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# Application of Media Combination of PhET Simulation and Spring Balance on Mathematical Concept Understanding of Grade XI Students on Vector Material

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**Abstract**

This study aims to determine the improvement in mathematical concept understanding of grade XI students after applying the combined media of PhET simulation and spring balance to vector material. The type of research used (pre-experimental) using a one-group pretest-posttest design. The sampling technique used is purposive sampling, namely 30 class XI MIPA 1 MAN Kota Palangka Raya students. Concept understanding data were analyzed using descriptive and inferential methods. Based on data analysis, it was found that the average pretest score was 23.4 while the post-test was 87.5. The t-test results show that $t\text{-}count$ = -39.594 < $t\text{-}tabel$ = 3.39624. Thus, it can be concluded that $H_O$ is rejected and $H_A$ is accepted, so there is a significant increase in the understanding of mathematical concepts of class XI students on vector material before and after applying to learn using a combination of PhET simulation media and spring balance. The implication of using the media is that it provides significant benefits in understanding mathematical concepts, skill development, and student engagement in learning so that students are more focused and learning becomes directed.

**Keywords:** mathematical concept understanding; media; PhET; vectors

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## INTRODUCTION

The development of the world has now entered the Industrial Revolution 4.0 era (Rymarczyk, 2020; Selisne et al., 2019). There are several sectors affected by technological developments, including the education sector. The world of education is one of the educational sectors that has implemented technology as a simulation and learning resource, one of which is learning physics (Abdi et al., 2021; Annovasho & Budiningarti, 2014; Dhawan, 2020). Physics is a general point in science class (Muzana & Astuti, 2017; Saregar, 2016) that explains how the physical form requires sophisticated and thorough understanding (Sasmita, 2017; Supriatin

et al., 2022). Unsuitable physics learning methods, such as memorizing formulas, will make it difficult for students to understand concepts (Harjono, 2022). So, physics is often less desirable learning to be learned by students (Harjono, 2022; Hasni & Situmorang, 2018; Nurdini et al., 2022).

The purpose of learning physics is for students to understand the concepts and their relationships to solve related problems in everyday life (Khofifah et al., 2024; Lubis, 2009). To achieve this goal, students must have sufficient knowledge of physics concepts. One of the materials that students often have to master is vectors which are closely related to other materials in physics that are widely used to solve problems such as motion, force, momentum, impulse, moment of force, effort, electricity, and magnetism (Yuwarti et al., 2017). Given the importance of mastering vector material to study physics, students must understand the concept of vectors as a whole, understand the decomposition of the resulting vectors, and connect them with mathematical concepts (Harjono, 2022).

In addition to teachers and learning methods, learning media also significantly influence the possibility of the success of the teaching and learning process (Kurniawan et al., 2020). For students to understand learning concepts, interesting learning media are needed to help them understand them. Therefore, in choosing learning media, educators should consider various aspects, such as students' thinking ability, level of understanding, psychological situation, and social situation, to ensure that the media used meets students' needs (Pujiyono et al., 2016).

One way to make it easier and as a medium to express students' desires to understand vector material is to apply virtual laboratory media, namely PhET simulations (Mahtari et al., 2020; Maulani et al., 2018; ; Nisa et al., 2022; Rizaldi et al., 2020) and practicum media, namely spring balance practicum as a means of direct learning to make it easier for students to understand vector concepts, both decomposing vector resultants and calculating them (Rahayu et al., 2019).

Based on several other studies, researchers only discuss PhET simulations or direct practicum. In fact, in addition to using virtual media with PhET simulations as a medium to invite and attract students' desire to learn vector material to make it more fun and easily display and explain things that are difficult to obtain in the real world (Ramadani & Nana, 2020), students also need to practice directly because learning using PhET simulations, which only seem to use practical tools, is different from using tools directly (Khumaidi & Amalia, 2023).

In addition, students must understand vector material as a whole and connect with calculations through mathematical concepts. Therefore, it is necessary to have simulations carried out virtually and experiments carried out in real life. Using PhET simulation learning media as an activity in a virtual lab in the learning and teaching process can increase students' knowledge, especially in understanding vectors (Muzana & Astuti, 2017). and experiments directly used in learning can improve students' motor skills in recognizing the application of material or concepts in everyday life (Rohim., et al., 2016).

A student's understanding of mathematical concepts is considered the foundation of a house. Therefore, if you want to build a solid house, you need a solid foundation. Students who are able to understand many concepts well will find it easier to understand all types of problems. In the view of (Kristanti et al., 2019), conceptual understanding is a very important ability for students. Practising mathematical concept understanding is very helpful for students

who want to learn physics meaningfully. According to Mawaddah & Maryanti (2016), students' concept understanding ability is to restate a concept taught, clarify objects and present them in various forms, using different methods (Setiani et al., 2022). Thus, students can explain the meaning of conditions and events, describe the relationship between concepts, and apply them usefully and appropriately to solve problems.

