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Unlocking Creativity: Exploring the Effects of Physics Modelling on Creative Thinking Skills

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Abstract: Unlocking Creativity: Exploring the Effects of Physics Modelling on Creative Thinking Skills. Objectives: Knowing the improvement of creative thinking skills through the implementation of physics Modelling learning is the purpose of the research conducted. **Methods:** The research was conducted using Experimental Design method. This research trial used one group pre-test post-test design on 33 high school students and the data were analyzed using n-gain score test results and hypothesis test using Wilcoxon's non-parametric statistical test to determine whether there was an average difference between two paired samples. **Findings:** The results of the analysis showed that the implementation of physics modelling learning can improve creative thinking skills with an n-gain of 0.496 for the fluency aspect, 0.72 for the flexibility aspect, and 0.87 for the originality aspect. Apart from that, there was a significant increase in creative skills between before and after the implementation of physical Modelling learning tested through the non-parametric Wilcoxon test. **Conclusion:** Thus, it can be concluded that physics Modelling learning can be used as an alternative learning because it is effective and significant for improving creative thinking skills.

Keywords: creative skill development, creative thinking skill, physics modelling learning.

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INTRODUCTION

Thinking skills are one of the student skills that can be developed at school through the learning process. 21st century skills consist of the 4Cs, namely *creativity & innovation, communication*, *Collaboration*, *critical thinking & problem solving* (Yanto & Enjoni, 2022). One of the skills that is important for students to have at this time, including to learn physics, is creative thinking skills (Han & Suh, 2020; Pasaribu, Lubis, & Medriati, 2022; Sutriyono, Ismet, & Wiyono, 2022; Yustina, Mahadi, Ariska, Arnetis, & Darmadi, 2022). The skill of creating something that is not the same or new and providing solutions in solving a problem is a creative thinking skill (Chen, 2021; Fitriyah &; Ramadani, 2021). Aspects of creative thinking skills include: *originality, fluency, and flexibility* (Marcos, Carrilo, Fernandez, & Gonzalez, 2023; Srikongchan, Kaewkuekool, & Mejaleurn, 2021; Wang & Li, 2022).

The creative thinking skills of students are still relatively low. This is supported by the results of the interview Mawarni, Sholahuddin, & Badruzsaufari (2022) together with a number of teachers gathered in the Natural Sciences Subject Teacher Conference (MGMP) in Banjarmasin, Indonesia information was obtained that creative thinking problems are one type of problem *HOTS* the most difficult for students to understand. The statement is also reinforced by the results of interviews and initial observations by Ulfah, Rusmansyah, & Hamid (2020) in one of the Banjarmasin State High Schools, information was obtained that students were still not used to producing diverse thoughts or answers so that students were considered to have low creative thinking skills. Choosing the right learning model can help students to form creative thinking skills (Ndiung, Sariyasa, Jehadus, & Apsari, 2021).

Physical modelling learning is an innovative learning that teaches physics as a whole and comprehensively, and can be implemented in classroom learning to support students to think creatively. Learning physical Modelling in it there are physical Modelling techniques. Physical Modelling studies a material by revealing phenomena to be modeled in the form of images, formulating mathematically predictive formulas which are then tested through experimental activities or simple experiments (Salam & Arifuddin, 2018). Image Modelling is important to do because in it learners will think creatively to make image models of existing physical phenomena. Mathematical Modelling is very important to use in studying physics because it is a process to present a phenomenon in the form of an equation formulation (Sari, 2020). Mathematical Modelling activities can form creative thinking skills because in it learners provide an interpretation of a phenomenon and then make mathematical equations. Demonstration/ practicum activities are also very effective in helping students learn physics, because learning by doing and finding their own concepts will facilitate students' understanding of the material (Gumay & Bertiana, 2018). Demonstration activities can train students' creative thinking skills because there are activities to design experiments or experiments. Learning with Modelling can improve students' understanding of concepts (Trisnawati, Sutopo, & Yulianti, 2021). This was reinforced by Arifuddin *et al.* (2010) in Salam & Arifuddin (2018) which states that physical Modelling can improve the learning outcomes of students and train critical thinking. Therefore, physics modelling learning can be applied in learning to improve students' creative thinking skills.

The aim of this research is to determine the improvement of creative thinking skills through the application of physics Modelling learning.

METHOD

Research Design and Participants

This part the research was conducted using quasi-experimental experimental methods or Quasi Experimental Design. The implementation design of this study is a *one-group pre-test post-test design* used was to compare the situation before and after treatment by implementing physical modelling learning. The test subjects in this study were 33 high school students.

