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Original Paper

Using Knowledge Sketching Strategy to Increase Ability in Solving the Multi-Concept Physics Problem

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Abstract

One of the fundamental problems for the college students is not being able to solve the multi-concept physics problems. The reason is that the problem solving strategies is limited to known-asked strategy (traditional strategy). Though this strategy can only be used to solve the problems of mono-concept physics. Therefore, this research on the use of knowledge sketching strategy as an alternative to help students to solve multi-concept physics problems is conducted. This study used "single-group pretest-posttest design" with treatment in the form of sketch knowledge strategy. The results showed that the average students' pretest score (n = 23) was 3.61 and the mean posttest score was 7.65. This indicates an increase in the average score of 4.04 after being treated. These results show that knowledge sketching strategy have an advantage in improving the ability to solve multi-concept physics problems compared to the known-asked strategy.

Keywords

mono-concept, multi-concept, strategy, problem solving

1. Introduction

The main problem to be answered in this research is "the unability of students to answer the problem of multi-concept physics". One of the reasons is that students do not have much knowledge about strategy in solving physics problems. So far, they have only used a strategy called "known-asked" strategy. This strategy has the following stages: (1) identification of variables, (2) using formulations or formulating equations, and (3) solving equations. This strategy is only good for the mono-concept of physics, but it is very difficult to apply to the problem of multi-concept physics. One of the weaknesses of this strategy lies in identifying the problem variables. At this stage, this strategy only determines the known variables and the variables asked in the problem. While hidden variables or variables that connect between one concept to another are difficult to determine.

To overcome the weakness of the "known-asked" strategy, the writer has developed a knowledge sketching strategy as one of the strategies in solving the multi-concept physics problem (Abdullah, 2018). This strategy is used by the writer to overcome the low ability of students in solving the problem of multi-concept physics.

Before the writer explains briefly about knowledge sketching strategy, there is an interesting thing that needs to be mentioned, it is the terms "mono-concept" and "multi-concept". Mono-concept and multi-concept are closely related to the use of concepts in physics problems. Many experts give different views on the meaning of concepts and it makes it very difficult to find the right definition. The writer does not want to discuss the meaning of the concept, but the writer just wants to provide examples related to concepts in physics such as: linear motion with fixed acceleration, free fall motion, projectile motion, second law Newton, conservation law of energy, conservation law of momentum and so forth. So the term of mono concept physics problem is a problem of physics whose material contains only one concept only. For example the following problem.

Problem-1.

The water drops fall at regular intervals from a tap 5 m above the ground. The third drop is leaving the tap at an instant when the first drop touches the ground. If g = 10 m/s-1, How far above the ground is the second drop at that instant? (Halliday & Resnick, 1995).

Figure 1. Problem 1

If you note the editorial of Problem 1 above, it reads clearly that the problem is only discussed about the use of the concept of free fall motion. This is what I mean by the mono-concept physics problem. Compare this with the following multi-concept physics problem.

Problem-2

Two loads m = 2kg and M = 3kg. A string through a pulley (see picture on the side). At first the load M is at an altitude of 1m above the floor, while m is on the floor and held. When m is off, load M move downwards. When M is about to touch the floor, the strap on the load m breaks. Determine the maximum height attained by the load m. Ignore the mass of the pulley, rope, and friction (take g = 10m/s2)

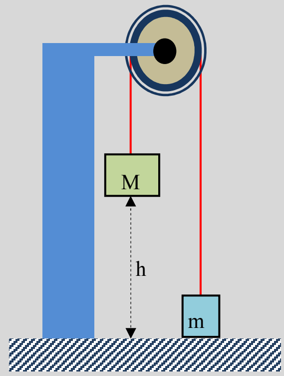

Figure 2. Problem 2

In problem 2, there are three concepts that are contained in the problem, Newton's Second Law, linear motion (vertical), and free fall motion. More details can be seen in the problem solving with knowledge sketching strategy in Figure 3.

