Physics Modeling Learning Module to Improve Analytical Thinking Skills on Material Elasticity

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***Abstract* – Students' analytical thinking abilities are still relatively limited, which can be attributed, in part, to a lack of teaching materials specifically designed to foster higher-order thinking. Therefore, this study aims to examine the development of a module on elasticity implemented through physics modeling learning to improve students' analytical skills. This module was created to address the need for teaching resources that facilitate higher-order thinking in physics education. This study adopted a development approach based on the ADDIE model. The test subjects consisted of 30 students of class XI MIPA Madrasah Aliyah Pendidikan Islam Parigi Habirau Tengah. The effectiveness of the module was measured using one-group pretest-posttest design, while the data was analyzed using learning outcomes test and N-gain score. The results indicated that the developed module was moderately effective in enhancing students' analytical thinking skills, as evidenced by an N-gain score of 0.48. There was an increase in students' analytical thinking skills which reached the moderate category. The application of physics modeling-based learning has been proven to produce statistically significant improvements in students' analytical thinking abilities, which was tested using the Wilcoxon nonparametric test.**

These findings suggest that physics modeling learning can serve as an effective and significant alternative to improve learners' analytical thinking skills.

***Keywords* – Effectiveness, elasticity of materials module, physics modeling, analytical thinking.**

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1. Introduction

Rapid development demands that the world of education prepare students with 21st century skills, including high-level thinking skills. One of the essential abilities in this regard is the ability to think analytically. Within physics instruction, this competency is essential because it drives learners to develop more than just a basic grasp of concepts, and additionally be able to solve physics problems and draw conclusions from physical phenomena and form students' critical characters [1]. In the context of global development, analytical thinking skills are an important competency that must be developed in students [2].

Analytical thinking skills are the process of breaking down complex information into simpler components to understand the structure and relationships between these components [3], [4]. Analytical thinking is not just about memorization; it also involves complex understanding and creativity to enhance the quality of learning. This skill represents a higher cognitive level that can be achieved after students have mastered basic skills such as remembering, understanding, and applying [5]. According to Bloom's Taxonomy, analytical skills are part of high-level thinking that is useful for helping learners adapt information and apply it in daily life [6].

However, several studies suggest that students' analytical thinking abilities remain at a relatively low level. This result is reinforced by research carried out by [7] showing that only 13.3% of students were in the high category for analysis and evaluation skills, while 60% of students were still in the low category.

These various research results provide strong support for this statement [8] with the finding that students have difficulty understanding physics problems in depth, composing arguments and drawing conclusions.

Preliminary observations indicate that students at the Parigi Habirau Tengah Islamic High School (Madrasah Aliyah Pendidikan Islam) are experiencing difficulties in solving physics problems that require analytical thinking skills. This situation is closely related to the lecture-oriented learning approach, limited infrastructure, and teaching materials that are not yet available are specifically designed to train analytical thinking skills. Generally, teachers only use textbooks, e-books, or learning videos, without modules specifically designed to practice these skills.

To overcome these problems, appropriate teaching materials and learning models are needed that are able to facilitate analytical thinking skills. One potential approach to be applied in the module is learning physics modeling, which is an approach that involves students to identify phenomena, involves creating visual representations, formulating mathematical equations, and validating them through simple experiments [9].

The material elasticity is ideal for it is used in the learning approach of physics modeling because it presents a real relationship between observable physical phenomena and mathematical formulas that can be created by students. In the study of solid body physics, elasticity includes three important things, namely an explanation of the relationship between shape change and position displacement, the balance between the forces acting inside and outside the object, and how materials respond to pressure or pull based on their natural properties [10]. This connection allows students to improve their capacity for analytical thinking, especially of distinguishing, composing, and relating various physics concepts in more depth through the modeling process. Approaches that involve the laws of physics have great potential to help solve elasticity problems, such as calculating Young's modulus. One study showed that the field of elasticity can be estimated only based on shape change data, without the need to know the amount of stress directly [11]. These findings reinforce the importance of elasticity learning based on physics modeling in schools, because it can help students understand concepts such as Young's modulus more thoroughly. In addition, this approach is also able to train analytical thinking skills by encouraging students to see the relationships between physical variables logically. This leads to the assumption that physics modeling-based learning modules can contribute to strengthening students' analytical thinking skills, especially in the elasticity material.

Various studies have proven effectiveness of modules in improving students' analytical thinking skills. The physics module, with a feasibility rate of 87.32%, was found to be effective in improving analytical skills [12]. Research by [13] proves that the STS-based elasticity module is able to improve learning outcomes with a moderate *n-gain* category. The results of the research conducted by [14] physics modeling-based e-modules were declared effective.

Based on this description, the purpose of this study was to analyze the effectiveness of a physics modeling-based material elasticity module on developing students' analytical thinking skills. This research is considered important because analytical skills are a key element of critical thinking skills, which are essential in the context of 21st-century education [15].

2. Methodology

This study aimed to develop and evaluate a physics learning module based on modeling activities to improve students' analytical thinking skills. The research employed a research and development approach using the ADDIE model and a quasi-experimental design to examine the effectiveness of the developed module. The following sections describe the research design, participants, instruments, data collection procedures, and data analysis techniques.

2.1. Types of Research

A research and development approach was adopted in this study, with the analyze, design, development, implementation, evaluation (ADDIE) model serving as the guiding framework. This model includes five primary stages: Analysis of needs, design, development, implementation, and evaluation, all aimed at ensuring product quality development results The ADDIE *development method* used starts from analyzing needs in learning, design development with a systematic process, by making products that are ready to be implemented, *implementation* by applying product design to real situations to evaluation by providing feedback on product use and improvements according to needs and objectives [16].

2.2. Subjects and Objects of Research

The research subject in this study is the material elasticity module. A total of 30 grade XI MIPA students participated as subjects in this study. Madrasah Aliyah Islamic Education Parigi Habirau Tengah in 2024/2025. Meanwhile, the object of this research is the feasibility of the material elasticity module through learning physics modeling to improve students' analytical thinking skills reviewed from the aspect of effectiveness.

2.3. Study Setting and Period

This research was conducted at Madrasah Aliyah Islamic Education Parigi Habirau Tengah which is located at Jl. Habirau Tengah, the research was carried out in the Daha District of South Hulu Sungai Regency, South Kalimantan, Indonesia. The research time in the even semester is from April to May of the 2024/2025 academic year.

