TUMPULS teaching aids as an alternative media for physics learning

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Abstract. Development of learning media needs to increase students' interest in learning and stimulate teacher creativity in creating an interactive learning atmosphere. This study aims to develop teaching aids as an alternative to physics learning media in momentum material. The method used in this study is research and development with the stages of analysis, design, development, implementation and evaluation. The stage described in this study is the development stage in the laboratory test section. The laboratory test results for momentum props found that the relative error of the data obtained for the initial momentum was 0.1% and the final momentum ranged from 9%. The momentum props developed were able to present data and show momentum calculations through equations.

1. Introduction

Learning is the process of students finding and seeking new knowledge. The learning process becomes an important part that must be consider by the teacher because it includes the transfer of knowledge to students [1]. The interaction between teacher and students raises academic communication in the classroom, learning media is an introduction to information from the sender to the recipient [2]. Learning media is an important part that supports communication between teachers and students [3].

Physics learning material that requires media as a tool in the learning process is momentum, however, learning media in the form of existing momentum teaching aids do not meet the needs of students for interactive learning [4-6]. Learning media development that meets the needs of students and can applied at school.

One of the learning media that could developed in the momentum learning process is teaching aids. Teaching aids can facilitate students to understand the concept because of the direct interaction of students in finding new knowledge [7-8], teaching aids are able to clarify the teaching material that the teacher delivers to good students in the form of questions and theories [9-10].

Teaching aids as learning physics can foster the interest of students to a systematically seek knowledge [11], for this reason, the research aims to develop teaching aids that are able to stimulate the curiosity of students in seeking knowledge in their entirety. The process of finding equations in momentum material was carried out sequentially, the props being developed support the understanding of students' concepts from several interrelated material, in this case momentum. Students are required to understand Newton's law in order to be able to solve the equation of the concept of energy, then from the sequence of the process [12], students can find the concept of momentum. Tumpuls teaching aids
here is made from remnants of wood modified to see the speed of objects moving in opposite directions but with the same height and plane and colliding.

2. **Experimental method**
The method used in this study is an experiment through laboratory tests to determine the magnitude of errors from the props. Laboratory testing tools in finding equations and calculations, so that errors in the use of tools could known. The research design that was made was by conducting research as much as three times the data retrieval through experiments rolling the ball with different mass variations on the track board. Experiments of rolling the ball are done three times at the same height from the left and right with the collision time calculated based on the time until the collision.

3. **Result and discussion**

3.1. **Design the props**
The design of the blending props being developed can be seen in Figure 1.

Figure 1 is the teaching aids consisting of track board was made from wood, meter scale for measuring distance of motion of the ball, the track also be equipped with left and right trajectories so that the ball can move naturally and collision can occur. The ball that use was plastic ball. The track length for the rolling ball is 1.5 m with a measuring scale on the edge (in cm). The track can be folded (into three parts) to facilitate storage while the two slides with the same height are stored at the end of the track.

3.2. **Data retrieval**
Laboratory tests are conducted to test whether the props developed are able to produce data. After practicing, the data obtained can be seen in table 1.

| $t$ (s) | $s$ (m) | $h$ (m) | $t_1$ (s) | $s_1$ (m) | $s_2$ (m) | $t_2$ (s) |
|--------|--------|--------|----------|----------|----------|----------|
| 3.83   | 2.50   | 0.013  | 1.0      | 0.101    | 0.0425   | 3.2      |
| 3.87   | 2.54   | 0.013  | 1.2      | 0.101    | 0.0423   | 3.0      |
| 3.82   | 2.45   | 0.013  | 1.0      | 0.101    | 0.0424   | 3.0      |
| 11.52  | 7.49   | 0.039  | 3.2      | 0.303    | 0.1272   | 9.2      |