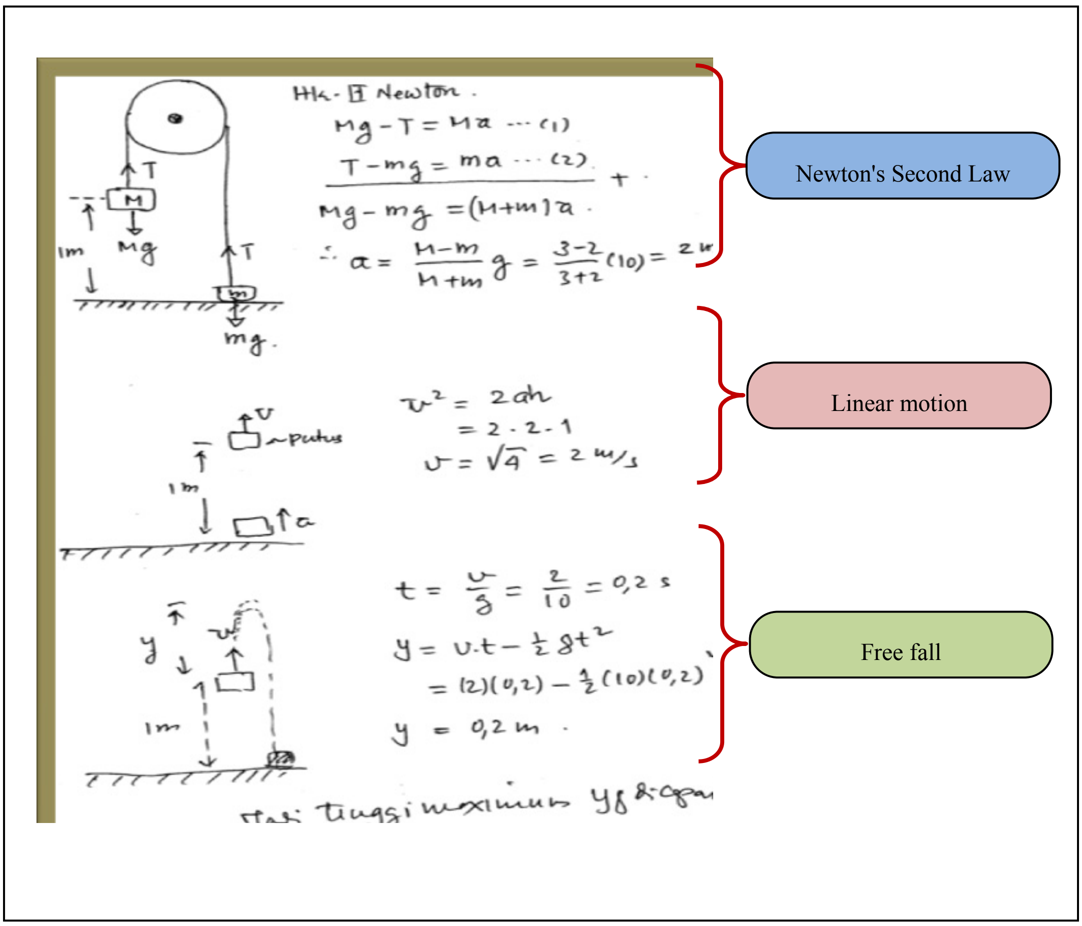

Figure 3. Multi-Concept Problem Solving with Knowledge Sketching Strategy

It can be seen in Figure 3 that the problem-solving procedure is performed using a knowledge sketching strategy. There are three stages of the process in the sketching strategy: (1) sketching, (2) formulating the equation, and (3) solving equations (Abdullah, 2018). The sketching step is the process of translating the statement of the problem into a sketch. The number of sketches made depends on each stage of the event. Stages of this event can be based on the time of the incident and can also be based on events for each concept. As in Figure 3 above there are three sketches made based on the type of concept for each stage of events. Then, each sketch made has been defined variables that accompany the event based on the statement of the problem. The variables that accompany the sketch can be either a predetermined variable in the statement of the problem or a variable that is not explicitly specified in the problem (Amin, Abdullah, & Malago, 2018).

