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# Assembling the Computer Simulation on Hypothetical Deductive Thinking Approach Learning to Improve Learning Achievement

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**Abstract** This research describes the impact of hypothetical-deductive learning supported by PhET Simulations on improving the learning achievement of high school students for physics lessons. The design of this study used quasi-experimental (quasi-experiment). The design of this study was a pre-test and post-test control group at a secondary school in Bima, Nusa Tenggara Barat, Indonesia. The experimental group consisted of 24 students who were taught by the hypothetical-deductive learning strategy supported by PhET Simulations. The control group consisted of 23 students taught by a direct lesson learning approach. There were two covariates, i.e., motivation and prior knowledge. Learning achievement as a dependent variable was measured using multiple choices (35 items). Learning achievement estimated cognitive domains including the level of understanding, applying, and analyzing. The statistical technique used in this analysis was ANCOVA techniques. The result found that this proposed strategy was more effective in improving learning achievement. This study found that motivation could not be used as a predictor for improving learning achievement in learning strategies. But, prior knowledge can be used as a predictor in enhancing learning achievement. In general, learning with a hypothetical-deductive approach assisted by computer simulation provides opportunities in the cognitive domain. The limitation of this study is that the impact is jointly between the hypothetical-deductive method and the simulation, but the effect of each factor on the achievement of learning cannot be described. In other indicators of learning success, there needs to be a separate study to find out the positive impact of this learning strategy. Learning strategies with deductive hypothetical thinking supported by PhET Simulations are new strategies in physics learning in Indonesia; especially for achieving learning performance on facing global education standards.

**Keywords** Computer Simulation, Learning Strategy, Physics Learning, Hypothetical-Deductive, Learning Performance, Prior Knowledge

## 1. Introduction

In facing the highly challenging globalization era, education is an essential aspect. It is expected to develop human resources that are skillful, creative and innovative. Realizing the complexity of the future challenges, the education commission of UNESCO (Com-mission Education for The “21” Century) proposed four competencies’ components which are communication, collaboration, critical thinking, and problem-solving, creativity and innovation. In achieving those competencies, the teacher plays a crucial role. The teacher plays a role in determining the quality of education and the student's success. The teacher needs to be sensitive to factors influencing the low quality of education to meet quality [1]. The Indonesian government still faces problems related to the limitation in the use of media and the learning strategies that are not appropriate. Those educator problems will profoundly influence the performance and the quality when they have to enter the global competition era in 21st-century learning [2]. In one side, the learning system needs an appropriate media to help them in understanding physics to achieve the goal because generally teachers of science subjects especially physics are less varied in teaching physics [3]. Physics learning needs suitable strategies and teaching techniques to be able to improve learner's learning achievement. There are some phases of hypothetical-deductive strategy in physics learning in senior high school. In physics teaching at school, learners still think that physics is not exciting and hard to

understand, so it influences the student's learning achievement. Many factors affect this condition. One of them is the low student's motivation and knowledge and the less variety of the learning implementation [4].

Learning by using PhET is learning with one of the computation media providing physics animations in the form of a blog. PhET simulations can display abstract materials, so it gives a comfortable and appropriate explanation for students [5]. Therefore, it expects that hypothetical deductive learning by using PhET simulations can encourage student's motivation in physics learning particularly in the ability of understanding concept, so student's learning achievement could improve.

Hypothetical-deductive learning supported by PhET Simulations can motivate students because physics learning becomes more interesting. The student's prior knowledge before learning materials is different. This prior knowledge shows the student's readiness in receiving materials delivered by the teacher. The teacher needs to know the student's motivation and prior knowledge before learning starts so that the teacher can understand the student's capability on the presented materials. By identifying the two aspects, the teacher can arrange the physics learning well and interestingly, so it can create better learning achievement by using the computer simulation features [6,7].

Based on the problems at school nowadays, the use of PhET Simulations is a reasonable alternative to make students interested in physics learning because it can encourage motivation and prior knowledge that will influence the increase of learning achievement.

Based on the explanation above, the researchers carried out research entitled assembling the computer simulation on the hypothetical-deductive learning strategy to improve learning Achievement.

# 2. Literature Review

### 2.1. Physics Learning in Senior High School

The physics learning process identifies the teaching activities carried out by the teacher and the learning activities done by students. Science learning in the 21st Century implements the scientific approaches in the learning system in various countries that have been determined through government regulation [8].