Data Collection and Data Analysis

Data on creative thinking skills was obtained from test results using a test instrument for learning results on solid substance deformation material in the form of a pre-test and post-test to measure the level of students' creative thinking skills. The assessment is seen from the scoring guidelines or creative thinking skills assessment rubric. The research instrument is in the form of five essay questions on the deformation of solids which create aspects of creative thinking skills (fluency, flexibility and originality) and was developed by the researcher. The data from the learning outcomes test obtained is then calculated using the normalized gain score. The categories include high for the value $(g) \geq 0{,}7$, medium for the value $0{,}7 > (g) \geq 0{,}3$ and low for the value $(g) < 0{,}3$ (Hake, 1999).

Statistical tests are carried out with non-parametric Wilcoxon statistical tests to determine whether there is an average difference between two paired samples. Hypothesis: "There are differences in students' creative thinking skills during pre-test and post-test, which means that there is an influence of the use of physical modelling learning student creative thinking skills".

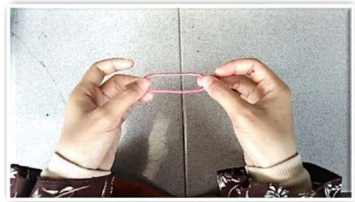
The test given to students is in the form of five essay questions consisting of 2 questions on fluency aspects, 2 questions on flexibility aspects and 1 question on originality aspects. In questions for the fluency aspect, students are expected to provide more than one idea that is relevant to problem solving and the disclosure is complete and precise. In questions for aspects of flexibility, students can provide answers in more than one way with the right process and results. In the matter of originality aspects, students can give answers in their own way and the calculation process and results are correct. The achievement of creative thinking skills is reviewed from tests in the form of pre-test and post-test scores for each aspect of creative thinking skills. The calculation results are adjusted according to the categories in the following table.

Table 1. Categories creative thinking skills

No.	Value	Category
1	$80 < N \leq 100$	Very creative
2	$60 < N \leq 80$	Creative
3	$40 < N \leq 60$	Quite creative
4	$20 < N \leq 40$	Less creative
5	$N \leq 40$	Not creative

RESULT AND DISCUSSION

This study uses modules developed by researchers arranged through syntax or stages of physics modeling learning. Physics modeling learning has five phases, including: 1) submission and identification of problems of physical phenomena, 2) provision of prerequisite information, 3) physics modeling, 4) finding solutions, 5) evaluation of processes and results.



(c)

Figure 1. Physics phemomena

In phase 1, the teacher proposes a physics phenomenon which will then be identified by the students. At the first meeting, the teacher proposed a phenomenon in the form of a rubber band that was pulled at both ends and then released. At the second meeting, the teacher proposed the phenomenon of a spring that is hung with a load at the end. In the third meeting, the teacher proposed the phenomenon of two springs arranged in series and two springs arranged in parallel at the end of which a load was hung. Each meeting students are asked to identify the observed physical phenomena and make scientific questions relevant to the phenomenon.

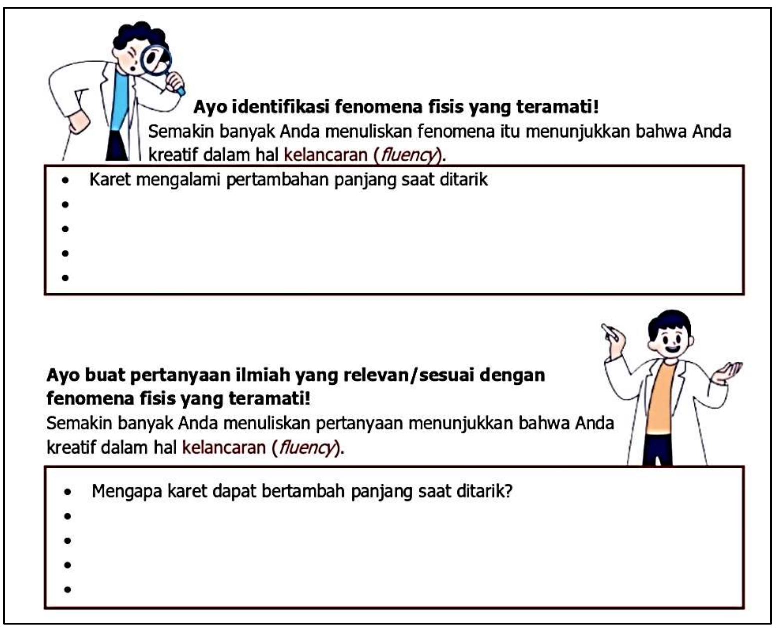
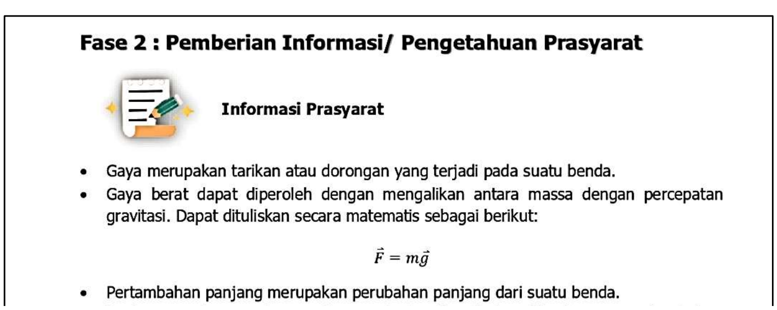