The stage of formulating the equation, i.e., the process of formulating the equation based on the events depicted in the sketch. In formulating equations always based on concepts that apply to every event. As shown in Figure 3, the first sketch uses the basic formulation of Newton's second law. As for the second sketch using the basic formulation of linear motion, and the third sketch using the basic formulation of free fall motion. From the three sketches will be obtained equations that describe the event in the statement of the problem.

The stage of solving equations is astep to perform mathematical operations on the equations that have been formulated. At this stage, it is done to simplify the equations and the formulation of the equations that have been formulated. Therefore this is the last stage last of the knowledge sketching strategy process that is by obtaining the answer to the problem. Therefore based on this explanation, then the question of this research is "*there is an increase of score in solving multi-concept physics in first-year students physics study program after being taught using knowledge sketching strategy*".

2. Method

This research was conducted on a group of physics students of Makassar State University who took a basic physics course. They were 23 students who have the same background knowledge. Given the number of research groups was only one group, the research design used was "single-group pretest-posttest design".

The research mechanism was conducted through four stages. **The first stage** was to give the 23 students a pretest. The test given was a multi-concept physics problem. The problem consists of three concepts, the concept of momentum, the concept of conservation of energy, and the concept of projectile motion (balls and bullets). The pre-test form and the rubric are shown in Appendix 1. After the test, the answer sheets were collected, then examined to determine the students' score and at the same time learning how they tried to solve it. The purpose is: (1) to get an idea of why students have difficulties solving pretest problems, and (2) to plan classroom teaching strategy.

The second stage was to give treatment to 23 students in the form of physics teaching by using the knowledge sketching strategy. The teaching process was done six times face-to-face in class. **The third**

stage was to give posttest to find out the increase in score in solving the problem of multi-concept physics. The posttest given consisted of the concept of momentum, the concept of conservation of energy, and the concept of projectile motion. The posttest form and the rubric are shown in Appendix 2. The data collected were pretest and posttest scores, analyzed in statistics description to see an increase of score in solving the problem of multi-concept physics after being taught the knowledge sketching strategy. The results will be presented on the research results.

3. Results and Discussion

The examination of the pretest and posttest answer sheets has resulted in the description of pretest and posttest problem-solving strategy by 23 students. The results are shown in Table 1.

Table 1. Percentage of Students Using Knowledge Sketching Strategy

problem-solving strategy	Percentage of students using problem solving strategies (n = 23)	
	Pretest	Post test
Known-Asked (Traditional)	82.61	0.00
Knowledge Sketching Strategy	0.00	65.22
Combination of both Strategies	17.39	34.78

It can be seen from Table 1 above, that generally students still use the known-asked strategy in solving the problem of multi-concept physics (pretest). In fact according to Amin, Abdullah, and Malago (2018) that the known-asked strategy is only able to solve the problems of mono-concept physics. As a result, the students got scores below which was expected. The pretest scores are shown in Table 2 including the posttest scores.

It can be seen from the Table 2 below that there is an increase in the score after using knowledge sketching strategy in the completion of multi-concept physics problem. The average increases in the score from the pretest to the posttest is 4.04. These results reinforce the belief that the knowledge sketching strategy is one of the best strategies used in solving multi-concept physics problems compared to the known-asked strategy.