The successful education in the 21st century means educated people must have skills of logical thinking and problem solving effectively and independently [9]. The characteristics of 21st-century learning are students can study independently anytime, anywhere and with any methods or media. Three concepts of the 21st century are 21st Century Skills, Scientific Approach, and Authentic assessment. Besides, the Bloom taxonomy also influences the 21st-century learning where the goal of the education developed to classify the knowledge itself [10].

In the senior high school level, 21st-century learning means the globalization era which is an era of technological products with huge quantity and sophisticated quality, particularly in the education field. Physics learning is essential to be taught as a separated subject for some considerations. The first is besides giving knowledge to students; physics is also a medium to develop critical thinking skill that is useful to solve problems in daily life. The second is physics needing to be taught for a more specific purpose which is occupying students with knowledge, understanding and some skills required for higher education level and developing science and technology in the education field. Physics learning is carried out with the scientific inquiry to develop thinking skills in learning independence, scientific working, and behaving, also communicating as one of the essential aspects of life skills [11].

### 2.2. Hypothetical-deductive Thinking

In Oxford Advanced Learner's Dictionary, thinking means "ideas or opinions about something." In other words, people who are thinking are people who have ideas or opinions about something. Knowing mindset can help students to get the utilization of patterns in the brain that influence their thinking process. An individual who is realizing his/her brain capacity will adjust with his/her capability and have the best method in developing thinking skills and improve deductive and critical thinking capacity [12].

In the hypothetical-deductive learning, some phases ease learners to master the concepts because it involves them in direct interactions with objects, phenomena, experiences, and environments. It matches the constructivism view by Ausubel that in teaching knowledge, it needs to relate prior knowledge and other previously known events so each can build his/her knowledge meaningfully [13]. Hypothetical-deductive thinking requires learners to be more critical and creative in receiving and understanding what they are learning and experiencing by themselves. Therefore, deductive learning can train the optimal essential skills of thinking of physics

### 2.3. PhET Simulations

UNESCO defines virtual laboratory as an electronic workspace for distance collaboration and experimentation in research or other creative activities, to generate and deliver results using distributed information and communication technologies". PhET is a simulation made by Virtual Laboratory. It is an interactive and complicated situation to solve a problem in the form of simulation in a group. One of the virtual laboratories utilized is Colorado PhET interactive simulation. PhET (Physics Education Technology) is a site providing physics learning

simulations that everyone can download for free for teaching in the class or individual learning. Colorado PhET interactive Simulation is an interactive simulation medium which is fun and research-based. It is a software used for clarifying the physics concepts or phenomena. Science Community created it through the PhET Project at the University of Colorado USA [14,15]. Simulations on PhET are available for free that everyone could download on http://www.PhET.colorado.edu.

