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The Application of Higher Order Thinking Laboratory (HOT Lab) in Momentum Concept Using PhET Simulation

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Abstract. Laboratory activities using the HOT Lab model can become a place to train students in increasing knowledge and higher-order thinking skills. This study aims to analyze the change in velocity before and after the collision and the effect of velocity on the amount of momentum. The method used in this research is experiment and library study. The results show that the change in velocity before and after the collision depends on the elastic coefficient. For perfect resilience with an elastic coefficient of 1, the velocity values before and after the collision are constant (0.50 m / s and 0.35 m / s). The partial resilience after the collision was reduced to 0.14 m / s and 0.29 m / s, and for the non-resilient speed of the two objects after the collision, the value was the same, namely 0.08 m / s. Thus, the relationship between velocity and momentum itself is directly proportional, so the greater the velocity of the object, the greater the momentum.

INTRODUCTION

Education is something dynamic that demands improvement from time to time. Learning carried out in schools is not only emphasized on mastery of the material, but also must be emphasized on developing aspects of skills. One way to empower students to increase their knowledge and skills in the field of science is by providing laboratory activities[1]. Through laboratory activities students can be trained in several skills such as observing, clarifying, measuring, communicating, interpreting data, and making conclusions[2]. Can solve the problem of abstract physics concepts[3]. Laboratory activities can also be an excellent environment for active learning, placing students at the center of learning[4] and being able to provide opportunities for productive and cooperative interactions between students and teachers[5].

The growing number of covid-19 cases[6] makes learning only possible remotely through online media[7]. One of the learning innovations is the use of computer-based media[8]. Computer-based experimental activities through virtual laboratories can be chosen to visualize physics concepts to be easily understood by students[9].

A virtual laboratory is a computer program that is used to carry out practical work using a set of simulations[10]. Virtual laboratories can be used when the tools needed for real practicums are too expensive, unsafe, and unavailable[11]. With the virtual laboratory, students are more flexible independently and in groups to do practicals[12]. Learning using a Virtual Laboratory has several advantages, namely: increasing students' mastery of concepts, improving creative thinking skills and scientific problem solving; develop skills in the field of ICT without neglecting knowledge of the laboratory[13]. However, the virtual laboratory should only be used as an addition to the real laboratory[14]. The disadvantage of using a virtual laboratory is that students cannot develop practical skills, such as the use of measuring instruments and measuring physical quantities[15]. One of the virtual laboratory equipment that is often used is the PhET (*Physics Education and Technology*)[16].

PhET is anapplication open source for science learning[17], featuring natural phenomena and equipped with simple experiments that can help in understanding concepts [18]. The simulation can be accessed free of charge on the website

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http://phet.colorado.edu [19]. Can be operated using various computer operating systems that are easy to run [20]. Learning physics with the help of PhET is effectively used, because it does not require much time in its implementation [21].

The practical model has been developed by experts. In the process of training and developing higher-order thinking skills, themodel is used Laboratory Higher Order Thinking (HOT Lab) [22]. The HOT lab framework was developed by combining themodels Creative Problem Solving (CPS) and Problem-Solving Laboratory (PSL)[23]. From the combination of these two models, the steps of the HOT Lab consist of five general processes: 1) understanding the challenges, 2) generating ideas, 3) preparing practical activities, 4) carrying out practical activities, and 5) communicating and evaluating the results of activities [24]. For this reason, this hot-lab model is used in the momentum material practicum.

The momentum of an object is defined as the product of its mass and its velocity [25].

$$\vec{p} = m\vec{v}$$

Sustainability momentum in the system described by the following equation:

$$m_A \vec{v}_A + m_B \vec{v}_B = m_A \vec{v}'_A + m_B \vec{v}'_B$$

wherein "Momentum before collision = momentum after the collision" [26].

Based on the explanation above, the purpose of this research is to analyze the change in velocity before and after the collision and the effect of velocity on the magnitude of the momentum.