Table 2. Results of Examination of Pretest and Posttest answer sheets

n_i	Score		$\Delta x = (x_f - x_i)$
	Pretest (x_i)	**Postest (x_f)**	
1	6	9	3
2	6	9	3
3	5	10	5

4	5	10	5
5	5	6	1
6	5	7	2
7	4	10	6
8	4	8	4
9	4	9	5
10	4	10	6
11	4	8	4
12	3	8	5
13	3	8	5
14	3	10	7
15	3	8	5
16	3	7	4
17	3	6	3
18	3	7	4
19	3	5	2
20	2	7	5
21	2	4	2
22	2	5	3
23	1	5	4
Average	**3.61**	**7.65**	**4.04**
Std	**1.30**	**1.85**	**1.50**

Why is there an increase in multi-concept completion scores after the students being taught a "knowledge sketching strategy"? This question can be answered by looking at two aspects: (1) aspect of the material content of the problem, and (2) aspect of the problem-solving strategy. Judging from the aspect of the material content about pretest and posttest, the actual content of the material consists of three interrelated concepts. According to the writer's experience in teaching physics, that the problem of multi-concept physics requires the thinking stages of imaginative thinking, analytical thinking, and synthesis thinking. Therefore, for the students who are rarely trained to use these three skills, it will be difficult to solve the problem of multi-concept physics. As an illustration, the following description will show the problem of pretest used in this study.

Pretest Problem

A 50-g ball is above the 1.25m high wall, from the horizontal direction of a 5-gram bullet moving toward the center of the ball mass. The bullet velocity when about the ball is 100m/s and translucent. If it turns out that the ball falls at a distance of 2m from the edge of the wall, then determine the distance of the falling bullet measured from the edge of the wall (g = 10m/s2).

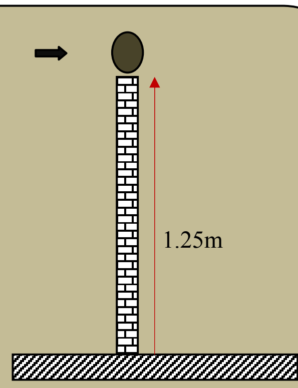

Figure 4. Pretest Problem

What do the student think after reading about the pretest? It is possible that they imagine about the process of the events of the problem. The process is: (1) when the bullet will hit the ball, (2) the moment after the bullet has penetrated the ball, and (3) when the ball and the bullet fall to the ground. Any student who has studied the concepts contained in the matter will be able to imagine the events in the problem. This process is called imagining events in the problem. However, the problem is the students cannot describe the equations depicted in their mind, especially for problems that contain complex events. Why is that? Because they are rarely trained formulate the equations based on the events that are reflected in their mind. The ability to formulate an equation based on the events depicted in the human mind is called imaginative thinking. In general the ability of imaginative thinking is the ability to actualize ideas or images in mind. Therefore, the main goal of physics teaching is to train imaginative thinking ability. Eisntein once argued that imagination is more important than knowledge (Hadzigeorgiou & Fotinos, 2007).

How to train students to think imaginatively in physics? The writer has explained in above section that one good way to train students thinking imaginatively is by using knowledge sketching strategy as a strategy in teaching physics. There are three stages in this strategy, but the core stage is the “sketching”. It is a way of translating the problem language into simple sketches or drawings (Abdullah, 2014). The process of this stage is somewhat similar to a painter who is able to pour ideas that are reflected in his mind in the form of paintings or sketches. Therefore, students who study physics should be treated as a painter. They should be trained to pour ideas in the form of design, narration, images, or prototype.

The physics problems is a set of concepts that make up the unit of knowledge. For example, the pretest problem above consists of the concept of momentum, free fall motion and parabolic motion. These three concepts form a unit of knowledge called “ballistic test knowledge”. In solving the pretest problem, the first thing students do is to read the problem. At the time of reading the problem, the students try to connect the concepts that have been known. In the process of connection, an imaginary image about the events mentioned in the problem will be formed in the head. In this condition, there are students who are already able to pour the image in the form of equations to obtain the answers. Students like this are classified as "genius" students. However, most students find it difficult to formulate the image in the head. For that, they need to be assisted through sketches before making the formulation. That is, the image formed in the head, first poured in the form of sketches. As for the pretest problem above, the sketch is as in the Figure 5 below.

