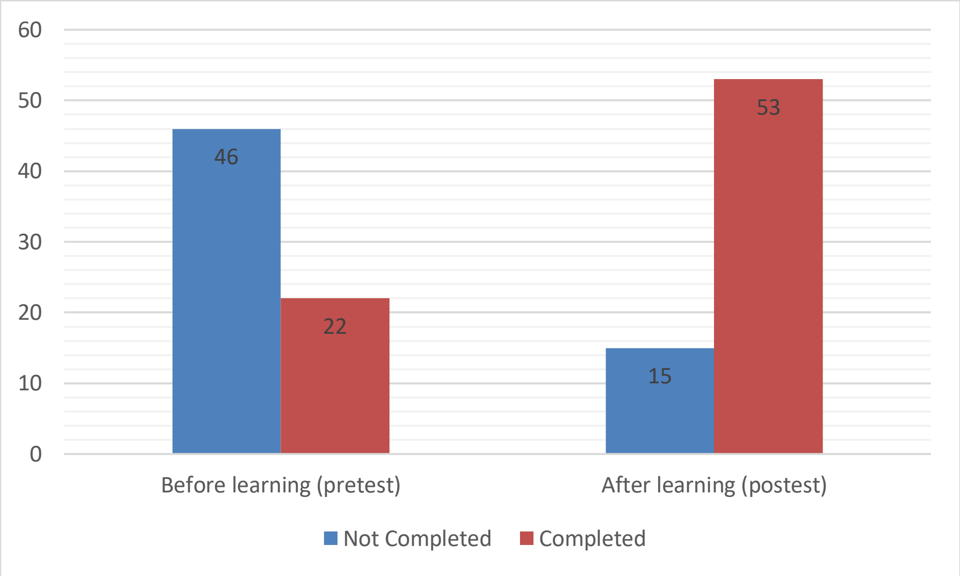

Figure 2. Student Completion Results Before and After Learning

The summary table of student learning completion before and after the learning session shows a significant difference. Pretest scores showed that 46 students had not yet completed the course, while 22 had. Meanwhile, after the learning session, posttest scores showed that 15 students had not yet completed the course, while 52 had. Consequently, there was a change in the percentages of pretest and posttest scores, with a 46% increase in the number of students who completed the course.

These results indicate that students retained their conceptual understanding after the learning session. This was further supported by observations that showed students were able to re-explain concepts learned, connect theory with concepts, and had minimal misconceptions after the lesson. This good retention was also attributed to experiential learning, active interaction with PhET simulations, and reinforcement through differentiated instruction. These findings align with Maye's [23] research, which found that simulation-based learning can improve long-term retention. Rutte's [24] research also suggests that simulations help strengthen students' conceptual understanding. Research by Al-Shara [25] also supports the idea that interactive learning improves student retention. Therefore, the use of PhET simulations with differentiated instruction in learning can not only improve learning outcomes but also strengthen students' medium-term concept retention.

The different learning gains across students with varying prior abilities may be explained by the differentiated instructional strategies implemented during the intervention. Students with high prior ability benefited from inquiry-oriented exploration, which enabled them to investigate electrical phenomena independently and to construct more complex conceptual relationships. Students with moderate ability showed substantial improvement through collaborative discussions and guided experimentation, which supported conceptual refinement through peer interaction. Meanwhile, students with low prior ability benefited primarily from teacher scaffolding, simplified worksheets, and continuous feedback, enabling them to understand fundamental concepts that might otherwise remain abstract.

This study has several limitations. First, the research employed a one-group pretest–posttest design without a control group, limiting the ability to establish causal relationships between the intervention and learning outcomes. Second, the study involved only one school with a relatively small sample, which may limit the generalizability of the findings. Third, students' conceptual retention was inferred solely from immediate posttest performance, as no delayed posttest was administered. Future studies are therefore encouraged to employ randomized controlled designs, larger and more diverse samples, and delayed posttests to examine long-term conceptual retention.