Figure 2. Phase 1 of the submission and identification of problems of physical phenomena



- Panjang awal merupakan panjang suatu benda sebelum diberikan gaya atau beban pada benda tersebut.
- Panjang akhir merupakan panjang suatu benda setelah diberikan gaya atau beban pada benda tersebut.
- Pertambahan panjang suatu benda dapat diperoleh dengan cara mengurangkan panjang akhir dengan panjang awal atau selisih antara panjang akhir dan panjang awal suatu benda. Dapat dituliskan secara matematis sebagai berikut:

Figure 3. Phase 2 of the provision of prerequisite information/knowledge

This phase supports students to think creatively about the fluency aspect, especially in identifying and making questions relevant to the observed physical phenomena for each meeting.

In phase 2, prerequisite information related to the material to be studied is presented. Teachers and students discuss this, then students are asked to read the information in the module.

Fase 3 : Pemodelan Fisika

Pemodelan Fisis dalam Bentuk Gambar

Fenomena pada gambar 5. karet gelang dapat dimodelkan dalam bentuk gambar fisis. Lengkapi gambar 6. berikut dengan simbol-simbol fisis yang berpengaruh dalam peristiwa tegangan, regangan dan modulus elastisitas. Hal tersebut akan menunjukkan bahwa Anda berpikir kreatif dalam hal keaslian (*originality*).

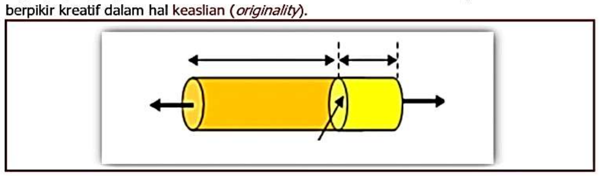


Figure 4. Phase 3 of physics modeling , modeling of physics in the form of drawings

In phase 3, students are asked to model the physical phenomena that have been proposed in phase 1 in the form of drawings, mathematics and simple experiments/experiments to test the empirical formulas obtained. At the first meeting, students are asked to complete the picture with physical symbols related to the phenomenon presented at the beginning of the lesson. As for the second and third meetings, students were asked to make their own models and drawings based on the phenomena observed in the phenomena presented in phase 1.

Pemodelan Fisis dalam Bentuk Matematis

Berdasarkan gambar 6, dapat dirumuskan beberapa persamaan matematis antara lain tegangan, regangan dan Modulus elastisitas.

Tegangan

Tegangan dapat diartikan sebagai gaya eksternal yang diberikan pada sebuah benda per satuan luas. Tegangan atau *stress* (σ) didefinisikan sebagai perbandingan antara gaya tarik yang bekerja pada sebuah benda ($\vec{F}$) dengan luas penampang benda (A). Tegangan berbanding lurus dengan gaya tarik yang bekerja pada sebuah benda dan berbanding terbalik dengan luas penampangnya.

$$\text{tegangan} = \frac{\text{gaya}}{\text{luas}}$$

Atau secara model matematis dapat dituliskan sebagai berikut:

$$\sigma = \frac{\dots}{\dots}$$

Figure 5. Phase 3 of physics modeling, physical modeling in mathematical form

Mathematical modeling is carried out by completing the existing formula in the module by referring to the modeling of the drawings that have been made. In the first meeting, students can read simple experiment procedures on 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.

Pemodelan Fisis dalam Bentuk Eksperimen/ Percobaan Sederhana

Untuk menguji secara empiris rumus yang diperoleh, maka dapat dilakukan percobaan sederhana.