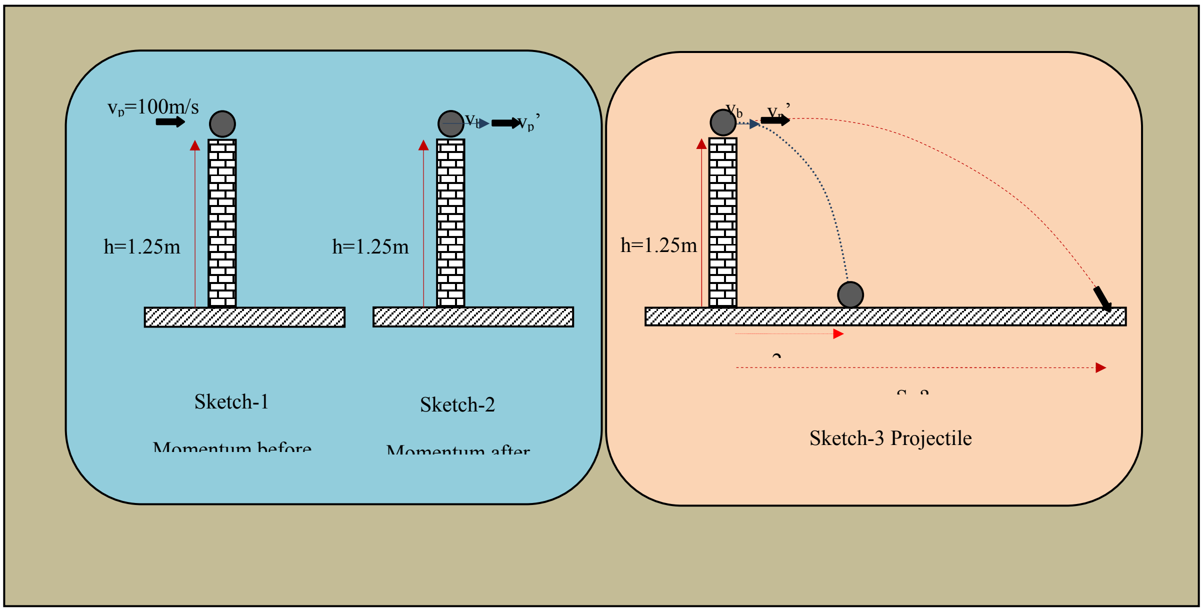

Figure 5. Stages in Translating Verbal Language into Sketch Form

As can be seen in the Figure 5, there are three sketch results were made. The first sketch describes the momentum occurrences before the collision, the second sketch of the momentum event after the collision, and the third sketch is parabolic motions of both ball and bullet. The interesting thing about these three sketches is that it clearly shows the relationship between one sketch and another. This relationship is determined by the velocity variables after the collision. This process is not found in the "known-asked" strategy.

Viewed from the aspect of teaching, if the knowledge sketching strategy is made as part of the physics teaching process, then there are many advantages that can be obtained by the students, one of the most important is "students are trained to think imaginatively". That is, through the teaching of knowledge sketching strategy, students will be trained to organize their knowledge and be able to pour the ideas in the form of sketches. This condition can only be done if the human mind has previous knowledge saved. It is commonly found in an expert's knowledge rather than a beginner's knowledge (National Research Council, 1999), and an expert knowledge has a deeper understanding than a beginner (Simon, 2001).

However, this view cannot be used as a limitation that only applies to an expert, but the organization of knowledge can also be applied to students who have had prior knowledge. The writer, therefore, assumes that the organizing of knowledge can be trained in the teaching process as long as the students who are taught have prior knowledge. If a student does not have prior knowledge of one of the concepts that are needed to solve the problem of physics, the writer believes that the student will not be able to organize his/her knowledge (Abdullah et al., 2013). And although the students have knowledge of all these concepts, but they are rarely trained to organize their knowledge in solving physics problems, the writer also believe that the students will have difficulty in solving the problem. This fact occurs because, in the teaching program, the curriculum is often designed in a way that makes it difficult for students to organize their knowledge (Santrock, 2010).