2.4. Research Design

This investigation implemented a *pre-test post-test* design involving only one participant group, which involved measurements before and after treatment in one group, where students are given an initial test (*pre-test)*, then participate in learning using modules, and end with a final test or learning outcome test (*post-test).* The learning model applied is physics modeling learning which consists of stages: Phenomenon identification, image modeling, mathematical modeling, simple experiments, and evaluation of learning outcomes [9].

2.5. Research Instruments

An assessment instrument was employed to measure the module's effectiveness, consisting of a descriptive test designed to evaluate students' analytical thinking skills. These measurement tool is structured as six items describing that elasticity of materials that contain aspects based on indicators of analytical thinking ability consisting of aspects of differentiating, organizing, and attributing, which are developed by the researcher himself. N-gain analysis was conducted on the data derived from the learning outcomes assessment to determine the level of improvement.

2.6. Data Collection Techniques

The data on the module's effectiveness were collected from pre-test and post-test results using an elasticity learning outcomes test instrument to measure students' analytical thinking ability. The assessment is seen from the scoring guidelines or the analytical thinking ability assessment rubric.

2.7. Data Analysis Techniques

Data analysis techniques are the design of steps that will be taken to analyze the data obtained during the research. The module effectiveness data is measured using the Learning Outcome Test, the calculation is performed using the N-gain value, or normalized gain score. The classification consists of three levels high if $\langle g \rangle \geq 0.7$, moderate if $0.7 > \langle g \rangle \geq 0.3$, and low if $\langle g \rangle < 0.3$.

A Wilcoxon Signed-Rank Test was conducted to examine whether there were statistically significant differences between the paired pre-test and post-test scores. Before carrying out the test, the initial stage carried out was a prerequisite test in the form of a normality test using the Shapiro-Wilk method, which is suitable for a sample count of less than 50. The results of the normality test are presented in Table 2, which shows that the significance value of the pre-test score is 0.027 (<0.05), which indicates that it is not normally distributed, while the *post-test* score has a significance value of 0.078 (>0.05), which means that it is normally distributed. Referring to the results listed in Table 2, it can be concluded that the *pre-test* scores data does not meet the assumption of normality so that the overall data is considered not to be distributed normally. Therefore, the Wilcoxon test is used as a nonparametric statistical analysis technique.

The hypothesis in this study reads " It was found that there was a difference in students' analytical thinking abilities between the *pre-test* and *post-test*", which shows that the application of physics modeling learning has an influence on students' analytical thinking abilities. To know improvement by students' analytical thinking skills after using the material elasticity module through physics modeling learning, the N-gain formula was applied to analyze the *pre-test* and *post-test* scores with the help of Microsoft Excel. The *N-gain* value obtained is then classified based on category criteria according to [17] listed in Table 1. Furthermore, students' analytical thinking ability results are seen from the increase in scores for each aspect of analysis, namely; differentiating, organizing and attributing. The results of the data analysis were used to assess the efficacy of the module in fostering students' analytical thinking skills.

Besides calculating the N-gain score, students' analytical thinking skills were further analyzed based on their achievement levels of each aspect of analytical ability, namely: Distinguishing, organizing, and attributing contained in learning outcome test questions in accordance with the bloom taxonomy indicator at *the fourth cognitive level* (C4) contained in 5 questions and one question at *the five cognitive level* (C5). The questions given to students were in the form of six questions describing the elasticity of materials that contained aspects based on indicators of analytical thinking ability consisting of 2 questions about differentiating aspects, 2 questions about organizational aspects, and 2 questions about attribution aspects. Items related to the differentiating aspect require students to identify variables that correspond to phenomena and distinguish physical characteristics from various materials based on available data with appropriate results. In questions for the organizing aspect, students should be able to comprehend the relationship between variables according to the phenomenon and organize information appropriately.

In questions for the attribution aspect, students are expected to be able to provide conclusions supported by evidence from the data obtained. The achievement of analytical thinking skills is reviewed from tests in the form of *pre-test* and *post-test* scores for each aspect of analytical thinking skills.

3. Results

The material elasticity module is developed through physics modeling learning to train students in thinking by differentiating, organizing and attributing by observing th e proposed physical phenomena at the beginning of the learning. Physics modeling learning is designed to improve students' analytical thinking skills. Developed with consideration of the resources and potential available to teachers and students, this research product seeks to fulfill the demands of high school physics education.

3.1. Analysis of Learning Stages

This study uses modules developed by researchers that are compiled through the syntax or stages of learning physics modeling. Physics modeling learning comprises five stages: Submission and identifying problems of physical phenomenon, provision of prerequisite information, engaging in physics modeling, finding solutions, and evaluating the processes and result.

In stage 1, the teacher proposes a physical phenomenon which will then be identified by the students. At the first meeting, the teacher proposed a phenomenon in the form of a bracelet from a string that was pulled at both ends and then released, as shown in Figure 1. At the second meeting, the teacher proposed the phenomenon per spring swing that was suspended with a load at its ends in a single, series and parallel. In the third meeting, the teacher proposed the phenomenon of bicycle wheels consisting of inner and outer tubes that are rolled by passing obstacles.

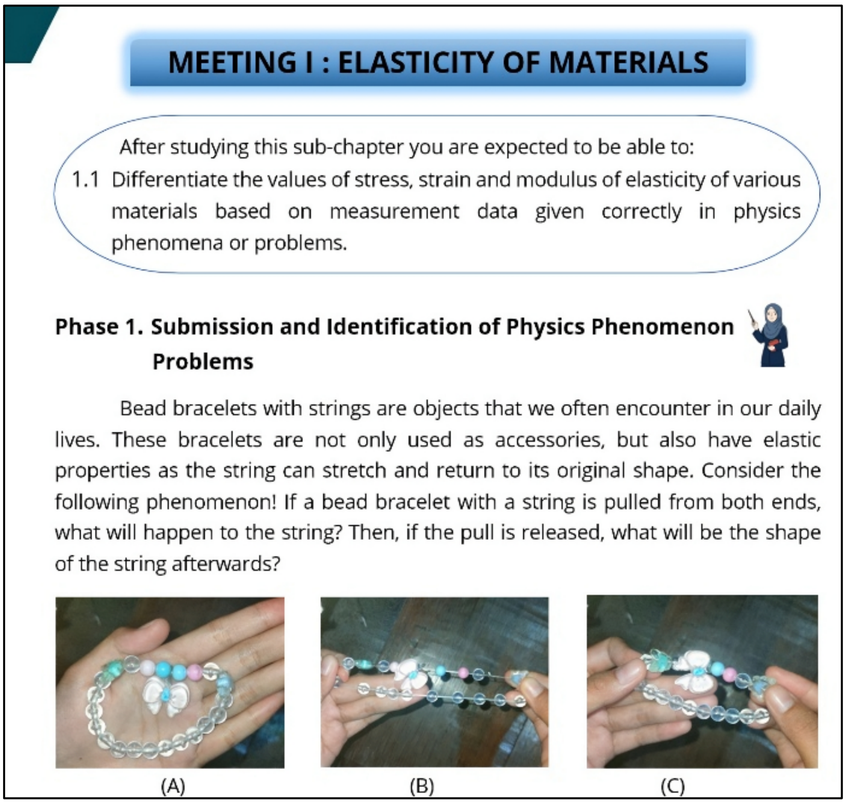


Figure 1. Physical phenomena

At each meeting, students were asked to identify observed physical phenomena and record their findings in a worksheet, as shown in Figure 2.