Ayo lakukan percobaan dengan bersemangat!

Tujuan

Menentukan nilai tegangan, regangan, dan modulus elastisitas.

Figure 6. Phase 3 of physics modeling, physics modeling a simple form of experiment

Fase 4 : Mencari Solusi

Setelah menentukan tujuan, alat/bahan dan prosedur percobaan maka lakukanlah percobaan untuk memperoleh data, kemudian bahas data yang diperoleh!

Data

Silahkan Anda catat hasil pengamatan yang sudah dilakukan pada tabel berikut ini!

Tabel 2. Hasil Pengamatan

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

No	Massa m (kg)	Gaya $\vec{F}$ (N)	Panjang pegas (m)		Perubahan panjang pegas Δl (m)	Tegangan σ (N/m^2)	Regangan e	Modulus elastisitas E (N/m^2)
			Awal l_o	Akhir l				
1								
2								
3								

Pembahasan

1. Gaya apa yang dimiliki beban?
   ....
2. Apa yang terjadi pada pegas saat Anda menggantungkan beban pada pegas?
   ....
3. Apa yang terjadi pada pegas saat Anda melepaskan beban dari pegas?
   ....

Figure 7. Phase 4 of finding a solution, conducting experiments based on the design that has been made

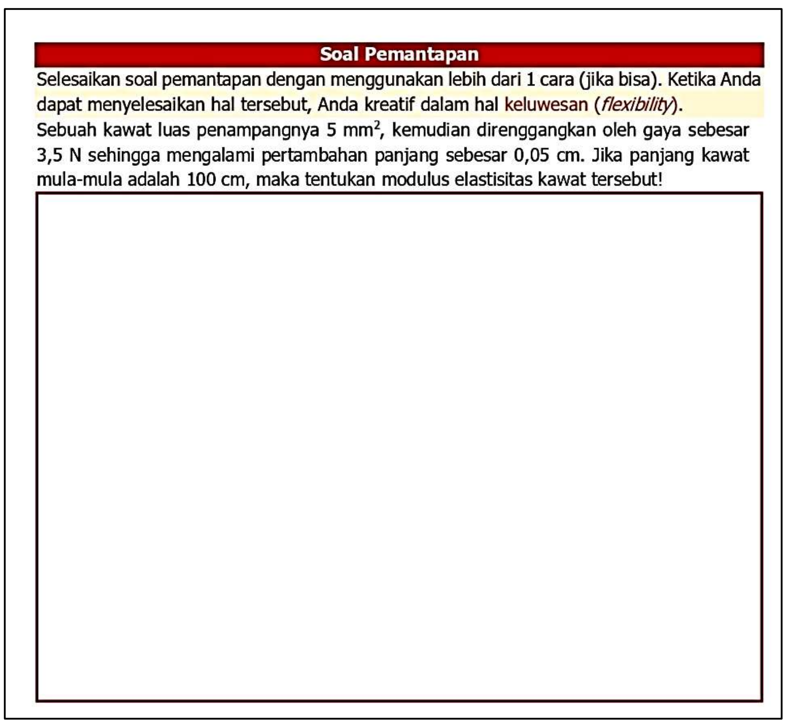
In this phase, students are given the opportunity to ask questions if they want to ask questions related to physics modeling. This phase also suppojrts students to think creatively about the aspect of authenticity, especially when making image modeling.

In phase 4 of finding a solution, students are asked to conduct experiments based on the design that has been made and then make conclusions based on the data obtained from the observation results. Furthermore, students are asked to work on consolidation questions that are relevant to the material discussed. Activities in this phase were accompanied by teachers and students were also given the opportunity to ask questions. This phase also supports students to think creatively about the flexibility aspect, especially working on consolidation problems.

Kesimpulan

Berdasarkan data dan pembahasan di atas, buatlah kesimpulannya!