Overall, the research results show that the combination of PhET simulation media and differentiated instruction has a significant impact on 1) students' understanding of physics concepts, 2) student learning activities, 3) retention of physics concepts, and 4) student learning engagement. This approach is also an effective solution to address the abstraction of physics concepts, differences in ability, and low student engagement in learning.

5. CONCLUSION

Conclusion

Based on this study's findings, integrating PhET simulations with differentiated instruction improved ninth-grade students' understanding of physics concepts related to dynamic electricity. The increase in the average score from the pretest to the posttest, together with an average N-Gain of 0.42 (moderate), indicates that students demonstrated better conceptual understanding following the learning intervention.

The implementation of differentiated instruction alongside PhET simulations also supported students with diverse initial ability levels. Classroom observations and interview findings indicated that students became more actively engaged in learning activities, participated in discussions, independently explored simulation features, and demonstrated greater confidence in solving physics problems. These findings indicate that integrating interactive simulations with adaptive instructional strategies can facilitate meaningful learning experiences for students with varying learning needs.

Nevertheless, the findings should be interpreted with caution. Since this study employed a one-group pretest–posttest design without a control group, the observed improvement cannot be attributed exclusively to the intervention, nor can it be concluded that this approach is more effective than conventional instruction. In addition, this study did not include a delayed posttest; therefore, no conclusion can be drawn regarding students' long-term conceptual retention.

Overall, the findings suggest that integrating PhET simulations with differentiated instruction has the potential to support students' conceptual understanding and engagement in physics classrooms. Future studies are recommended to employ controlled experimental designs with larger, more diverse samples and delayed posttests to examine the long-term effectiveness and retention of conceptual understanding.

Recommendations

Based on the research results, several recommendations can be made, namely:

a. For teachers
   - Teachers can use PhET simulations sustainably in physics instruction.
   - Teachers need to develop their ability to implement differentiated instruction to accommodate diverse student needs.
   - Learning should emphasize exploratory activities and discussions.

b. For schools
   - Schools need to provide technology-based learning support facilities.
   - Teacher training is needed regarding the use of digital-based interactive learning media and innovative learning strategies.

c. For further research
   - Conduct research with a larger sample.
   - Use a more complex experimental design.

REFERENCES

[1] L. A. Putri and A. Widiyono, "Pengembangan Buku Interaktif Berbantuan Simulasi PhET-STEM Rangkaian Listrik: Peningkatan Keterampilan Berpikir Kritis Siswa Sekolah Dasar," *Pedagogik Journal of Islamic Elementary School*, vol. 9, no. 1, pp. 15–35, Jan. 2026, doi: 10.24256/pijies.v9i1.9266.

[2] R. E. Susanto, "J I I M Jurnal Ilmiah Ipa Dan Matematika," *Jurnal Ilmiah Ipa Dan Matematika*, vol. 3, no. 2, pp. 106–112, 2024.

[3] R. R. Sasmi, "Perspektif Siswa SMA Terhadap Kearifan Lokal, Literasi Sains, dan Motivasi Belajar dalam Pembelajaran Fisika," *Reog: Journal of Ecoethnoscience Education*, vol. 1, no. 1, pp. 32–39, 2025, doi: https://doi.org/10.58706/reog.v1n1.p32-39.

[4] S. Sylviani, F. C. Permana, and R. G. Utomo, "PHET Simulation sebagai Alat Bantu Siswa Sekolah Dasar dalam Proses Belajar Mengajar Mata Pelajaran Matematika," *Edsence: Jurnal Pendidikan Multimedia*, vol. 2, no. 1, pp. 1–10, 2020, doi: 10.17509/edsence.v2i1.25184.

[5] A. M. Muhsin, S. H. B.P, and Harijanto, "Efektivitas Penggunaan Simulasi Phet Dalam Pembelajaran Online Terhadap Hasil Belajar Siswa," vol. 11 no 1, pp. 16–27, 2022, doi: https://doi.org/10.19184/jpf.v11i1.30612.