Based on the results of observations at MAN Kota Palangka Raya through interviews with physics teachers, it was found that the most difficult material for students to understand is vectors, especially in understanding the decomposition of vector resultants and mathematical concept analysis, supported by concept understanding test questions distributed by researchers to students in class 12 MIPA 1. The average score was 20.8824. This shows that the understanding of mathematical concepts in vector material is very low.

Therefore, there is a need for a combination of PhET simulation media and real experimental media (Rohim et al., 2022), which needs to be applied in the latest research. The combination used is PhET simulation media as a medium to simulate axis decomposition, depiction, addition, and subtraction of vectors and real experimental media using a spring balance tool (dynamometer) to calculate the magnitude of the resultant vector. Using a spring balance, we can find out the value of the force shown. Combining the two media during learning, students can understand the overall vector material and improve their understanding of mathematical concepts.

Thus, the researchers raised the title "Application of Media Combination of PhET Simulation and Spring Balance to Understanding Mathematical Concepts of Class XI Students on Vector Material" to know the increase in understanding of mathematical concepts of students in class XI MIPA MAN Kota Palangka Raya on vector material before and after using media combination of PhET simulation and spring balance.

## METHOD

The method used in this research is the experimental method. The experimental method is a quantitative research that looks at the effect of independent variables (treatment) on the dependent variable (results) under controlled conditions. Research design with pre-experimental methods using One Group Pretest-Posttest Design, which is a research design involving a study group that receives a pre-test before research and then treatment and a final test (Sugiyono, 2019; Tabuena, 2021; Wamunyima, 2023; Yilmaz & Duygulu, 2021).

Table 1 One-group pretest-posttest design

| | | |
|---|---|---|
| **$O_1$** | **X** | **$O_2$** |

This research has been conducted at MAN Kota Palangka Raya with a total sample of 30 people in class XI MIPA 1 with a sampling technique in the form of purposive sampling with certain considerations, namely based on the group with the highest average score in each class and the level of understanding of students on vector material for three meetings in the 2023 odd semester and carried out in several stages as follows:

### Initial observation

Initial observation was conducted to find out the school's state and the problems teachers face, especially in learning physics, through interviews with physics teachers in class XI MIPA MAN Kota Palangka Raya.

### Planning

After the initial observation was carried out, the planning stage was carried out as follows:

1) Collecting information about curriculum analysis, developing

research instruments including mathematical concept understanding tests, independent curriculum teaching modules and student worksheets, and implementation observation sheets.
2) Overall validation of research instruments by validators
3) Validators validate instruments in the form of concept-understanding test questions and then continue with empirical validation for randomly selected XII IPA students. The validator sufficiently validates the independent curriculum teaching module, student worksheets, and observation sheet after being designed and revised according to the validator's opinion before use.

**Implementation**

After all components of the research instrument were completed and validated, the next implementation stage was to give a pre-test question about understanding mathematical concepts, then provide treatment using a combination of PhET simulation media and spring balance, then give a post-test question of understanding of mathematical concepts.

**Evaluation**

At this evaluation stage, the study's results were analyzed through the initial and final tests; then, the collected data were analyzed for N-Gain values, normality tests, and hypothesis tests using the IBM SPSS Statistics 25 application. The data analysis techniques are as follows:

**Descriptive Analysis**

The criteria for assessing understanding of mathematical concepts are listed in Table 2.

Table 2 Criteria for understanding mathematical concepts

| Aspect Percentage | Score |
|---|---|
| Very High | 80-100 |
| High | 66-79 |
| Fair | 56-65 |
| Low | 40-55 |
| Very low | 30-39 |

The range of Normalized N-Gain Category values is listed in Table 3 and the equation that can be used to calculate N-gain is as follows:

$$g = \frac{posttest\ score - pretest\ score}{maximum\ score - pretest\ score} \quad \ldots (1)$$

Table 3 Normalized N-Gain category

| Normalized Gain Value | Interpretation |
|---|---|
| $0{,}70 \leq g \leq 100$ | High |
| $0{,}30 \leq g \leq 0{,}70$ | Medium |
| $0{,}00 \leq g \leq 0{,}30$ | Low |
| $g = 0{,}00$ | No increase |
| $-1{,}00 \leq g < 0{,}00$ | Decrease |

**Inferential Analysis**

- Normality Test

The normality test formula uses Kolmogorov-Smirnov as below:

$$D = maximum\ [Sn_1(x) - Sn_2(x)] \ldots (2)$$

- Hypothesis Test

The equation used in testing this hypothesis is as follows:

$$t = \frac{\bar{x} - \mu_0}{\frac{s}{\sqrt{n}}} \quad \ldots (3)$$

$H_O$ = There is no significant increase after applying the combined media of PhET simulation and spring balance on vector material to improve the mathematical concepts of class XI students (Ho: $\mu = 0$).