This phase supports students to think about differentiating aspect analysis, especially in the activity of finding relevant differences from the observed physical phenomena for each meeting.

Let's Find The Observed Physical Phenomena!

Write down the physical phenomena you observe to show that you are analysing by differentiating.

- The bracelet consists of beads and strings.
-
-
-

Figure 2. Stage 1 identification and documentation of physical phenomena issues

At stage two, preparatory information pertinent to the study material is delivered, as shown in Figure 3.

Teachers and disciples discuss this matter, then students are asked to read the information in the module.

Phase 2. Provision of Information (Prerequisite Knowledge)

Prerequisite Information

- Force is a form of pull or push that acts on an object.
- The force can be calculated by multiplying the mass of the object by the acceleration of gravity. Mathematically, the formula is expressed as follows:
$$\vec{F} = m.\vec{g}$$
- Length increase refers to the change in size of an object due to the effect of force or load.
- The initial length is the size of an object before a force or load is applied to it.
- The final length is the size of an object after a force or load is applied to it.
- The increase in length of an object can be obtained by subtracting the final length and the initial length of an object. Mathematically, it can be written as follows:
$$\Delta l = l - l_0$$
- Cross-sectional area is the area of a plane or a surface.
- The concept of stress and strain is the change in shape of an object.

Figure 3. Stage 2 provision of information/prerequisite knowledge

In stage 3, students construct visual representations of the previously presented physical phenomena by incorporating appropriate physical symbols, thereby facilitating their comprehension of physics concepts, as shown in Figure 4.

Students were also asked to complete a table linking the phenomena presented at the beginning of the lesson with corresponding physical phenomena, in order to help them organize information obtained from direct observation and image-based modeling. As a means for students to identify the relationship between physical concepts involved in a physical phenomenon.

Phase 3. Physics Modelling

Physics Modelling in the Form of Pictures

The phenomenon in Figure 5. The bead bracelet can be modelled in the form of a physical image. Complete Figure 6 below with the symbols of the physical symbols that influence the stress, strain and modulus of elasticity events and fill in the table of the relationship between the bracelet string and the beads based on their change in shape when a force is applied. This will show that you are analysing in terms of organisation.

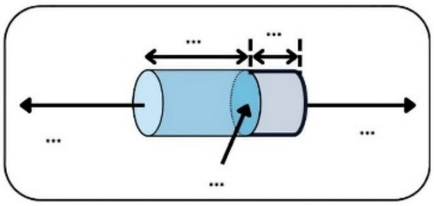


Table 1. Relationship of elasticity properties of materials based on bead bracelet phenomenon

Fill in the columns in the following table according to the phenomenon in Figure 6!

Bracelet Parts	Material Type	Response to Force

Figure 4. Stage 3 physical modeling in the form of images and relationship tables of physical phenomena

In stage 3, for mathematical modeling at the first meeting, students complete the formula in the module by referring to the modeling of the image that has been made with the description of the formula in the module.

However, in the second and third meetings, mathematical modeling became more independent, where students were asked to complete formula information based on existing drawings without being given direct instructions in the module, as shown in Figure 5. It aims to improve analytical thinking skills and understanding of mathematical relationships in physics.

Physical modelling in mathematical

Based on Figure 6, several mathematical equations can be formulated, including stress, strain and modulus of elasticity.

Tegangan

Stress is the external force acting on an object per unit area. Stress *(stress)* (σ) is defined as the ratio between the tensile force acting on an object $(\overrightarrow{F})$ with the cross-sectional area of the object (A). Stress is directly proportional to the tensile force acting on an object and inversely proportional to its cross-sectional area.

$$\text{Stress} = \frac{\text{Force}}{\text{Sectional area}}$$

The mathematical model can be written as follows:

$$\boxed{\ldots = \frac{\ldots}{\ldots}}$$

Description :

... = stress $(\mathrm{N/m^2})$, ... = pulling force (N), ... = sectional area $(\mathrm{m^2})$

Figure 5. Stage 3 physical modeling in mathematical form

Another activity in this stage is an experiment or a simple experiment to test the empirical formula that has been obtained, as shown Figure 6. At the first meeting, students simply read the experimental procedures available in the module.

Meanwhile, in the second and third meetings, students are directed to design their own experimental procedures using the tools and materials that had been provided. In this process, students are given the opportunity to ask if there are things that are not understood related to physics modeling.