On the basis of the views of experts mentioned above, the writer believes that to form expert knowledge on the students it is necessary to do the teaching that emphasizes the process of imaginative thinking. The process of imagination is very important in science learning. Even Smolucha and Smolucha (1986) suggested that imagination is a higher mental function because it consciously directs the thinking process. The same opinion is stated by Liang et al. (2012) that imaginative thinking is the basis to cultivate creative thinking. Thus, the writer believes that the sketching stage in the knowledge sketching strategy is very good to be used in teaching physics to train the ability of imaginative thinking.

In addition to the sketching stage, the formulating stage is the stage of analysis thinking process. Why? Because through the sketches of the problems described, then the students' minds will form the process of assimilation. In this process, there is an incubation period of knowledge, the period in which there is an adjustment between the concept it possesses with the concepts contained in each sketch. If more than one sketch is made, there is a process of knowledge orientation based on the sketches.

The last step is the process of combining the equations that have been formulated at the formulating stage. This process requires mathematical skills to relate one equation to another to find answers. Therefore, in this last stage, the aspect that students need is the ability of mathematical operations.

4. Conclusions

The knowledge sketching strategy is a good way to solve a multi-concept physics problems. In its use as a physics teaching strategy, this strategy has benefits for students: (1) in training to organize knowledge, (2) in translating ideas in the form of sketches or drawings, (3) in practicing imaginative thinking skills, (4) in analysis thinking training, and (5) in training to use mathematical operations.

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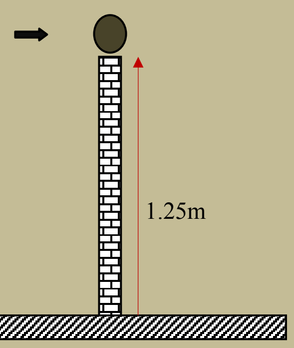
Appendix 1

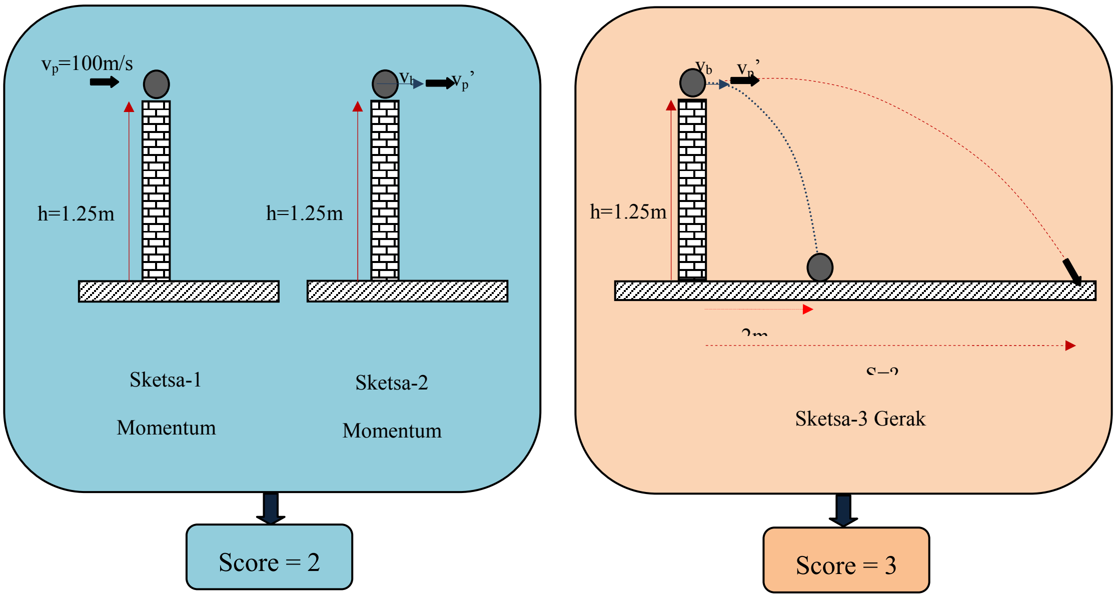
Solusi Dan Rubrik Penilaian Soal Pretest (in Indonesian)