Figure 8. Phase 4 of finding a solution, draw conclusions



Soal Pemantapan

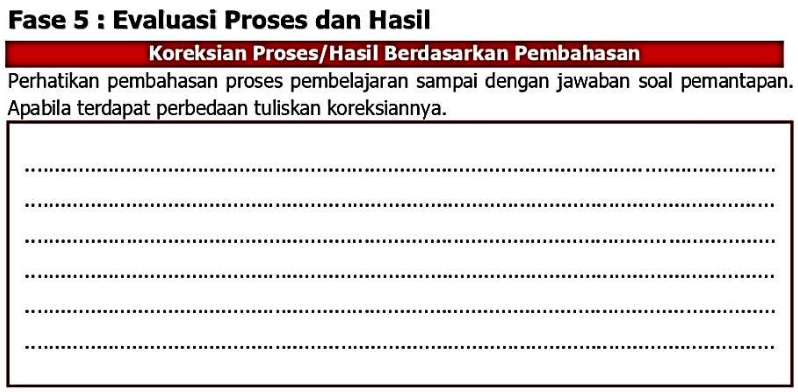
Selesaikan soal pemantapan dengan menggunakan lebih dari 1 cara (jika bisa). Ketika Anda dapat menyelesaikan hal tersebut, Anda kreatif dalam hal keluwesan (*flexibility*).

Sebuah kawat luas penampangnya 5 mm^2, kemudian direnggangkan oleh gaya sebesar 3,5 N sehingga mengalami pertambahan panjang sebesar 0,05 cm. Jika panjang kawat mula-mula adalah 100 cm, maka tentukan modulus elastisitas kawat tersebut!

Figure 9. Phase 4 of finding a solution, matters of consolidation

In phase 5 of the process and results evaluation, teachers check the results of students' work in general and provide feedback to students. Educators and students discuss the results obtained during learning, then ask students to write corrections on the module if there are errors or differences. Finally, teachers and students make conclusions from the lessons that have been carried out and write them down in the modules.

The results *of the pre-test and post-test* are used as a benchmark to determine the improvement of students' creative thinking skills before and after implementing physics modelling


Fase 5 : Evaluasi Proses dan Hasil

Koreksian Proses/Hasil Berdasarkan Pembahasan

Perhatikan pembahasan proses pembelajaran sampai dengan jawaban soal pemantapan. Apabila terdapat perbedaan tuliskan koreksiannya.

Figure 10. Phase 5 process evaluation and results


Simpulan Akhir

Tuliskan simpulan akhir yang Anda peroleh dari proses pembelajaran yang telah dilakukan hari ini!

Figure 11. Phase 5 final result

learning. The results of the pre-test show that students have not been able to solve physics problems by thinking creatively. Post-test results show an increase in students' creative thinking skills. This is supported by the acquisition of n-gain scores in the medium category and the results of non-parametric statistical tests that show that the hypothesis is accepted, meaning that there is a difference between students' creative thinking skills before being given treatment (pre-test) and after being given treatment (post-test).

Creative thinking skills are measured using pre-test and post-test learning outcomes tests. The learning outcome test consists of 5 questions made with aspects of creative thinking skills, namely fluency, flexibility, and originality. The tests given to students include 2 questions on fluency aspects, 2 questions on flexibility aspects and 1 question on originality aspects. The following are the results of calculating n-gain of creative thinking skills.

Table 2. show the average pre-test and post-test scores for each aspect of creative thinking skills. The fluency aspect is in the medium category, the flexibility aspect is in the high category, and the originality aspect is in the high category. On average pre-test all aspects of creative thinking skills obtained the category of

Table 2. Results of calculating n-gain of creative thinking skills

	Pre-test average	Post-test *average*	*N gain*	Category
Fluency	0	49.62	0.496	Medium
Flexibility	3.41	72.73	0.72	High
Originality	0	87.12	0.87	High

not creative. Furthermore, the average post-test obtained quite creative categories in the aspect of fluency, creative in the aspect of flexibility, and very creative in the aspect of originality. Students experience an increase in creative thinking skills after the implementation of physical Modelling learning in classroom learning. The physics Modelling learning syntax supports learners to think creatively at every meeting. Each meeting students are asked to identify observed physical phenomena and make questions relevant to the observed physical phenomena, this supports students to think creatively in aspects of fluency because it asks students to provide more than one idea that is relevant to the existing problem. Students are also asked to make image models based on observed phenomena, this supports students to think creatively about aspects of originality because it makes students think for themselves how to solve it. In addition, at each meeting students are also asked to do stabilization questions using more than one way so as to support students to think creatively in aspects of flexibility. Table 2 shows the average results of learners' answers for each aspect of creative thinking before and after being treated with the implementation of physical Modelling learning in class. Based on the results obtained, it is known that every aspect of creative thinking has improved from pre-test *to* post-test. Learning physics modelling that is applied has an influence on students in improving creative thinking skills.