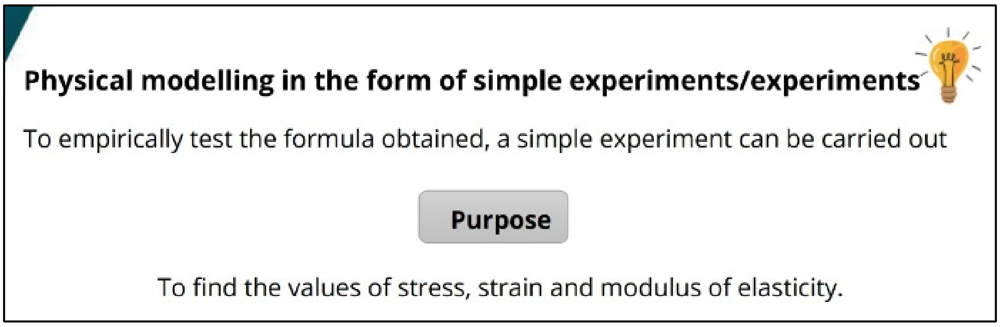
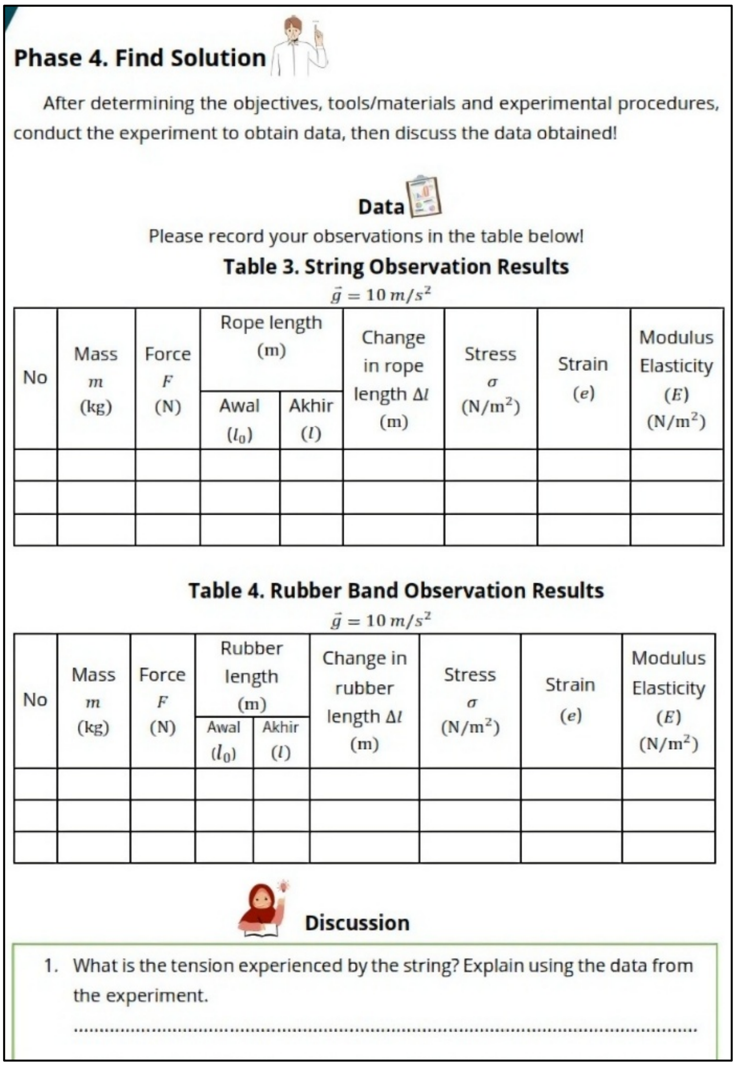


Figure 6. Stage 3 physical modeling in the form of experiments/ simple experiments

In the fourth phase, students are directed to find solutions to problems from the phenomena that have been studied in the previous phase through experimental activities.

Following this, students engage in experiments, obtain data, and note the outcomes within by module, as shown in Figure 7. Furthermore, the discussion for the first meeting and for the second and third meetings was conducted in groups.



Phase 4. Find Solution

After determining the objectives, tools/materials and experimental procedures, conduct the experiment to obtain data, then discuss the data obtained!

Data

Please record your observations in the table below!

Table 3. String Observation Results

$\vec{g} = 10\ m/s^2$

No	Mass m (kg)	Force F (N)	Rope length (m)		Change in rope length Δl (m)	Stress σ (N/m^2)	Strain (e)	Modulus Elasticity (E) (N/m^2)
			Awal (l_0)	Akhir (l)				

Table 4. Rubber Band Observation Results

$\vec{g} = 10\ m/s^2$

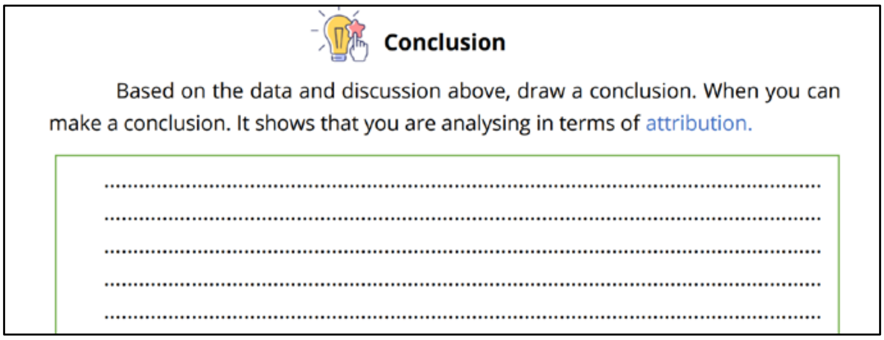
No	Mass m (kg)	Force F (N)	Rubber length (m)		Change in rubber length Δl (m)	Stress σ (N/m^2)	Strain (e)	Modulus Elasticity (E) (N/m^2)
			Awal (l_0)	Akhir (l)				

Discussion

1. What is the tension experienced by the string? Explain using the data from the experiment.
....

Figure 7. Phase 4 finding solutions by conducting experiments based on the designs that have been made

After students conduct experiments based on the design that has been made, the next step in the fourth phase is to draw conclusions from the entire modeling process, as shown Figure 8 to fill in the conclusion. At this juncture, learners are required to reflect on the observation results, experimental data, and empirical formulas that have been obtained, then make conclusions by describing the relationship between the observed physical phenomena and the mathematical model and the results of the experiment. This phase supports learners to think analytically about the attribution aspect, especially when making conclusions.


Conclusion

Based on the data and discussion above, draw a conclusion. When you can make a conclusion. It shows that you are analysing in terms of attribution.

....
....
....
....
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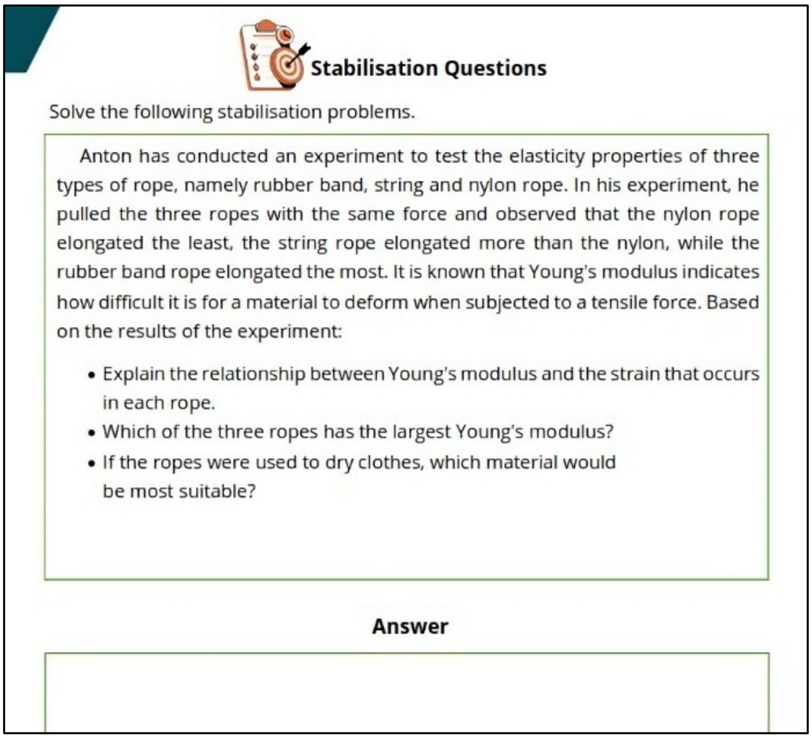
Figure 8. Phase 4: finding solutions by drawing conclusions