METHOD

The method used in this research is an experimental method and library research. The research flow can be seen in figure 1.

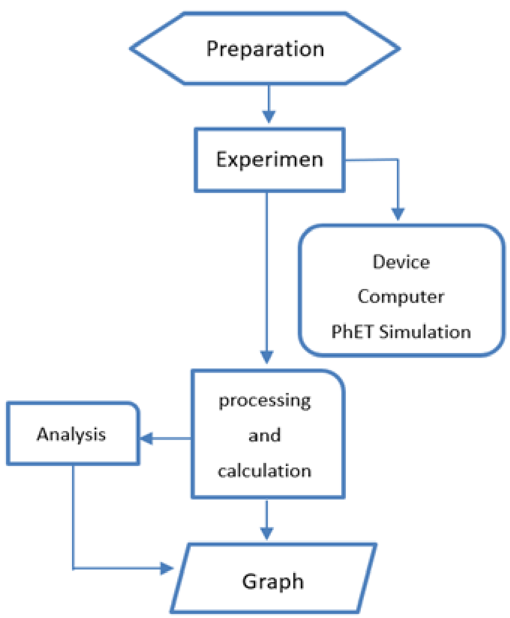

FIGURE 1. Research Flow

Experiment was carried out through a practicum virtual lab using the phet application with the following steps; Prepare the equipment that will be used for lab such as laptops and simulation Phet "collision lab"; Opening simulation Phet"collision lab" using firefox or google chrome by typing the keyword "Phet Colorado", then click on the existing page comes out early. After the page opens, click "Physics" and select collision lab. PhET simulation can be seen in figure 2.

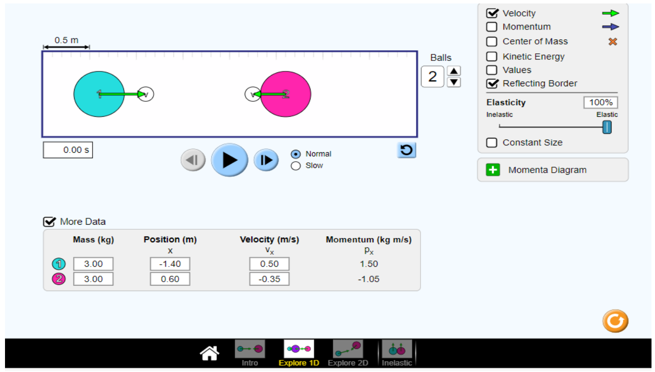

FIGURE 2. PhET Simulation

The first experimental stage is to determine the mass and velocity of the two objects with the elasticity of 100%. (perfectly elastic), then measure the speed of the object after experiencing the collision and record it on the observation table, finally repeating the experiment 20 times. After that repeat the initial steps to the end with a large elasticity of 50% (partially elastic) and 0% (not elastic). In the second experiment: determine the magnitude of the two objects' masses and their speed, mass as a fixed variable and velocity as an independent variable, then take 6 data with each data repeated 20 times.

The data obtained from the experiment was processed and analyzed quantitatively and then made tables and graphs. Finally, do library research from various reading sources in the form of journals, articles, and other reading sources which will then be compared to get comprehensive results.

RESULT AND DISCUSSION

The first experiment used two objects with the same mass (m1 = m2 = 3 kg), but different velocities (v1 = 0.50 m/s and v2 = -0.35 m/s) . The data taken is the magnitude of the momentum of the two objects before and after the collision, for the elasticity is 100%. (perfectly elastic), 50% (partially elastic) and 0% (not elastic).