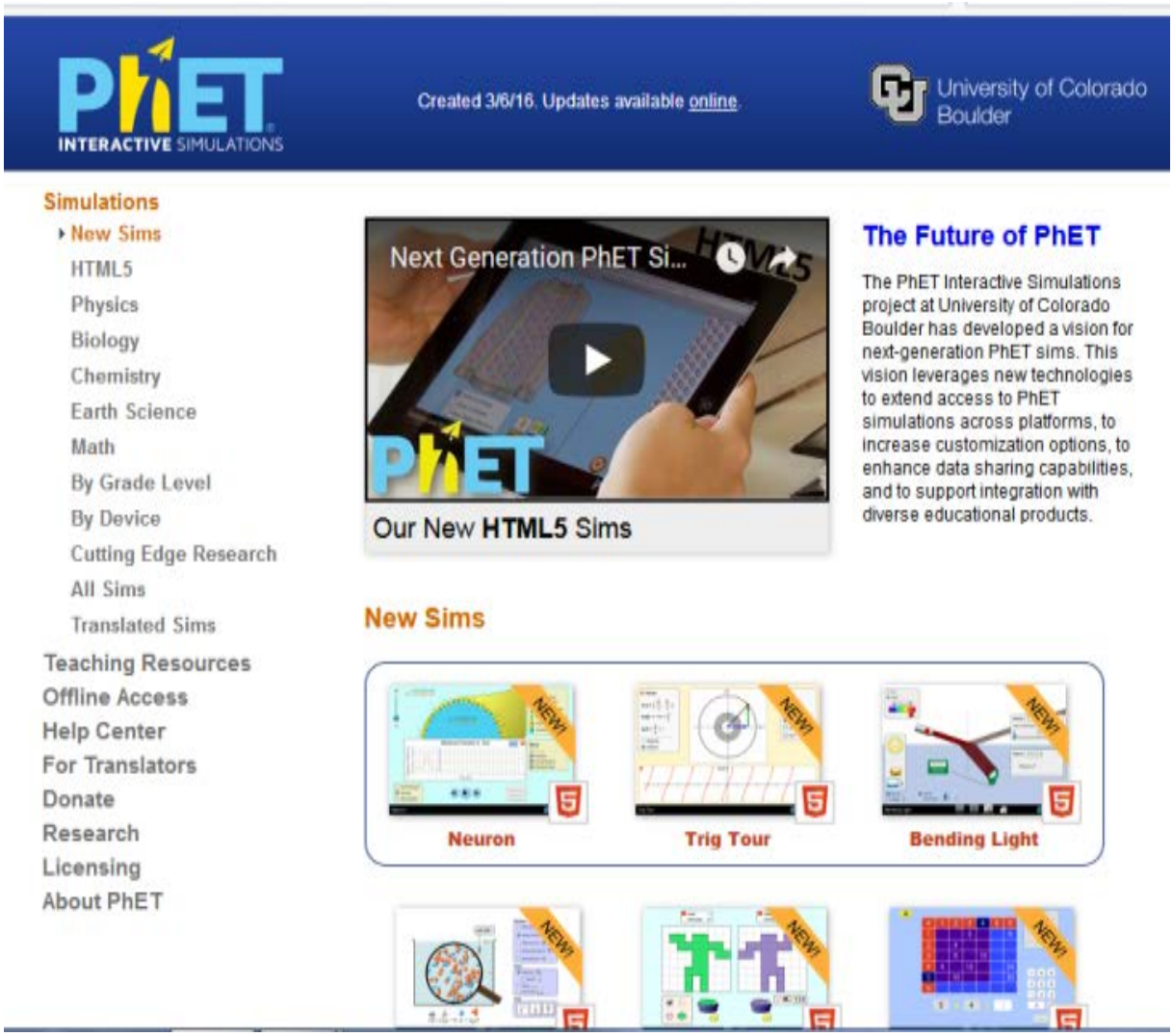


**Figure 1.** PhET homepage

### 2.4. Learning Achievement

In physics learning, it is essential to measure the student's learning achievement to check the student's comprehension of what they have learned. Physics learning with hypothetical deductive strategy in the learning process views physics as a science containing natural phenomena processed in physic and empirical evaluation known as concepts, laws, and principles applied in technology. Therefore, physics exists because of the invention process to create better learning achievement [16, 17, 18].

## 3. Methods

### 3.1. Population and Sample

The research location was in a school in Bima West Nusa Tenggara, Indonesia. This area is a rural area with less ICT access as in Java Island. The population was all tenth-grade students of a senior high school. The research subjects were two classes consisting of class X1 MIPA (CL-1) as the experimental class with 24 students and class X2 MIPA (CL-2) as the control class with 23 students. The experimental group implemented hypothetical deductive learning strategy while the control group implemented conventional learning.

### 3.2. Research Design

This research was quasi-experimental research with non-randomized control group pretest and post-test research design model. In this research, the experimental class implemented the hypothetical-deductive learning strategy by using PhET Simulations to improve learning achievement in Physics subject, while the control class implemented conventional learning.

### 3.3. Variables

In this research, the independent variable (IVAR) is the hypothetical -deductive strategy. The learning phases of the hypothetical-deductive strategy were as follows:

#### 3.3.1. Exploration Phase

In this phase, students explored an object and questioned "the reason why?" of a surrounding phenomenon, observation, or event.

#### 3.3.2. Concept Introduction Phase

In this phase, the teacher introduced students the formal concept underlying an event of an object observed. Based on the observation and introduction of the formal theory, students propose a hypothesis if and so. Therefore, in this phase, the teacher is only a facilitator and students actively participate in learning.

#### 3.3.3. Application Phase

In this phase, learners tried to understand relevant concepts and reasoning pattern related and then they discussed and applied in other situations to prove the hypothesis: accepting, rejecting, or revising hypothesis. In this research, the dependent variable is learning achievement (DVAR). To measure learning achievement is by using questions of knowledge level (C1), understanding level (C2), application level (C3), and analysis level (C4) of Bloom taxonomy.