Results of non-parametric tests from learners' pre-test and post-test data show the negative ranks of creative thinking skills between pre-test and post-test are 0, indicating that there is no decrease from pre-test to post-test scores. Positive ranks of creative thinking skills between pre-test and post-test showed 33 positive data which means that 33 students obtained an increase in scores from pre-test to post-test. The average increase was 17.00 and the number of positive ratings was 561.00. Pre-test and post-test results do not have the same value, this is indicated by a ties value of 0.

From the results of non-parametric statistical tests carried out, it was obtained Asymp values. Sig. (2-tailed) is 0.000. The test results show that the hypothesis is accepted because the value of $0.000 < 0.05$ which means that there is a difference between the creative thinking skills of students before being given treatment (pre-test) *and after being given treatment* (post-test), *so it can be concluded that there is an influence of the use of physics modelling learning on students in improving creative thinking skills.*

The following are questions and answers from students before and after the implementation of physics modelling learning in class. Problem number 1: A wire that has a cross-sectional area of 1.5×10^{-5} m^2 and a length of 6 m is hung vertically with its free end given a load of 60 kg. If the wire extends by 5 mm, determine its Young's Modulus! ($g = 10\ \mathrm{m/s^2}$!) Here are the answers from students during the pre-test and post-test:

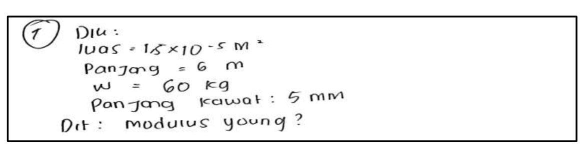


Figure 12. Student pre-test answers for flexibility aspects

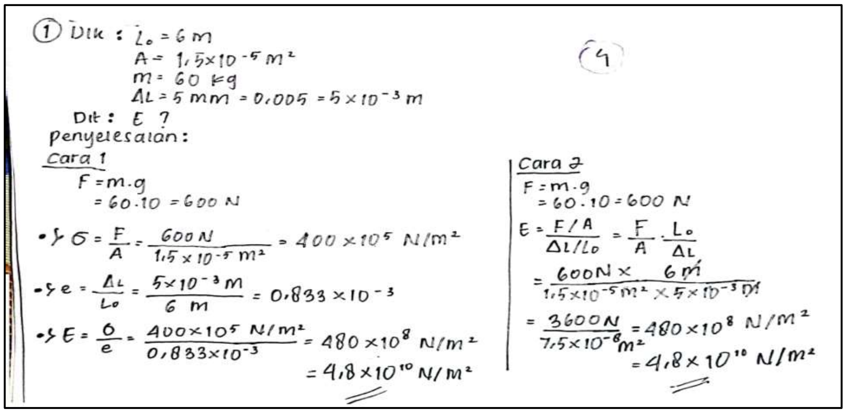


Figure 13. Learners' post-test answers for flexibility aspects

The improvement of students' creative thinking skills can also be seen in figures 12 and 13 for aspects of flexibility in test question number 1. Question number 1 expects students to be able to determine Young's Modulus by giving answers in more than 1 way that the process and results are correct. Figure 1 shows that students have not been able to answer question number 1 as expected, students only write down the known magnitude on the problem. Furthermore, figure 2 shows the answers of learners after being treated with the implementation of physical Modelling learning in class. Based on figure 2, it is known that students are able to provide answers in 2 ways to obtain the Young's Modulus value with the correct process and results. This shows that the implementation of physics Modelling learning is able to make creative thinking skills in aspects of flexibility increase. At the learning stage of physical Modelling "looking for solutions" in addition to students being asked to identify, collect, analyze data and synthesize data, students are also asked to answer solidification questions. The solidification questions that are solved every meeting accustom students to answer in more than 1 way so that they can train students to think flexibly. Students can show the ability to answer questions in more than 1 way, meaning that students have thought flexibly (Jamali, 2020; Kim, 2019; Wet & Tselepis, 2020).

Question number 5: There are 10 springs with each spring constant as shown in the following table.