Soal Pretest

Sebuah bola bermassa 50 gr berada di atas tembok yang tingginya 1.25m, dari arah mendatar sebuah peluru bermassa 5 gr bergerak menuju pusat massa bola. Kecepatan peluru saat mengenai bola adalah 100m/s dan tembus. Jika ternyata bola jatuh pada jarak 2m dari tepi tembok, maka tentukan jarak jatuhnyanya peluru diukur dari tepi tembok (g=10m/s^2).



Tahap 1. Menerjemahkan Soal Dalam Sketsa (Identifikasi Variabel)



Tahap 2. Menjabarkan Persamaan Berdasarkan Sketsa (Score = 3)

Persamaan untuk sketsa-1adalah momentum sebelum tumbukan

$$M_i = mv + M(0) = (5gr)\left(\frac{100m}{s}\right) = 500grm/s$$

Persamaan untuk sketsa-2 adalah momentum sesudah tumbukan

$$M_f = mv_p + Mv_b = (5gr)(v_p) + (50gr)(v_b)$$

Berlaku momentum sebelum tumbukan sama dengan momentum sesudah tumbukan, sehingga berlaku:

$500gr\frac{m}{s} = (5gr)(v_p) + (50gr)(v_b)$ atau

$$v_p + 10v_b = 100m/s \qquad (1)$$

Persamaan untuk sketsa-3 ada dua yaitu persamaan gerak untuk bola dan peluru. Karena keduanya berada pada ketinggian 1.25m, maka waktu untuk sampai ke tanah adalah:

$$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{(2)(1.25)}{10}} = 0.5s$$

maka kecepatan mendatar bola dan peluru adalah:

$$v_b = xt = (2)(0.5) = 1m/s \qquad (2)$$

$$v_p = S.t = 0.5S \qquad (3)$$

Tahap 3. Menyelesaikan Persamaan (Eksekusi) (Score = 2)

Untuk menjawab pertanyaan soal, maka persamaan (2) dan (3) di subsitusi ke persamaan (1), maka diperoleh:

$0.5S + 1 = 100$ maka:

$S = \frac{99}{0.5} = 198m$

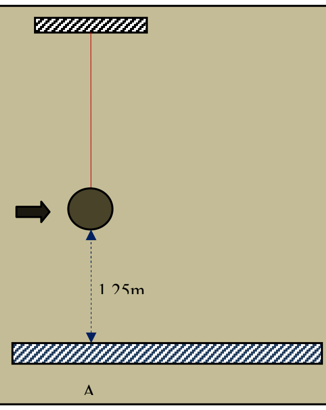
Jadi jarak jatuhnya peluru diukur dari tembok adalah 198m