In this research, the control variable is learning materials, learning time duration, the teacher, and tenth-grade students of senior high school. In this research is prior knowledge (COV-1) and student's motivation (COV-2).

### 3.4. Instruments

#### 3.4.1. The Simulation

The research instruments were based on the phases of hypothetical-deductive. In the PhET simulation, there is a simulation (virtual lab) in which there is one application in physics learning on the subject matter of business and energy using the PhET simulation. In the business material and simulation energy that can be used is the ramp or inclined plane.

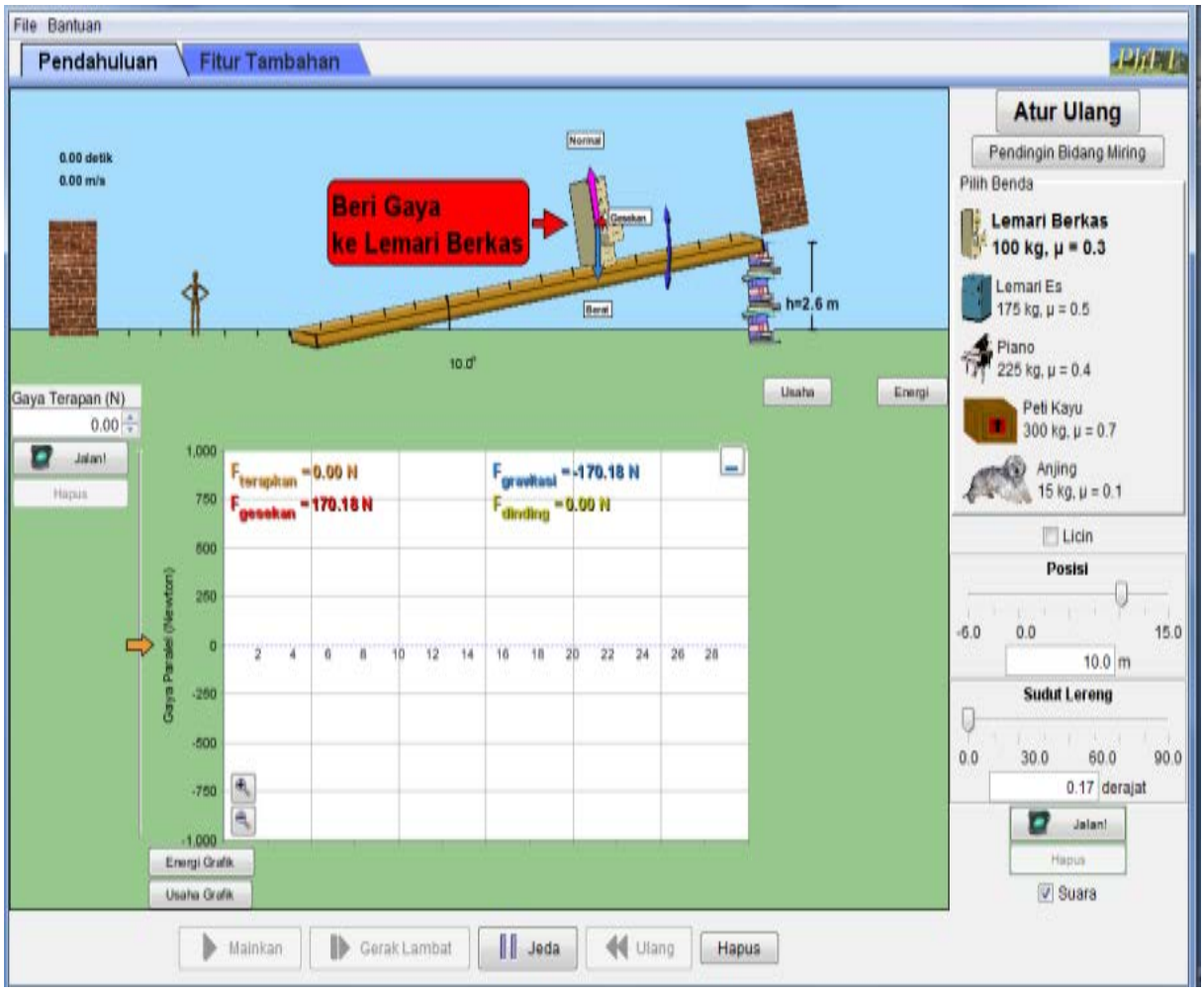


**Figure 2.** Ramp simulation

In simulating of the ramp, students can experiment to find out the concepts of work, energy, potential energy, kinetic energy independently or in groups of students.

