The Video-Based STEM Experiment: An Observation of the Momentum of a Bouncing Ball

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Abstract. We have performed a video-based STEM experiment of a bouncing ball using a force plate logger sensor and Neulog application. Our objective was to observe the students understanding the relationship between impulse and momentum, examine this relation by bouncing a ball on a force plate logger sensor, and calculate impulse and change in momentum. All the data, such as raw data of force and time, video recorded, and the questions given to the 10th-grade senior high school students. Then, their answer will be analyzed to confirm the understanding of momentum during the learning process by video-based STEM experiments.

1. Introduction

As a fundamental concept in Physics, momentum is one of the topics in Physics Subject for senior high school students and undergraduate students. However, the basic knowledge of momentum is probably already introduced by the teacher for the students in the primary. In Indonesia, according to the national curriculum 2013 (revision), momentum is provided for senior high school students 10th grade[1]. There are some studies on momentum. Kaniawati et al reported that the student has difficulty understanding the conservation of energy and momentum[2]. Xu et al report that the connections between net force, time, and change in momentum become the main difficulties for the students[3]. Furthermore, the efforts to improve the understanding of momentum have been implemented by the teachers using teaching aids[4], learning media[1], and learning approach[5], [6].

Among these efforts, the learning approach believed can be effectively improved student understanding during the learning process[7]. As well known, by using teaching and learning approach-based science, technology, engineering, and mathematics (STEM) believed that teaching in physics laboratory or experiment could be more effectively improved physics understanding[8]. Others believed that the integration of science, technology, engineering, and mathematics stimulates the students to have a scientific behavior include engagement in inquiry, logical reasoning,
collaboration, and investigation[7], [8]. Hence, by the STEM, systematical a set of thinking, reasoning, teamwork, investigative, and creative skills of the students could be developed.

The covid-19 outbreak causes all the activities to include the schools were to be closed. Online learning is becoming the best alternative to keep the learning process keep running. It is a novel condition for the students, video-based STEM experiments combined with e-learning activities are supposed to be a good choice for the students to obtain experience during the learning process[9]. Others reported that of the video-based problem, the students able to correlate theoretical objects and procedures with experimental observations and measurements[10].

In this paper, the video-based STEM experiments for senior high school student 10th grade to observe the momentum have been reported. The physics understanding of the student will be explored based on the observation by a video-based STEM experiment to determine the value of velocity, impulse, and momentum of the ball motion.

2. Method
To facilitate the video-based STEM experiments, we have prepared a force plate logger sensor, laptop, camera, Neulog application, USB 200 module, and basketball (0.49kg). We then dropped a basketball on a force plate with the height of 100 cm. The ball will bounce as many times as possible on the force plate. The bouncing ball which represented by the graph (force versus time) recorded by the Neulog application. All the experiment activities were presented by video streaming. Then, the STEM experiment presented by the video was observed and analyzed by all the participants who are 10th-grade senior high school students (MAN 1 Bekasi, West Java, Indonesia). There were 40 participants during the activity. Furthermore, the recorded video, and experiment result were given to the students to be analyzed and answered. To analyze the experimental experiment, we provided the instruction as follows: 1) determine the velocity before hitting the plate, 2) determine the velocity after hitting the plate, 3) determine the change in momentum, and 4) analyze the ratio between impulse and change in momentum.

3. Results and discussion
As revealed in the feedback from the students, video-based STEM experiments can be used to replace the role of experiments in classroom activity. However, by using video-based, there is a limited learning experience as students obtained. Most of the students (>90%) agreed that they cannot have experience in direct investigative and creative skills to operate the experiment. Meanwhile, by using the video-based, about 80% agreed that thinking, reasoning, and teamwork can be performed virtually by the online discussion.

Furthermore, to elaborate the understanding of momentum of the bouncing a ball, we analyze the student skill to plot the data as the graph from the data. The graph represents the relationship between force and time. The basketball dropped on a force plate, then will bounce a few times. Furthermore, the force applied will be measured as a function of the time of the experiment and can be recorded by Neulog application. Figure 1 shows the graph pattern of the bouncing ball which represented by force versus time.

![Figure 1. The bouncing ball pattern.](image-url)
Figure 1 shows the graph pattern of the bouncing ball. Based on the sheets answer, most of the students able to plot the graph as seen in the figure. Meanwhile, to observe the impulse, all the students have difficulties determining it from the graph. They just mentioned that impulse is the value of force versus time. Most recently, Amin et al reported that the factors causing these difficulties are the ability to read the graph and understanding the connection between the equation and the graph[11]. Hence, we assumed that the students do not understand the mathematical principle to interpret the graph as physics phenomena. In this case, an impulse as the value of multiplication force and time can be calculated from the graph by observing the area of the spike. Let us consider the second pike of the graph (figure 1). There are six areas under the spike (figure 2), hence, we obtained the value of the impulse is 2.77 Ns.

Figure 2. Second pike of the graph of force applied to a force plate during the time of the hit.

In the bouncing ball experiment, the student observed the ball with a height of about 100 cm falls without any external force and hits the surface of a force plate. By consider the second spike, to calculate the velocity before hitting the force plate, we can use the equation of $v_1 = -\frac{gt}{2}$. As well known, $g$ is the gravitational acceleration. A minus sign indicates the direction of the ball in the same axis with a negative y-coordinate. Meanwhile, the time ($t$) is the time between first hitting and before the second hitting a plate. Further, the velocity after hitting the plate can be observed in figure 1. As seen from figure 1, the velocity can be calculated by considering the time after the second hitting and before the third hitting a plate. Hence, the change in momentum could be determined (2.94 Ns). If we compared to the impulse, we obtained the ratio between impulse and change in momentum of 94%.

In contrast, most of the students used the momentum equation to determine the velocity. It is a bottleneck for the student to find out the change in momentum. We predicted, most of the students focus on the equation of momentum without considering the graph. It’s meant the student has difficulties correlate the physics concepts (such as the law of momentum conservation and impulse) with the experimental observation and measurement as presented through the video. Nevertheless, other reported that the use of video able to effectively attain and improve student knowledge[10].

4. Conclusions
In summary, we conclude that video-based STEM experiments can be used as a learning process to understand the Physics of momentum. Even though, there is limited experience in direct investigative and creative skills to operate the experiment. Further investigation, we found that the students have difficulties to determine the Physics variable such as the velocity of the bouncing ball, change in momentum, and the ratio between impulse and momentum. We predict that the student has difficulties correlate the physics concepts with the experimental observation and measurement.
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