$t$ is the time used to find the acceleration when the ball rolls without a barrier, $s$ is the distance when the ball stops. $h$ is the height of the inclined plane while $t_1$ for the time when the ball before pounding the barrier and $s_1$ is the distance the barrier is placed, then $s_2$ is the distance the ball stops after colliding and $t_2$ is the time it takes for the ball to stop after colliding.
3.3. Data processing

Data that has been obtained is then processed before entering into calculations. Processing data using the mean equation on data like equation 1 and 2.

\[
\bar{n} = \frac{\sum n}{n} \quad (1)
\]

\[
\Delta n = \frac{1}{2} n st \quad (2)
\]

This equation is used if the data obtained is single, while for data grouped equations are used in equations 3 and 4.

\[
\bar{n} = \frac{\sum n}{n} \quad (3)
\]

\[
\Delta n = \frac{1}{n} \sqrt{\frac{n \sum x^2 - (\sum x)^2}{n-1}} \quad (4)
\]

The results of the processing are then calculated through several equations. The results of processing can be seen in table 2.

| Variabel | Value |
|----------|-------|
| \( T \)  | \( \bar{t} \pm \Delta t = |3,840 \pm 0,0153| \text{ s} \) |
| \( S \)  | \( \bar{s} \pm \Delta s = |2.49 \pm 0.02| \text{ m} \) |
| \( s_1 \) | \( \bar{s}_1 \pm \Delta s_1 = |101,00 \pm 0.05| 10^{-3} \text{ m} \) |
| \( s_2 \) | \( \bar{s}_2 \pm \Delta s_2 = |0.0420 \pm 0.00005| \text{ m} \) |
| \( t_1 \) | \( \bar{t}_1 \pm \Delta t_1 = |1,07 \pm 0.06| \text{ s} \) |
| \( t_2 \) | \( \bar{t}_2 \pm \Delta t_2 = |1,07 \pm 0.06| \text{ s} \) |
| \( H \)  | \( \bar{h} \pm \Delta h = |13,00 \pm 0.05| 10^{-3} \text{ m} \) |

The processed variables will then be calculated to determine the relative errors of the tools in each data retrieval.

3.4. Calculation

Calculations to obtain momentum values through several equations, the calculation begins with the concept of potential energy \( E_p = m \cdot g \cdot h \) and kinetic energy \( E_k = \frac{1}{2} m v^2 \) [13]

\[
E_m = E_m \quad (5)
\]

\[
E_{p1}E_{k1} = E_{p2}E_{k2} \quad (6)
\]

The energy equation is intended to find the acceleration of the ball, the equation used in finding the acceleration of the sphere is \( v = \sqrt{2 g h} \), the value is used to calculate the initial velocity where the ball has not collided [14], the equation used is

\[
v_1 = v_0 + at \quad (7)
\]

Momentum is obtained after the steps above are carried out systematically, the momentum value is obtained from the equation [15]:

\[
P = m \cdot v \quad (8)
\]

Calculation of data after processing is also seen in terms of the relative errors that are made during the calculation, the equations used in finding relative errors are

\[
KSR = \frac{\Delta n}{n} \times 100\% \quad (9)
\]

Meanwhile, each value obtained from the calculation results is presented in table 3.
Table 3. Calculation results from data processing.

| Variable             | Value                                      | Relative Error |
|----------------------|--------------------------------------------|----------------|
| Velocity             | $\bar{v} \pm \Delta v = |0.5047 \pm 0.0008| m/s$   | 0.17%          |
| Acceleration         | $\bar{a} \pm \Delta a = |0.1314 \pm 0.0005| m/s^{-2}$ | 0.4%           |
| Infinite Velocity    | $\bar{v}_t \pm \Delta v_t = |0.644 \pm 0.001| m/s$    | 1.2%           |
| Momentum             | $\bar{P} \pm \Delta P = |0.03290 \pm 0.00022| kg m/s$  | 0.15%          |
| Finite Velocity      | $\bar{v} \pm \Delta v = |0.0396 \pm 0.0036| m/s$    | 9.2%           |
| Finite Momentum      | $\bar{P} \pm \Delta P = |0.00202 \pm 0.00018| kg m/s$  | 9.1%           |

The final momentum and final velocity have a relative error of 9% while the speed, acceleration and initial momentum are around 0.1%. This laboratory test shows that the momentum props developed can produce data and are able to explain physical equations related to the concept of momentum. This gives the meaning that the use of teaching aids that have the right calibration in learning can motivate students to be more active in learning [16]. Another research also said that students performance achievement in mechanics especially in momentum could be increase if we use the right media for learning [16].