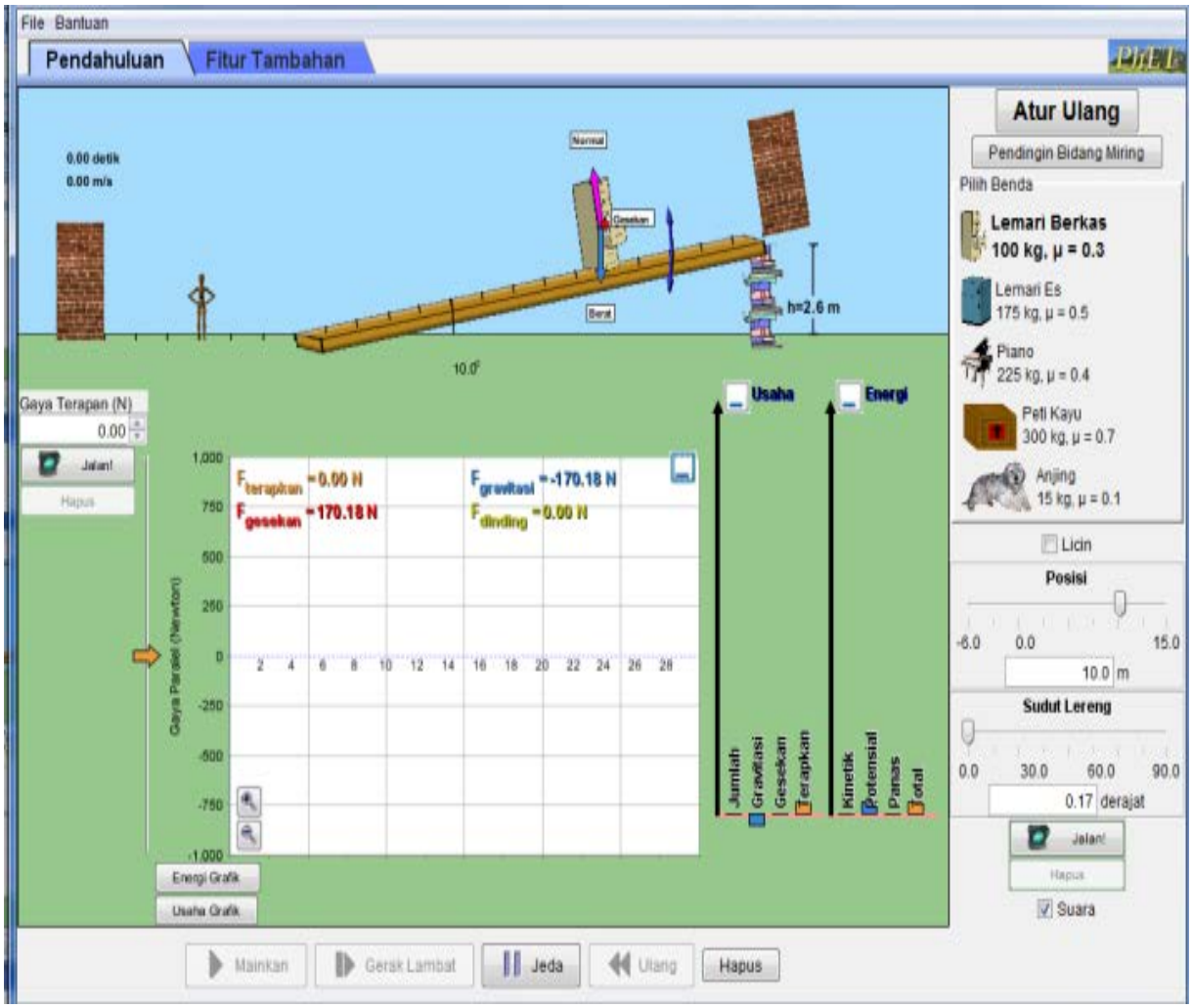


**Figure 3.** Work and energy simulation

In the simulation as presented by Fig. 2, there is a button and a tool to adjust the position of objects, the angle of the inclination or ramp angle, and choose the type of object with different masses. Using this simulation, the student experienced to use different objects and may draw the proper concept understanding especially on work and energy. The variable in this simulation is the objects' characteristics and the ramp angle. Used as learning media in the experimental class, some objects in PhET have the characteristics as Table 1.