Furthermore, students are asked to work on consolidation problems that are relevant to the material discussed, as shown in Figure 9.

During this phase, the teacher guided the activities, while students were encouraged to ask questions.


Stabilisation Questions

Solve the following stabilisation problems.

Anton has conducted an experiment to test the elasticity properties of three types of rope, namely rubber band, string and nylon rope. In his experiment, he pulled the three ropes with the same force and observed that the nylon rope elongated the least, the string rope elongated more than the nylon, while the rubber band rope elongated the most. It is known that Young's modulus indicates how difficult it is for a material to deform when subjected to a tensile force. Based on the results of the experiment:

- Explain the relationship between Young's modulus and the strain that occurs in each rope.
- Which of the three ropes has the largest Young's modulus?
- If the ropes were used to dry clothes, which material would be most suitable?

Answer

Figure 9. Phase 4 finding solutions with consolidation problems

In phase 5 of the evaluation of the process and results, the teacher checks the results of the students' work in general and provide feedback to students. The educator and the students discuss the results obtained during the lesson, then ask the students to write corrections in the module if there are errors or differences.

Finally, the teacher and the students make conclusions from the learning that has been carried out and write it down in the module, as shown in Figure 10.

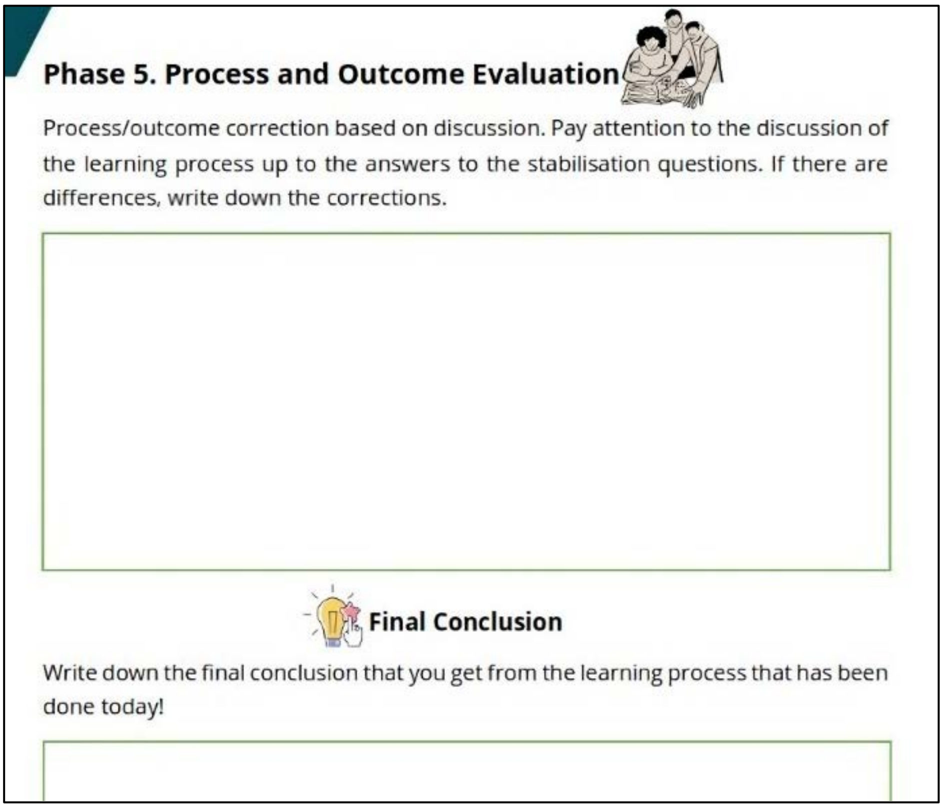


Figure 10. Phase 5 process and outcome evaluation

3.2. Analysis of Analytical Thinking Ability

The material elasticity module developed by the researcher supports students to think analytically in each meeting. The indicators of analytical thinking ability are divided into three, namely differentiating, organizing and attributing. The three indicators can be seen in the following description:

3.2.1. Differentiating Aspect Analysis Ability

In the module section “Let’s find observed physical phenomena!” students are encouraged to generate as many answers or ideas as possible, as shown in Figure 11. This can support students to think analytically on the differentiating aspect.

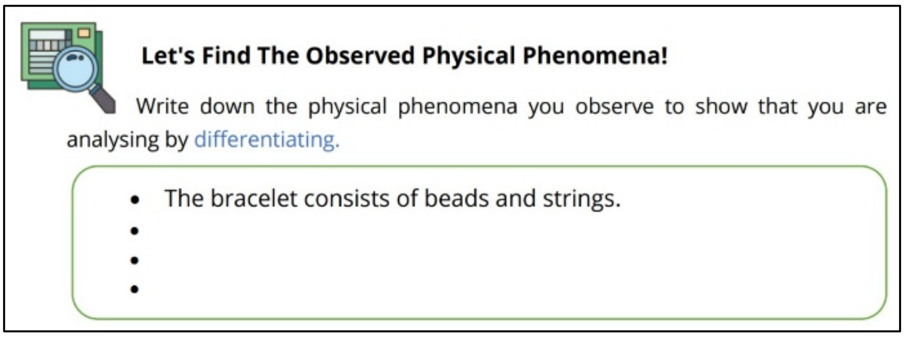


Figure 11. Ability to think and analyze aspects of differentiation

3.2.2. Organizational Aspect Analysis Skills

In the physics modeling phase, students develop physical models in the form of drawings. They are asked to create their own representations based on the physical phenomena observed in the first phase. In addition, students complete the relationship table by linking the observed phenomena with their corresponding physical representations. This supports students to think analytically on the organizational aspect, as shown in Figure 12.