$H_A$ = There is a significant increase after applying the combined media of PhET simulation and spring balance to the understanding of mathematical concepts of class XI students on vector material (Ho: $\mu \neq 0$).

**RESULT AND DISCUSSION**

**Descriptive Analysis**

The following is a description of the results of students' understanding of mathematical concepts in class XI MIPA

1 before and after being taught using a combination of PhET simulation media and spring balance. For quantitative research, the result contains detailed parts in subtopics related directly to the research focus and categories.

Table 4 Mean value of pre-test, post-test, gain and n-gain of mathematical concept understanding

| Mean | Value |
|---|---|
| Pre-test | 23.4 |
| Post-test | 87.5 |
| Gain | 64.1 |
| N-Gain | 0.8428 |
| Interpretation | Tinggi |

The data in Table 4 shows that the average pre-test score is in the very low category, the post-test score is in the very high category, and the N-Gain value obtained is 0.8428 in the high category. This shows that there is a difference and an increase in the results of the pre-test and post-test questions of understanding mathematical concepts before and after using the media combination of PhET simulations and spring balances, which ranged from low to high categories after the application of learning using the media combination of PhET simulations and spring balances on vector material for three learning meetings. If each student's pre-test and post-test data are compared, the data is presented in Figure 1.

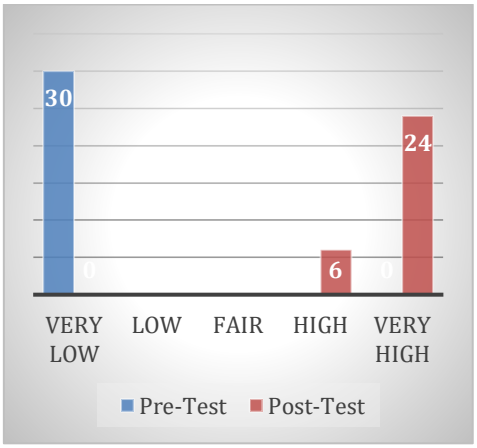


Figure 1 Comparison of post-test and pre-test scores

Figure 1 is a diagram showing the comparison of the pre-test and post-test. As many as 30 students at the time of the pre-test had scores in the very low category range, while at the time of the post-test, six students were in the high category, and 24 students were in the very high category. This means that the treatment of the combined media of PhET simulation and spring balance taught influences students' understanding of mathematical concepts, and there is a comparison after the learning is done.

**Inferential Analysis**

*Normality Test*

The data analysis prerequisite test is conducted to qualify before hypothesis testing (Bekker-Grob et al., 2015; Supena et al., 2021). It consists of a normality test with the following explanation.

Table 5 Normality test results of mathematical concept understanding data

| | Shapiro-Wilk | | |
|---|---|---|---|
| | Statistic | Df | Sig. |
| Pretest | .960 | 30 | .308 |
| Posttest | .979 | 30 | .806 |

Table 5 shows the data from the pretest and post-test results of understanding mathematical concepts using Shapiro Wilk with a significance value > 0.05 if normally distributed. The significance value shown in the pretest data is 0.308, which means that the pretest data on understanding mathematical concepts is normally distributed because it is 0.308 > 0.05. While the significance value shown in the post-test data is 0.806, the post-test data for understanding mathematical concepts is normally distributed because 0.806 > 0.05. So, the pretest and post-test data were used in research at MAN Kota Palangka Raya.

*Hypothesis Test*

After obtaining data on students' understanding of mathematical concepts with a normal distribution (Morales et

al., 1997; Tsagris et al., 2020), the hypothesis can be tested using parametric statistical tests (*One Sample T-test*) with the criteria for testing if the t value is positive if $t_{-count} > t_{-table}$ then Ha is accepted and Ho is rejected, while the value of $t_{-count} < t_{-table}$ then Ho is accepted and Ha is rejected, if the t value is negative then if $t_{-count} < t_{-table}$ then Ha is accepted and Ho is rejected, while the value of $t_{-count} > t_{-table}$ then Ho is accepted and Ha is rejected. The calculated t value has a negative value so that the t table value also adjusts to be negative, or in other words, hypothesis testing is carried out on the left side (Aras et al., 2023; Yusuf & Ichsan, 2021). Positive or negative results only indicate the direction of hypothesis testing and linearity, not the amount (Poernomo & Wulansari, 2015; Sarwono, 2015).