**Table 1.** Object characteristics for simulation

| Objects | Mass (kg) | friction ($\mu$) |
|---|---|---|
| Second Cupboard | 100 | 0.3 |
| Fridge | 175 | 0.5 |
| Piano | 225 | 0.4 |
| Wooden Box | 300 | 0.7 |
| Dog | 15 | 0.1 |

Table 1 describes the characteristics of objects contained in the PhET Simulations. The unit of mass is kg and μ is friction constant. Students may change the object to find out their effect. The teacher provides the student with sheet to guide the activity. In this sheet, students experience on individual objects, and the slope angle is changed to see the effect on effort and energy.

### 3.4.2. Prior Knowledge and Learning Achievement

Prior knowledge and learning achievement were measured using multiple choices of 35 questions. This question has previously been tested for its feasibility in terms of item validity, level of difficulty and discrimination level. Questions used were in the level of knowledge (C1), understanding (C2), application (C3), and analysis (C4) of Bloom taxonomy. To measure the student's learning achievement as daily score, it used the multiple choices questions. To determine whether the items were valid and reliable or not, it used validity and reliability test

A test is accurate if the result matches the criteria, which means they have the alignment between the test result and the valid research result criteria if there is a similarity between the collected data and real data on the observed objects. A test is reliable if the result of the analysis shows

the provision. Reliability of question instruments can use Kuder- Richardson - 20 (KR-20) formulation as follows.

3.4.3. The Motivation

Prior Motivation questionnaires are developed from the ARCS model (Attention, Relevance, Confidence, and Satisfaction). This questionnaire consists of 36 items arranged in several negative and positive statements. The scale of this questionnaire is the Likert scale from 1 to 5. The percentage of the total score of each participant to the maximum score then converted to the decision as mentioned in Table 2.

**Table 2.** Scoring Criteria

| Percentage | Conclusion Remark |
|---|---|
| 81 – 100 | Strongly Agree |
| 61 – 80 | Agree |
| 42 – 60 | Doubtful |
| 21 – 40 | Disagree |
| 0 – 20 | Strongly Disagree |

### 3.5. Analysis Technique

The tool to analyze used SPSS 16.0. Before ANCOVA testing, normality and homogeneity test were done to the questions. Next was the ANCOVA test; linearity test is to find out whether independent variable and dependent variable have a linear relationship. The independent variables were the hypothetical-deductive learning strategy and conventional strategy. The dependent variable was learning achievement. Linearity testing used SPSS 16.0 with a test of linearity. Data testing criteria have linear regression if the significance number is less than the significance level of 5% or 0.05 by using F-Test, the null hypothesis is rejected if calculated F is higher than F from the table. The acceptance or rejection of the null hypothesis can be involved through probability (significance) number. If significance is less than 0.05, then the null hypothesis is accepted; vice versa. After analysis precondition, that is normality of variant homogeneity score distribution and linearity test, complete, and the next is hypothesis testing. Hypothesis testing used one-way ANCOVA test with two included variables. ANCOVA is a combination of variant and regression analysis.

## 4. Result and Discussion

### 4.1. Result

4.1.1. Validity and Reliability

This validity test is carried out to the questions used to obtain data of learning carried out. The validity test consisted of 40 multiple choice questions. From the result of the analysis, it appears that r from table is equal to 0.304 and calculated r is equal to 0.470. The question items are valid if calculated r is higher than r from table vice versa. After being analyzed, five questions were invalid. The others were valid to be used in the research. There were five invalid items.

The next is the reliability test. The question items are reliable if valid and if calculated r is higher than r from table vice versa. Based on the calculation result of instrument reliability, it appears that calculated r (0.882) is higher than r from the table, so the question items were reliable. Then, the number of problem for measuring the prior knowledge and learning achievement is 35 problems.

4.1.2. Normality and Homogeneity

In the normality test, it appears that in the score calculation of the experimental class, the significance score is 0.200, while the significance score of the control group is 0.056. Since the significance scores of experimental and control groups are more than 0.05, so the data coming from the population have a normal distribution.