The existence of a relationship table of these phenomena can support effective learning because it facilitates understanding and serves as a reminder of concepts to help students connect concepts that are a form of organizing information at the *fourth cognitive level* (C4) of the Bloom Taxonomy.

This phase also emphasizes the importance of analytical skills, especially in organizing information, which is seen when learners fill out tables the relationship of the phenomenon presented at the beginning of learning.

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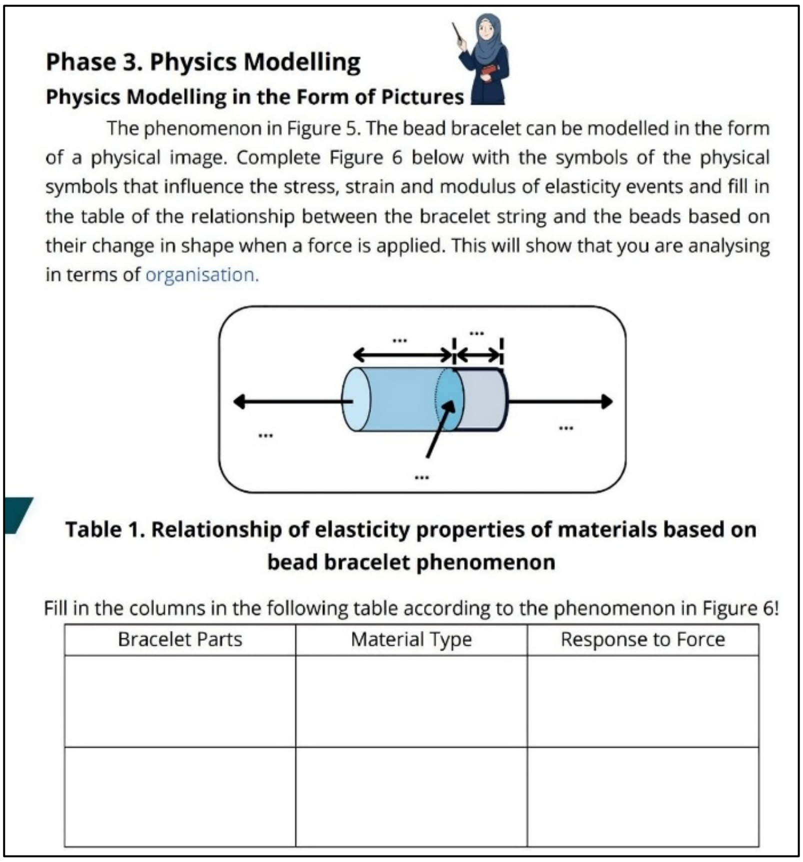


Phase 3. Physics Modelling

Physics Modelling in the Form of Pictures

The phenomenon in Figure 5. The bead bracelet can be modelled in the form of a physical image. Complete Figure 6 below with the symbols of the physical symbols that influence the stress, strain and modulus of elasticity events and fill in the table of the relationship between the bracelet string and the beads based on their change in shape when a force is applied. This will show that you are analysing in terms of organisation.

Table 1. Relationship of elasticity properties of materials based on bead bracelet phenomenon

Fill in the columns in the following table according to the phenomenon in Figure 6!

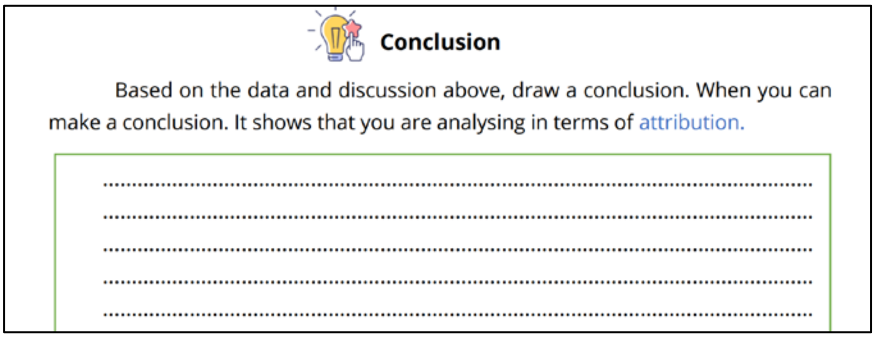
Bracelet Parts	Material Type	Response to Force

Figure 12. Analytical thinking skills in organizational aspects

3.2.3. Attribution Aspect Analysis Ability

The analytical ability in this attribution aspect is found in the phase of finding solutions, namely in the conclusion section, as shown in Figure 13.

Students were asked to make conclusions after conducting a simple experiment and after obtaining the results of the experiment data. This supports students to think analytically on the attribution aspect.



Conclusion

Based on the data and discussion above, draw a conclusion. When you can make a conclusion. It shows that you are analysing in terms of attribution.

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....

....

Figure 13. Ability to think analysis of attribution aspects

3.3. Effectiveness Analysis

The data from the preliminary and subsequent assessments reflected use as a provided a standard for comparing students' analytical thinking abilities before and after the adoption of physics modeling-based learning, demonstrating that of the initial assessment indicated that students were generally unable to solve physics problems through analytical reasoning.

This finding is corroborated by the N-gain score, which falls within the medium category, suggesting that there is a measurable difference in students' analytical thinking abilities before receiving the instructional intervention *(pre-test)* and after being given treatment (*post-test)*. Analytical thinking ability is measured using learning outcome tests from *(baseline test)* and *(follow-up test*). The assessment of students' learning achievements consists of six questions made with the aspect of analytical thinking ability, namely differentiating, organizing and attributing.

The questions given to students include 2 questions on the differentiating aspect, 2 questions on the organizational aspect, and 2 questions on the attribution aspect.

The outcomes of the *n-gain* calculation of analytical thinking ability are presented below.