Appendix 2

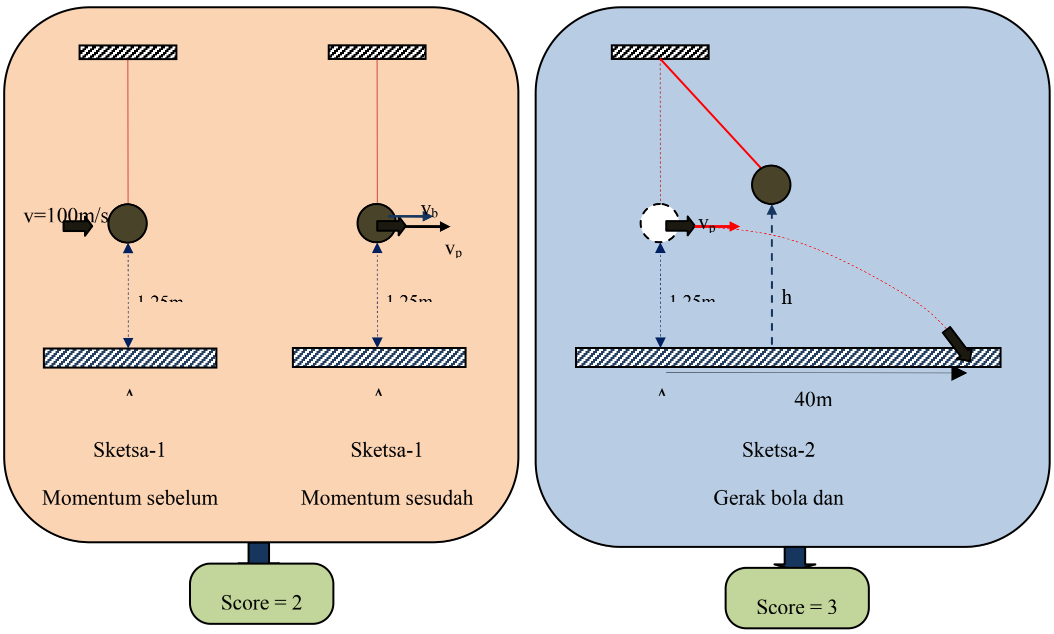
Solusi Dan Rubrik Penilaian Soal Post-Test (in Indonesian)

Soal Posttest

Sebuah peluru bermassa 5gr ditembakkan menuju bola yang tergantung bebas pada seutas tali (lihat gambar). Massa bola 50 gr dan tingginya dari lantai 1.25m. Jika kecepatan peluru saat akan menembus bola adalah 100m/s dan peluru jatuh pada jarak 40m dari titik A, maka tentukan tinggi maksimum yang dicapai bola setelah tertembus peluru ($g=10 m/s^2$).



Tahap-1: Menerjemahkan soal dalam sketsa (identifikasi variabel)



Tahap-2 Menjabarkan persamaan berdasarkan sketsa (Score = 3)

Persamaan untuk sketsa-1adalah momentum sebelum tumbukan

$$M_i = mv + M(0) = (5gr)\left(\frac{100m}{s}\right) = 500grm/s$$

Persamaan untuk sketsa-2 adalah momentum sesudah tumbukan

$$M_f = mv_p + Mv_b = (5gr)(v_p) + (50gr)(v_b)$$

Berlaku momentum sebelum tumbukan sama dengan momentum sesudah tumbukan, sehingga berlaku:

$500gr\frac{m}{s} = (5gr)(v_p) + (50gr)(v_b)$ atau

$v_p + 10v_b = 100m/s$ … (1)

Persamaan untuk sketsa-3 ada dua yaitu gerak untuk bola dan peluru. Untuk gerakan peluru berlaku

$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{(2)(1.25)}{10}} = 0.5s$ maka kecepatan mendatar bola dan peluru adalah:

$v_p = xt = (40)(0.5) = 20m/s$ … (2)

maka persamaan (1) menjadi:

$20m/s + 10v_b = 100m/s$

$v_b = 8m/s$ … (3)

Untuk gerak bola yang mencapai ketinggian h, berlaku hukuk kekekalan energy yang dirumuskan:

$Mv_b + Mg(1.25m) = 0 + Mg(h)$ … (4)

Tahap-3 Menyelesaikan persamaan (eksekusi) (Score = 2)

Dengan mensubsitusi persamaan (3) ke persamaan (4), maka diperoleh nilai h yaitu:

$8 + 12.5 = 10h$ atau

$h = 2.05m$