In the homogeneity test, the significance score is 0.691 that is more than 0.05, so the null hypothesis is rejected, and the alternative hypothesis is accepted. The conclusion is data of experimental and control classes are homogenous and have the same population variant.

4.1.3. ANCOVA

The results of the descriptive statistical analysis are shown in table 3. From the table, it can be seen that the learning achievement of the experiment group was higher than the control group. The AN-COVA test was then carried out to find out the effect of the covariate.

**Table 3.** Descriptive Statistics

| Dependent Variable: Learning Achievement | | | |
|---|---|---|---|
| **GROUP** | **Mean** | **Std. Deviation** | **N** |
| Experiment group | 76.8333 | 11.72758 | 24 |
| Control group | 58.9130 | 8.91328 | 23 |
| Total | 68.0638 | 13.73888 | 47 |

Table 4 shows the result of the univariate without covariate (COV-1 and COV-2). This table describes the effect of the learning strategy only on the learning achievement (DVAR).

The learning used the effectiveness of hypothetical-deductive learning strategy in the experimental class and conventional learning in the control class. The test was done by eliminating motivation and prior knowledge covariates. From the result, it appears that the significance score is lower than 0.05 so the null hypothesis is rejected. Table 4 shows that F score is 30.957

with the significance of 0.00. It shows the influence on the post-test towards learning.

**Table 4.** The univariate test without covariate

| Dependent Variable: Learning Achievement (DVAR) | | | | | |
|---|---|---|---|---|---|
| **Source** | **Type III Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| Corrected Model | 2392.129[a] | 2 | 1196.064 | 8.366 | .001 |
| Intercept | 588.303 | 1 | 588.303 | 4.115 | .049 |
| COV_1 | 2212.118 | 1 | 2212.118 | 15.473 | .000 |
| COV_2 | 165.390 | 1 | 165.390 | 1.157 | .288 |
| Error | 6290.680 | 44 | 142.970 | | |
| Total | 226419.000 | 47 | | | |
| Corrected Total | 8682.809 | 46 | | | |

a. R Squared = .276 (Adjusted R Squared = .243)

The result of testing by using hypothetical deductive learning strategy compared to the conventional method with the covariate (COV-1 and COV-2) is mentioned in Table 5.

**Table 5.** Tests of Between-Subjects Effects

| Dependent Variable: Learning Achievement (DVAR) | | | | | |
|---|---|---|---|---|---|
| **Source** | **Type III Sum of Squares** | **df** | **Mean Square** | **F** | **Sig.** |
| Corrected Model | 2392.129a | 2 | 1196.064 | 8.366 | .001 |
| Intercept | 588.303 | 1 | 588.303 | 4.115 | .049 |
| COV_1 | 2212.118 | 1 | 2212.118 | 15.473 | .000 |
| COV_2 | 165.390 | 1 | 165.390 | 1.157 | .288 |
| Error | 6290.680 | 44 | 142.970 | | |
| Total | 226419.000 | 47 | | | |
| Corrected Total | 8682.809 | 46 | | | |

a. R Squared = .276 (Adjusted R Squared = .243)

To find out the success of learning achievement is by seeing the significance score. If the significance score is less than 0.05, the null hypothesis is rejected.

Based on Table 5, the F score of prior knowledge (COV-1) is 15.473 with the significance of 0.00 which is less than 0.05. It shows that there is an influence of learning towards prior knowledge in learning. Viewing from F score, it shows that prior knowledge affects learning both in the experimental and control classes. Since the all significance level is less than 0.05, the null hypothesis is rejected. It means physics learning by using this learning strategy is more effective than the conventional method on prior knowledge.

Next, Table 5 shows that F score of motivation (COV-2) is 1.157 with the significance of 0.288 which is more than 0.05. It shows that there is no difference in learning achievement influenced by motivation. However, viewing from F score, it shows that motivation affects the learning both in the experimental and control classes.

The next is to find out the influence of prior knowledge (COV-1) motivation (COV-2) towards learning achievement analyzed with linear regression test. Table 6 presents the data of regression test.