[6] D. Aprima and S. Sari, "Analisis Penerapan Pembelajaran Berdiferensiasi Dalam Implementasi Kurikulum Merdeka Pada Pelajaran Matematika SD," *Cendikia : Media Jurnal Ilmiah Pendidikan*, vol. 13 (1), no. 1, pp. 95–101, 2022.

[7] Maryam paso, Rahmat olii, and Yurike bala, "Strategi Pembelajaran Diferensiasi : differentiate learning strategies," *Journal of education and culture (JEaC)*, vol. 2, no. 1, pp. 8–14, 2022.

[8] M. Sobirin, "Learning Styles In Differentiated Instructions Are Mistakes: A Literature Study," *Jurnal Pustaka Cendekia Hukum dan Ilmu Sosial*, vol. 1, no. 2, pp. 191–196, 2025.

[9] N. K. N. N. Pande, A. S. Kusuma, D. M. D. U. Putra, and A. G. Willdahlia, "Analysis Of The Influence Of Progressivism Education Philosophy On The Implementation Of The Free Learning Curriculum – Merdeka Campus (MBKM)," *Cendikia: Media Jurnal Ilmiah Pendidikan*, vol. 13, no. 5, pp. 689–696, 2023.

[10] S. et al Soleh MS, *Media Pembelajaran*, Pertama., vol. 1. Jawa Tengah, 2023.

[11] H. H. Batubara, *Media Pembelajaran Efektif*, Pertama. Semarang: Fatahawa Puslishing, 2020.

[12] Kemendikmen, *Undang-Undangan Republik Indonesia No 20 Tahun 2003 Tentang Sisitem Pendidikan Nasional*. Indonesia: Kemendikmen, 2003, p. 42.

[13] C. Wieman, "PhET Impact Report 2024," Colorado, 2024.

[14] Z. Rohmah Ainur, "Strategi Pembelajaran Diferensiasi Berbasis Aktivitas Dalam Meningkatkan Motivasi Belajar Siswa SD," vol. 4, no. 4, pp. 214–222, 2024.

[15] E. Sujarwanto, "Pemahaman Konsep dan Kemampuan Penyelesaian Masalah dalam Pembelajaran Fisika," *Diffraction 1(1) 2019*, vol. 1, no. 1, pp. 22–39, 2019.

[16] A. Mardiyah and R. Ariaji, "Dan Aktivitas Mahasiswa Melalui," vol. 1, pp. 15–20, 2017.

[17] J. W. Creswell, "RESEARCH DESIGN Qualitative, Quantitative. and Mixed Methods Approachesle," vol. 2, pp. 1–26, 2003.
[18] P. D. Sugiyono, *Metode Penelitian Kuantitatif, Kualitatif dan R&D*, 19th ed. Bandung, 2013.
[19] S. Arikunto, *Prosedur penelitian suatu pendekatan praktik*, Revisi. 2010.
[20] A. dkk Malik, *Pengantar statistika Pendidikan*. Deepublish, 2018.
[21] C. Wieman, "PhET Impact Report 2024," Colorado, 2024.
[22] T. Carol, "HOW TO Differentiate Instruction INMixed-Ability Classrooms," 2nd ed., Virginia USA: Association for Supervision and Curriculum Development Alexandria, Virginia USA, 2001, ch. edisi 2, p. 128.
[23] R. C. C. and R. E. Mayer, *E-Learning and the Science of Instruction: Proven Guidelines for Consumers and Designers of Multimedia Learning*. 2012.
[24] et al Rutten, "The learning effects of computer simulations in science education," 2020, doi: https://doi.org/10.1016/j.compedu.2011.07.017.
[25] M. I. and O. Al-Shara, "Impact of Interactive Learning on Knowledge Retention," Verlag Berlin Heidelber, 2007.