Table 1. Results of calculation of N-gain thinking ability analysis

Indicator	Average *Pre-test*	Average *Post-test*	*N gain*	Category
Differentiate	23.33	59.67	0.47	moderate
Organize	30.50	60.88	0.44	moderate
Attribution	20.58	62.50	0.53	moderate
average		0.48		moderate

Table 1 shows the attainment of analytical thinking skills among students pre- and post-learning using the modules developed by the researcher. On average, the pre-test of all aspects of analytical thinking ability of students obtained a bad category. Furthermore, the average post-test obtained a sufficient category in the differentiating aspect, the category was good in the aspect of organizing and attributing. This improvement shows that the material elasticity module based on physics modeling is able to encourage the development concerning learners' analytical thinking competencies. Modules designed of mechanics content and problem-solving problems can function to evaluate and develop students' analytical reasoning skills, especially through that stages of analyzing important information in physics problems, understanding the relationships between concepts, and constructing solutions logically. This approach is in line with modeling-based physics learning, including material elasticity material, which requires students to actively build conceptual understanding through a high-level thinking process [18].

A normality analysis is carried out to verify if the *pre-test* and *post-test* datasets conform to a normal distribution.as a requirement for parametric tests. The results of the normality test used two methods, namely Kolmogrov-Smirnov and Shapiro-Wilk, which are shown in Table 2 .

Table 2. Normality test results

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pre-test	.142	30	.126	.920	30	0.027
Post-test	.171	30	.026	.938	30	0.078

According to the Kolmogorov–Smirnov test results, the significance value for the initial assessment was 0.126 (> 0.05), whereas the final assessment yielded a value of 0.026 (< 0.05).

Furthermore, the Shapiro–Wilk test indicated significance values of 0.027 for the initial assessment and 0.078 for the final assessment. Since at least one dataset did not conform to a normal distribution, the normality assumption was not satisfied. Consequently, hypothesis testing was conducted using the non-parametric Wilcoxon Signed-Rank Test.

Table 3 shows the results of the non-parametric analysis comparing students' initial and final assessment data revealed zero negative ranks, indicating that no decline occurred between the two measurements. In contrast, the positive ranks totaled 30, demonstrating that all students experienced an improvement in their analytical thinking scores from the initial to the final assessment. The mean rank was 15.50, with a sum of positive ranks amounting to 465.00. These findings confirm that the scores obtained in the initial and final assessments were not identical, this is indicated by a series value of 0. The following is a table of Wilcoxon test results.

Table 3. Wilcoxon test results

Component	Value
Sample Count (N)	30
Total Negative Ranks	0
Total Positive Ranks	30
Number of Series Data (Ties)	0
Total Positive Ranks (W^+)	465.00
Total Negative Ranks (W^-)	0.00
Mean rank (Total Positive Ranks/N)	15.50
Test Statistical Value (W count)	0
Critical Values (W table, α = 0.05, n = 30)	137
Results	H_0 Rejected
Interpretasi	There was a significant difference ($p < 0.05$)

4. Discussion

This section discusses the learning process and the effectiveness of the developed physics modeling-based module in improving students' analytical thinking skills. The discussion is organized based on the learning stages and the results of the effectiveness analysis.

4.1. Analysis of Learning Stages

The first phase, illustrated in Figures 1 and 2, focuses on presenting and identifying physical phenomena. During this phase, the teacher introduces the lesson topic and clearly explains the learning objectives. ext, the teacher proposes a physical phenomenon related to the material to be studied. In the first meeting, teacher proposes a phenomenon beaded bracelets that undergo deformation when drawn for material tension, strain and modulus of elasticity of the material's elasticity sub-properties. In the second meeting, the teacher proposed the phenomenon of a spring swing at the end of which hung a load strung in a single, series and parallel manner for the sub-material of Hooke's law. In the third meeting, the teacher proposed the physics phenomenon of two inner tubes and outer tubes of a bicycle that were rolled by passing through obstacles from a wooden block. After presenting the physical phenomenon, the teacher guides students to observe, compare, and identify differences among the phenomena. Students then document their findings in the module. This stage supports the development of analytical thinking skills, especially in the differentiating aspect.

The second phase of providing information/ prerequisite knowledge is shown in Figure 3. The teacher conveys information about the learning process to be carried out and provides information about the tools and materials that will be used in learning. Next, the teacher discusses and asks students to understand the prerequisite information presented in the module. At this stage, the teacher conveys information about learning and the tools/materials used properly and completely, and students also read the prerequisite information in the module. Educators also instruct students to ask questions if there is something they do not understand. According to [19], teachers have many opportunities to improve and train how to ask students' questions where the guidance provided will exert a beneficial influence on students' learning participation. Feedback from teachers and learners is an important factor that influences the success of learners. Providing good and correct feedback by teachers will be the solution to achieving learning goals [20].

The third phase is the physics modeling shown in Figure 4, Figure 5, and Figure 6. A representation of the real thing is called a model that can be represented in the form of pictures and tables [21]. In Figure 4, learners are required to create drawing-based models of the physical phenomena introduced during the initial phase, tables of relationships between phenomena, mathematics and simple experiments.

At the first, second and third meeting, students were asked to complete the picture with physical symbols related to the phenomenon presented at the beginning of the lesson. The use of simplified visual representations helps students better understand the learning material [21]. This phase also supports students to think about the analysis of organizational aspects, especially when filling in the table of relationships between phenomena that occur.

As for the mathematical modeling shown in Figure 5 at the first meeting, it is carried out by completing the formula in the module by referring to the modeling of the image that has been made with the description of the formula in the module. As for the second and third meeting, the mathematical modeling carried out by the students in the activity of completing the formula, the students were asked to complete the formula information themselves based on the modeling of the images that had been made based on the phenomena presented in phase 1. A similar conclusion was reported in the study by [22], it explains that mathematical modeling supports the mathematical learning process that helps students understand learning better. Mathematical modeling is learners' ability to represent real life situations in daily life into a mathematical model that can be analyzed and solved.

Further, [23] highlights that modeling plays a crucial role in assisting learners in selecting appropriate physical laws and representing experimental phenomena in mathematical terms. Therefore, the teacher's role in adapting the instructional approach is essential, so that this process can be adjusted to the needs of students and encourage high-level thinking skills. In line with that, research by [24] shows that the success of students in solving physics problems is greatly influenced by mathematical skills. Problem-solving requires not only an understanding of physical concepts, but also the ability to apply mathematical principles to analyze and interpret phenomena.This reinforces that physical modeling approaches that integrate mathematical aspects are relevant for developing analytical thinking skills, particularly in material elasticity.

Physical modeling in the form of an experiment is shown in Figure 6. At the first meeting, students can read the simple experiment/experiment procedure in the module. As for the second and third meetings, students were asked to design their own procedures to test empirical formulas based on the tools and materials that had been provided. In this phase, learners are encouraged to raise questions during the learning process if there is anything they want to ask related to physics modeling.