**Table 6.** Linear Regression result

| Coefficients[a] | | | | | | |
|---|---|---|---|---|---|---|
| **Model** | | **Unstandardized Coefficients** | | **Standardized Coefficients** | **T** | **Sig.** |
| | | **B** | **Std. Error** | **Beta** | | |
| 1 | (Constant) | 24.040 | 11.851 | | 2.029 | .049 |
| | Prior Knowledge | .731 | .186 | .505 | 3.934 | .000 |
| | Motivation | .059 | .055 | .138 | 1.076 | .288 |

a. Dependent Variable: Learning Achievement

Table 6 reiterates that motivation, in this case, cannot be used as a predictor of learning achievement. Furthermore, it can also calculate the relative and effective contribution of both covariates. Table 7 shows the result

**Table 7.** Relative and Effective Contribution

| Covariate | Relative Contribution | Effective Contribution |
|---|---|---|
| Motivation | 77% | 3.79% |
| PriorKnowledge | 9.23% | 46.0% |
| Total | 1 | 49.8% |

From Table 7, the relative and effective contributions of prior knowledge (COV-1) towards learning achievement (DVAR) are 9.23% and 46.0%. It shows that the contribution of prior knowledge is very high.

But, from Table 7 it seems that relative and effective contributions of motivation (COV-2) towards learning achievement (DVAR) are 77% and 3.79%. The calculation result shows that contribution of motivation towards student's learning achievement is in fair (me-dium) level.

### 4.2. Discussion

Based on the outcome of the research, the score distribution of experimental and control classes are on the normal distribution. Implementing learning with hypothetical deductive strategy by using PhET Simulations in the tenth grade MIPA1, based on the research, student's pre-test score of the experimental class is 67.00 and control class is 54.47. In the experimental group, the level of student's prior knowledge is higher than the control class. The post-test score of the experiment group is 97.05, and the score of the control

class is 71.26. The learning achievement test used questions with C4 ability level (analysis). Based on the review, it appears that implementing physics learning achievement test used problems with C4 ability level (analysis). Based on the analysis, it seems that implementing physics learning by using PhET Simulations can develop the student's thinking skill.

Experimental and control classes PhET as virtual media can explain, demonstrate and ease learning materials of work and energy on a ramp. The score of learning achievement used minimum completeness criteria score determined by the school. Based on the result of the research, the student's average score of the experimental class is 95, and the control class is 70.

ANCOVA gives the score to find out the effectiveness of physics learning viewed from the significance score. If the significance score is less than 0.05, the null hypothesis was rejected. The significance score of prior knowledge is 0.00 which is less than 0.05, so the null hypothesis was rejected. It means physics learning with deductive strategy is more effective compared to the conventional method. In the motivation questionnaire, the significance score is 0.419 which is more than 0.05, so the null hypothesis is rejected. It means physics learning with the strategy is more effective compared to the conventional method. It shows that there is no difference in learning achievement influenced by motivation. However, viewing from F score, it shows that motivation affects learning both in experiment and control classes.

In this research, students of the experimental class were more active than the control class proven with daily evaluation during direct learning. At first, the activity was only 75% then increased to become 90%. Learning with Hypothetical deductive strategy is more effective than the conventional method. Previous researchers also proved the success in the research of hypothetical-deductive learning strategy.

In this study, the researcher explored the impact of both hypothetical-deductive learning strategy and simulation supporting learning strategy. But, the researcher has not studied the effects of each approach on the improvement of learning achievements yet. There are many learning performance indicators. The study on another one will give the benefit to the learning activity in the classroom. In general, the finding of this study indicates the same result of the previous research [11, 19] that most students have positive learning by using deductive thinking learning towards critical thinking skills. Even though students have many obstacles during learning, the hypothetical-deductive learning strategy could make students more active in solving problems. We believe that this strategy will support education changing as other educators do [17, 21]. Considering the new competencies in 21st-century learning, hypothetical-deductive thinking plays a significant role in scientific studies for educational innovation. Learning in PhET has been proposed by Perkins (2013) stating PhET simulation to manage conducive school environment to have a thinking pattern. Students can combine their prior knowledge with virtual experience using the simulation for better ability. Learning to use PhET Simulation is delightful and varied learning in science learning [22, 23, 24].

This research finding implies that this learning strategy improves not only the motivation but also the conceptual understanding, especially on work and energy concepts

## 5. Conclusions

In today's education, it is necessary to develop various learning innovations that are conducive and following current competency needs. Hypothetical-deductive learning strategy supported by PhET simulations is one of the strategies that can be applied in physics learning. This strategy besides being able to improve understanding of physics material can also increase student learning motivation. Activities when carrying out simulations encourage the formation of positive thinking patterns following the knowledge of the scientific process.

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