4. Conclusion
The props developed are able to produce data and can be calculated. The relative error in the initial momentum was around 0.1% and the final momentum was 9%. This laboratory test shows that the teaching aids developed are able to show the concept of momentum systematically and can be interpreted in schools as an alternative medium of physics learning in material momentum and impulses.

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References
[1] Constantinou C P and Papadouris N 2012 Teaching and learning about energy in middle school: an argument for an epistemic approach Stud. Sci. Educ. 48 161–86
[2] Joshi S 2014 Physics of Gulli-Danda Phys. Educ. 30 36–48
[3] Lattery M 2011 Steps toward learning mechanics using fan cart video demonstrations Phys. Educ. 46 73
[4] Rahma U, Desnita D and Raihanati R 2015 Pengembangan Alat Peraga Momentum dengan Sistem Sensor J. Penelit. Pengemb. Pendidik. Fis. 1 75–80
[5] Suhendi H Y, Mulhayatiah D, Anjani R, Ramdani M A and Ardiansyah R 2018 HATRAVY: a virtual laboratory of heat transfer concept in microscopic form IOP Conference Series: Materials Science and Engineering vol 434 (IOP Publishing) p 12288
[6] Wilensky U 2003 Statistical mechanics for secondary school: The GasLab multi-agent modeling toolkit Int. J. Comput. Math. Learn. 8 1–41
[7] Garfield S 2005 The Impulse and physics of movement
[8] Mulhayatiah D, Suhendi H Y, Zakwandi R, Dirgantara Y and Ramdani M A 2018 Moment of Inertia: development of rotational dynamics KIT for physics students IOP Conf. Ser. Mater. Sci. Eng. 434 12014
[9] Alatas F, Mulhayatiah D and Jahrudin A Penggunaan Alat Peraga Rotation Timer dan Roda Fleksibel untuk Meningkatkan Kemampuan Analisis Siswa J. Penelit. dan Pembelajaran IPA 1 60–75
[10] Sparavigna A C 2013 Teaching physics during the 17th century: some examples from the works of Evangelista Torricelli arXiv Prepr. arXiv1307.4942
[11] Muchlis F, Sulisworo D and Toifur M 2018 Pengembangan Alat Peraga Fisika Berbasis Internet of Things untuk Praktikum Hukum Newton II J. Pendidik. Fis. Phys. Educ. 6 13–20
[12] Kim M, Cheong Y and Song J 2018 The Meanings of Physics Equations and Physics Education
[13] Yuhua F New Newton Mechanics Taking Law of Conservation of Energy as Unique Source Law (Revised Version 3)
[14] Arons A B 1999 Development of energy concepts in introductory physics courses Am. J. Phys. 67 1063–7
[15] Cummings K, Laws P W, Redish E F and Cooney P J 2004 Understanding physics Underst. Physics, First Ed. by Karen Cummings, Priscilla W. Laws, Edward F. Redish, Patrick J. Cooney, pp. 1224. ISBN 0-471-37099-1. Wiley-VCH, March 2004. 1224
[16] Suhendi H Y, Mulhayatiah D and Zakwandi R 2018 The Effectiveness of Worksheet Based Learning of Rotational Dynamics on Students’ Critical Thinking Skills Viewed from IQ Score Sci. Educ. J. Pendidik. Sains; Vol 7, No 1 June