Table 6 One sample t-test hypothesis test results

| Hypothesis Test | Value |
|---|---|
| Mean | -64.067 |
| Std. Deviation | 8.863 |
| Std. Error Mean | 1.618 |
| Lower | -67.376 |
| Upper | -60.757 |
| t | -39.594 |
| t tabel | 3,39624 |
| Df | 29 |
| sig | 0.002 |

Table 6 shows the results of the one-sample t-test output with a t value of -39.594 and a t table of 3.39624, so $t_{count} < t_{table}$ so that -39.594 < 3.39624 then $H_O$ is rejected, and $H_A$ is accepted. If the t-count price is smaller or equal to the t-table price (t-count ≤ t-table), then H0 is accepted, and HA is rejected (Sugiyono, 2019).

From the pre-test data, the average pre-test score for understanding mathematical concepts was 23.4 in the very low category. This may be due to several factors, including (1) a lack of student interest in physics subjects. This is supported by the teacher's monotonous teaching style, which makes students bored. (2) A lack of practice in solving problems based on understanding mathematical concepts makes students difficult and stiff when faced with problems that the teacher has not taught. (3) Because the use of physics learning media is minimal, no suggestion can attract students' attention to the material. (4) There is a lack of practicum conducted on vector material. Furthermore, after implementing learning using a combination of PhET simulation media and spring balance, the average post-test result is 87.5 in the very high category. This shows that applying the media combination of PhET simulation and spring balance has increased and obtained an N-Gain value in the high category.

The increase in post-test and pre-test data is due to the media used during learning, namely PhET simulations and spring balance sheets, so that students can play an active role in being directly involved in learning. PhET simulation media and spring balance can attract students' attention to vector learning, whereas there is still minimal practicum in this vector material. Therefore, using internet-based media such as PhET simulation and media directly using a spring balance can pique students' curiosity. This is evidenced by students' enthusiasm in using the PhET simulation and the ability scale in each work group. The function of the PhET simulation and the spring balance itself helps students make it easier to understand mathematical concepts in vector material, so it has an impact on increasing students' understanding of mathematical concepts carried out during the study.

In line with research conducted by Marbun et al., (2022), which stated that the use of PhET simulation learning media as an activity of a virtual lab in the learning and teaching process could increase knowledge, especially the conceptual understanding of students in vector material (Durkaya, 2023; Sylvere

& Minani, 2023). In addition. Research conducted (Rohim et al., 2016) states that experiments directly used in learning can improve students' motor skills in recognizing the application of material or concepts in everyday life (Flick, 1993).

Based on the comparison of pretest and post-test results, it is found that there is an increase in students' understanding of mathematical concepts before and after applying the combined media of PhET simulation and spring balance. This statement is supported by the analysis results using the t-test with the achievement of t-count = -39.594 < t-table = 3.39624. This means that Ho is rejected, and HA is accepted. Thus, it can be concluded that there is a significant increase in the use of the media combination of PhET simulation and spring balance in understanding the mathematical concepts of grade XI students on vector material.

This also agrees with Ismaun (2019), who states that PhET simulation media influences improving concept understanding (Eveline et al., 2019). It is also in line with Agung, who states that direct experiments have a big effect as a series of learning activities that allow students to apply skills and practice the material taught directly (Agung, 2018; Carlson & Sullivan, 1999).

Hands-on experiments provide concrete, practical experience, allowing students to see and measure physical phenomena in real time, thus strengthening basic understanding and laboratory skills. Meanwhile, PhET simulations offer visualization of abstract concepts and allow flexible and safe exploration of variables, which helps students understand mathematical relationships more deeply. The combination of these two methods creates a comprehensive learning approach. The combination of these two methods creates a comprehensive learning approach. Hands-on experience helps students connect theory with practice, while simulation allows experimentation without time and resource constraints. Thus, integrating hands-on experiments and simulations can enrich students' understanding of mathematical concepts effectively and deeply.

## CONCLUSION

Based on the results of the study, it can be concluded that there is a significant increase in the understanding of mathematical concepts among students in class XI MIPA 1 MAN Kota Palangka Raya before and after the implementation of learning using a combination of PhET simulation media and spring balance. The effect of combining PhET simulation with spring balance media for vector materials is that the concept of vector yield can be understood in a more concrete context, with more physical constraints such as time, space, and laboratory equipment. In addition, student engagement is enhanced through an interactive learning environment, flexibility, and the development of data analysis skills.

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