TABLE 1. Type of Collision

Collision type	Elasticity (%)	v_1 (m/s)	v_2 (m/s)	v_1' (m/s)	v_2' (m/s)
Perfectly elastic	100	0.50	0.35	0.35	0.50
Partially elastic	50	0.50	0.35	0.14	0.29
Not elastic	0	0.50	0.35	0.08	0.08

Table 1 shows that the velocity of the object after the collision from the treatment of the three types of collision is different. In a perfectly elastic type with an elastic coefficient of 1, the value of the object's velocity before and after the collision does not change, therefore the momentum before the collision will be the same as after the collision, and in this case there is no loss of energy, then the perfectly elastic collision applies the law of conservation of kinetic energy and the law of conservation of momentum. For partially elastic with an elastic value of 0.5, it can be seen in the table that there is a change in the velocity of the object before and after the collision, where the velocity value of the object after the collision has decreased to 0.14 m/s and 0.29 m/s, this is because there is energy The lost kinetic energy is converted into other forms of energy, such as heat energy, sound energy or potential energy. For collision is not elastic with the elastic value of 0 shows that the speed of the two objects equal v_1' = v_2' = 0.08 m/s). The two objects after the collision will approach each other and move together.

The second experiment through experiments with the mass variable was made the same for each experiment, namely 3 kg and for speed the independent variable was made. Data velocity and momentum can be seen in table 2.

TABLE 2. Data Velocity and Momentum

No	Velocity (m/s)	Momentum (kg m/s)
1	0.25	0.75
2	1.00	3.00
3	1.25	3.75
4	1.50	4.50
5	1.80	5.40
6	2.50	7.50

Based on the measurement results of the relationship between velocity and momentum shown in figure 3

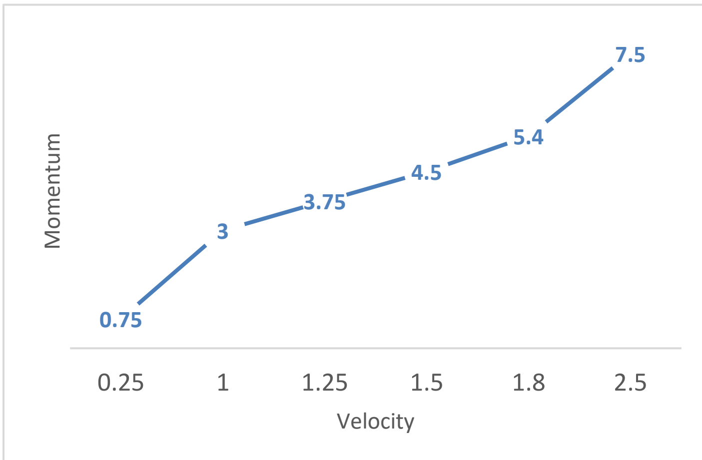

FIGURE 3. The relationship between velocity (v) and momentum *(p)*

Based on figure 3, we get a graph in the form of a line that is increasing, where the greater the velocity of the object, the greater the momentum. Thus, velocity is directly proportional to momentum.

Virtual experiments are effective as supporting students to do a practicum [27]. PhET provides simulations that follow scientific concepts and follow facts in life [28]. Learning becomes more meaningful, especially in physics concepts that cannot be presented and observed directly in everyday life [29]. PhET simulation-assisted learning can be used as a 21st century learning application [30], it affects student learning independence, student activity increases during learning and students are more active in seeking knowledge [31]. Virtual experiments in the PhET application provide an easy solution to the problem of collisions that exist in momentum and impulse materials, namely providing simulations of the differences between three types of collisions, perfectly elastic collisions, partially elastic collisions and completely inelastic collisions.

The drawback in this study is that there is no treatment in which the mass is made an independent variable and the object moves in any direction. In future research, it is expected to be able to conduct experiments with varied treatments, in order to provide broader learning.

CONCLUSION

In this study, it was concluded that the change in velocity before and after the collision depends on the elastic coefficient, where for perfect elasticity which has an elastic coefficient of 1, the velocity value of the two objects before and after the collision is fixed, for partially elastic which has an elastic coefficient of 0.5 the velocity decreases after experiencing a collision, and is inelastic which has an elastic coefficient of 0 the velocity of the two objects after the collision will be the same value. The relationship between velocity and momentum itself is directly proportional, where the greater the velocity of the object, the greater the momentum.

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