This activity also trains students' analytical thinking skills in the aspect of organizing, for example when they compile and fill in tables that describe the relationships between phenomena observed during experiments. In physics learning, modeling aims to enable students to describe, explain, and predict phenomena. Students build models based on evidence, then use those models to obtain new evidence. This process creates iterative interactions between models, evidence, and experimental tools, which strengthen students' understanding of physics concepts, including material elasticity [25].

The fourth phase is the solution-finding phase, as shown in Figure 7. In this phase, the teacher asks students to conduct a simple experiment that has been previously designed. The results are then recorded in the observation table provided in the module. Furthermore, students engage in discussions and draw conclusions about physical phenomena based on their observational findings, thereby promoting analytical thinking related to the attribution aspect, as shown in Figure 8. Furthermore, students are required to complete consolidation tasks related to the subtopic, as shown in Figure 9. They are also encouraged to formulate their own questions, thereby promoting deeper conceptual understanding and active engagement in the learning process.

The fifth phase is the evaluation of the process and results, as shown in Figure 10. In this phase, the teacher reviews students' answers, confirms their correctness, and provides feedback on the correct and incorrect aspects. Students then revise their work based on the feedback and record the corrections in the module.

4.2. Effectiveness Analysis

Based on Table 1, the reported mean scores for each dimension of analytical thinking indicate that all aspects are at a moderate level. On average, all aspects of analytical thinking ability were categorized as poor. In addition, the average post-test obtained sufficient categories in the differentiating aspect, the category was good in the aspects of organizing and attributing. The implementation of the physics modeling method resulted in improved analytical thinking skills among students.

The learning syntax of physics modeling supports learners to think analytically at each meeting. In each meeting, learners are asked to identify the observations of physical phenomena and find differences relevant to the observed physical phenomena. This supports the learner to think analytically in the differentiating aspect as it asks the learner to identify the variables that correspond to the phenomenon and distinguish the physical characteristics of the various materials based on the available data with the right results.

Students are also asked to create drawing-based models and complete a table of relationships between variables based on the observed phenomena. This activity supports students' analytical thinking in the organizational aspect. It encourages them to understand the relationships among variables and to organize information appropriately according to the phenomenon. In addition, at each meeting, students are also asked to draw conclusions after conducting experiments so as to support students to think analytically in the attribution aspect. Table 3 shows the average results of students' answers for each aspect of analytical thinking before and after being treated for the application of physics modeling learning in the classroom. Evidence from the study shows that all dimensions of analytical thinking increased after the instructional intervention. The learning of applied physics modeling has an influence on students in improving analytical thinking.

This improvement is supported by the statistical test results. As presented in Table 1, all aspects of analytical thinking demonstrated progress from the initial to the final assessment. Prior to hypothesis testing, a normality test was conducted to verify the distribution of the data. The results shown in Table 2 indicate that the initial assessment produced significance values of 0.126 in the Kolmogorov–Smirnov test and 0.027 in the Shapiro–Wilk test, whereas the final assessment yielded values of 0.026 and 0.078, respectively. Given that the sample size was fewer than 50, the Shapiro–Wilk test was used as the primary reference. The findings revealed that the initial assessment data were not normally distributed ($p < 0.05$), while the final assessment data followed a normal distribution ($p > 0.05$). Consequently, the normality assumption was not satisfied, and the analysis proceeded using the non-parametric Wilcoxon Signed-Rank Test.

The improvement is further supported by the results of the non-parametric Wilcoxon Signed-Rank Test presented in Table 3. Calculations conducted using Microsoft Excel produced a positive rank (W^+) of 465.00 and a negative rank (W^-) of 0.00, resulting in a test statistic (W) of 0. This value was then compared with the critical table value at a significance level of 0.05 for $n = 30$, which was 137. Since the calculated W was lower than the critical value ($0 < 137$), the null hypothesis (H_0) was rejected in favor of the alternative hypothesis (H_1). These findings indicate a statistically significant difference between students' initial and final assessment scores following the instructional intervention. Thus, there is an effect of the use of the material elasticity module through learning physics modeling on students in improving analytical thinking skills.

These results align with prior research [26] which emphasizes that the integration of physical information and mathematical models is essential to accurately solve the problem of material elasticity. Understanding the material elasticity of materials requires the skill of building mathematical models based on the laws of physics, which is at the core of developing analytical thinking skills through modeling approaches. This is reinforced by [27], [28] which confirms the importance of integrating the laws of physics into mathematical models to understand phenomena such as elasticity. This principle is reflected in the learning of physics modeling applied in the classroom. Moreover, [29] also emphasizing that learning physics can improve high-level thinking skills through the activity of designing, testing, and revising models based on the concepts learned. In the context of material elasticity, students are required to relate the concepts of style, strain, and Hooke's law analytically through model representations of real phenomena.

Future learning solutions include the use of scientific-based modules with a learner-centered approach. Module designed is not only visually appealing, but it also encourages active engagement and independent learning, with teachers acting as facilitators [30]. The elasticity and Hooke's law modules developed have proven to be effective in improving critical thinking skills, including analytical aspects. The activity encourages students to distinguish information, organize concepts, and attribute the laws of physics appropriately [31]. These findings reinforce the urgency of the physics modeling approach as a strategy to strengthen students' understanding of analytical thinking skills.

5. Conclusion

Based on the research findings and discussion, it can be concluded that the implementation of physics modeling learning contributes to the improvement of students' analytical thinking skills. The improvement is evidenced by higher post-test scores compared to pre-test results, supported by non-parametric statistical analysis and moderate N-gain values. Gains were observed across all analytical thinking dimensions, namely differentiating, organizing, and attributing.

Therefore, Physics Modeling learning has a positive effect on improving students' analytical thinking skills. This study contributes by offering an alternative instructional model for physics education aimed at enhancing students' analytical thinking skills. However, the study is limited by its focus on a single physics topic, suggesting the need for future research to examine the effectiveness of this approach across a broader range of physics content.

The implications of this study indicate that upper secondary physics teachers may adopt a module-based physics modeling approach as an effective strategy for fostering higher-order thinking skills, especially analytical thinking skills. The use of modules that are designed in a contextual and problem-based manner can be a means to encourage students to think scientifically from an early age. As for further research, it is recommended that the physics modeling learning model be tested on various other topics such as harmonic motion, fluids, or dynamic electricity to see the consistency of its influence on analytical thinking skills and other scientific skills. In addition, furthermore, the development of digitally based interactive modules incorporating a modeling approach may serve as an alternative for addressing the challenges of physics education in the contemporary digital era.

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