Spring	Spring constant *k* (N/m)
Spring 1	10
Spring 2	20
Spring 3	15
Spring 4	25
Spring 5	20
Spring 6	10
Spring 7	5
Spring 8	15
Spring 9	25
Spring 10	10

These springs can be arranged into parallel, series, or a combination of both. Arrange the springs so that the value of the replacement spring constant obtained is 15 N/m and draw it! (*use at least 3 different springs and make as many as you can*) Here are the answers from students during the pre-test and post-test:

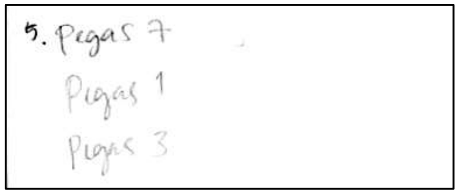


Figure 14. Learners' pre-test answers for fluency aspects

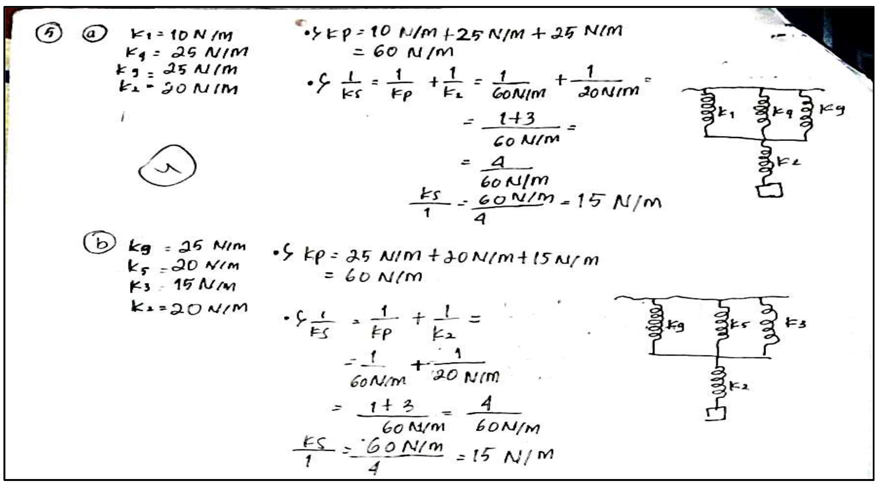


Figure 15. Learners' post-test answers for fluency aspects

The improvement of students' creative thinking skills in the aspect of fluency can be seen in figures 14 and 15 which show students' answers to test question number 5. Question number 5 expects students to be able to make a spring arrangement either series, parallel or a combination of both with at least 3 different springs in order to obtain a spring constant of 15 N/m along with the picture. Students are expected to provide more than 1 answer idea that is relevant to problem solving and the disclosure is complete and precise. Figure 3 shows that students have not been able to answer question number 5 as expected, students only write springs. Furthermore, figure 15 shows the answers of learners after being treated with the implementation of physics Modelling learning in class. Based on figure 4, it is known that students are able to provide more than 1 answer idea that is relevant to the problem, the answer is also equipped with pictures and the right solution. This shows that the implementation of physical Modelling learning is able to make creative thinking skills in aspects of fluency increase. At the learning stage of physical Modelling "submission and identification of problems of physical phenomena" in addition to students being stimulated by the provision of a physical phenomenon, students are also asked to identify and provide questions relevant to the observed phenomenon more than one answer idea. At each meeting students identify physical phenomena and make questions relevant to physical phenomena with more than 1 idea so as to train students to think fluently. Students can show the ability to provide more than 1 answer idea that is relevant to the problem, meaning that students have thought fluently (Jankowska, Gajda, & Karwowski, 2019). Question number 4: Take a look at the following picture!

A hanging spring under normal circumstances is 25 cm long (figure a). Then the end of the spring is hung by a load that has a mass g so that the final length of the spring becomes cm and a spring constant value of 10 N/m is obtained (figure b). Specify:… …

a. Mass of dependent load

b. Spring end length

($g = 10\ \mathrm{m/s^2}$) Here are the answers from students during the pre-test and post-test:

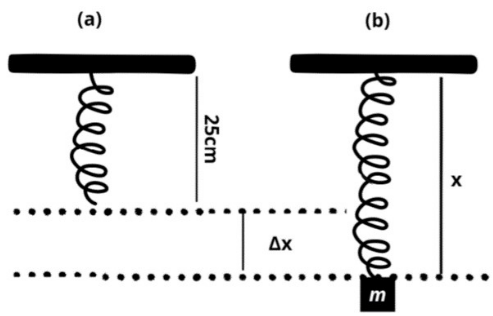


Figure 6. Picture from creative thinking skills test

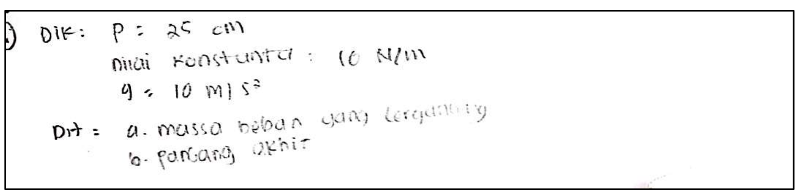
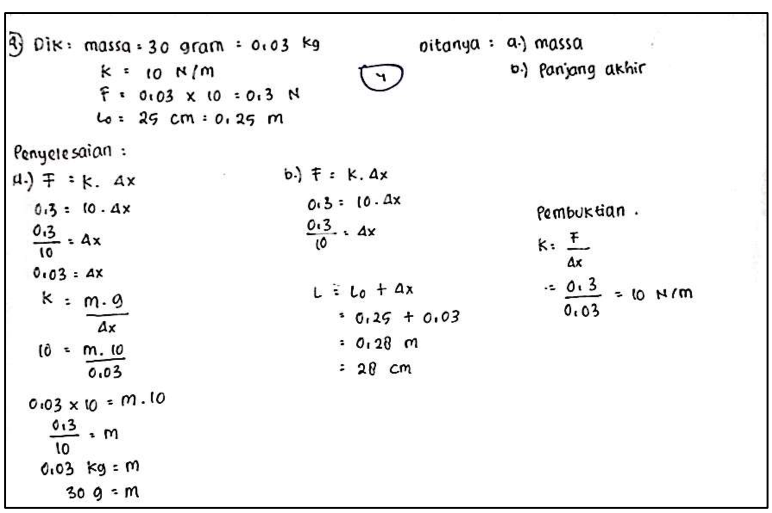

Dik: P = 25 cm
nilai konstanta : 10 N/m
g = 10 m/s²
Dit : a. massa beban yang tergantung
b. panjang akhir

Figure 16. Learners' pre-test answers for originality aspects


4) Dik: massa = 30 gram = 0,03 kg
k = 10 N/m
F = 0,03 x 10 = 0,3 N
L₀ = 25 cm = 0,25 m

Ditanya : a.) massa
b.) panjang akhir

Penyelesaian :
a.) F = k. Δx
0,3 = 10 . Δx
0,3/10 = Δx
0,03 = Δx
k = m.g/Δx
10 = m.10/0,03
0,03 x 10 = m.10
0,3/10 = m
0,03 kg = m
30 g = m

b.) F = k. Δx
0,3 = 10 . Δx
0,3/10 = Δx
L = L₀ + Δx
= 0,25 + 0,03
= 0,28 m
= 28 cm

Pembuktian .
k = F/Δx
= 0,3/0,03 = 10 N/m

Figure 17. Learners' post-test answers for originality aspects

Improving students' creative thinking skills aspects of originality can be seen in pictures 16 and 17 which show students' answers to test question number 4. Question number 4 expects students to be able to determine the mass of the hanging load and the final length of the spring by giving answers through their own way and the process and results are not wrong. Figure 5 shows that students have not been able to answer question number 4 as expected, students only write down the known magnitude on the problem. Furthermore, figure 6 shows the answers of learners after being treated with the implementation of physics Modelling learning in class. Based on figure 6 it is known that students are able to provide answers through their own way which process and results are not wrong, students can determine the mass of the hanging load and also the final length of the spring. This shows that the implementation of physical Modelling learning is able to make creative thinking skills in the aspect of originality increase. At the learning stage of physical Modelling "physics Modelling" learners are asked to make mathematical Modelling and simple experiments / experiments but before that make image Modelling with their own thoughts based on the phenomena observed at the stage of submitting and identifying physical phenomenon problems. At each meeting students are asked to make image Modelling with their own thoughts so that they can train students to think originally. Students can demonstrate the ability to answer questions in their own way, meaning that students have thought originally (Jamali, 2020; Kim, 2019).

Based on the comparison description between the value of creative thinking skills during the pre-test and *post-test* and non-parametric statistical tests, it is known that creative thinking skills for each aspect have increased and there are differences between students' creative thinking skills before and after the implementation of physics Modelling learning. So it can be said that through the implementation of physical Modelling learning, creative thinking skills can improve.

CONCLUSION

Based on the results of research and discussion, it was concluded that creative thinking skills can be improved by implementing physics Modelling learning. Based on non-parametric statistical tests, it can be concluded that there are differences in students' creative thinking skills between before and after the implementation of physics Modelling learning so that physics Modelling learning affects students in improving creative thinking skills.

This research has the impact of providing an alternative physics learning model in improving students' critical thinking skills. The limitation of this study is that it uses one physics topic in implementation, so it is necessary to test on various physics learning topics.

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