



# Analysis of Restitution Coefficient Value on the Ball Using Tracker Software by Utilizing Video Based Laboratory

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**Abstract:** Conducting experimental activities in a laboratory with available equipment is not as simple as it may appear. Experimentation can be challenging, and various factors can lead to inaccuracies. Systematic errors result from measurement tool inaccuracies, and external factors can also influence outcomes. Recognizing and addressing these potential errors during experiments is crucial. Tracker software is a valuable tool for enhancing laboratory accuracy. This software tracks and analyzes experimental elements to produce precise data. Researchers can closely monitor object movements and behaviors in video-based laboratory, making data measurement and recording more precise. This technology improves laboratory procedures by enhancing reliability and efficiency. In summary, manual data collection for marbles yields restitution coefficient values of  $e = 0.5136 \pm 0.004214$  and  $e = 0.4566 \pm 0.01736$  for the ping pong ball. In contrast, using tracker software for data collection provides  $e = 0.5397 \pm 0.0008731$  for marbles and  $e = 0.5115 \pm 0.001154$  for the ping pong ball. This demonstrates the software's ability to enhance accuracy in experimental results, improving the overall laboratory process.

**Keywords:** Experimental activities; Restitution; Tracker; Video based laboratory

## Introduction

Without a doubt, the significance of viable research facility encounter is irrefutable within the preparing of understudies over different disciplines (Aprilia et al., 2020; Fatmawati et al., 2021). The basis behind this declaration lies within the need for understudies to apply their newly discovered hypothetical information by testing with real-world frameworks (Fitri et al., 2022; Khoiri et al., 2023; Marpaung et al., 2021; Utari et al., 2019). In an perfect situation, each understudy would have their claim research facility hardware; in any case, commonsense imperatives regularly make this unattainable (Hujatulatif et al., 2022; Islami et al., 2021). These limitations emerge due to the common bundling of research facility gadgets with exclusive instructive computer program, requiring understudies to contribute time in comprehending the complexities of framework engineering (Agusti et al., 2023; Melinia et

al., 2021). Besides, the support of a considerable stock of research facility hardware requests significant money related assets.

Various companies offer testing gadgets, and these frequently posture network challenges. In any case, a later wave of articles has been committed to the improvement of cost-effective exploratory devices that use the computational capabilities of individual computers. This development encourages the creation of more reasonable testing apparatuses utilizing off-the-shelf components, subsequently investing them with instructive capabilities comparable to those of complicated and high-cost frameworks. Experimental activities can be carried out in a laboratory using the available tools (Gamage et al., 2020; Yanti et al., 2020). But in practice, conducting experiments is not as easy as imagined (Bancong et al., 2020). There can be some errors as a cause of erroneous measurement results such as systematic errors in the form of inaccuracy of

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measurement results due to tools and error creations in the form of things that can affect the measurement results from outside (noise, parallax, brown motion, electric voltage fluctuations and others) (Clifford et al., 2021). For example, when doing an experiment to calculate the value of the restitution coefficient on an object in momentum material. It is difficult to see the exact movement of the pendulum with the naked eye only.

Currently, the development of science and technology is increasingly advanced (Hidayah et al., 2023). In helping experimental activities carried out in the laboratory, there is a software that can help experimental activities produce more accurate data, namely tracker software (Fahrunnisa et al., 2021). Tracker software is a video analysis program that can be used to analyze various videos related to the topic of kinematics and light spectrum (Peebles et al., 2021). The tracker software has a calibration facility, so the measurements result will be very close to reality (Fadholi et al., 2018). The video recording is taken from the real condition of the object's motion, and then processed using a tracker so that it is also known as a Video Based Laboratory (VBL).

VBL is an educational tool that can combine theoretical and experimental aspects in teaching physics (Aouifi et al., 2024; Sudirman, 2023; Weng et al., 2023). Students can focus on describing physical symptoms in the video and not on data collection techniques. Through software developed for VBL that interactively processes digital video, it allows students to carefully analyze movement through computer-generated graphics (Khalil et al., 2023). It is very difficult to make impulse measurements by directly observing fast-moving objects. To measure the impulse in the event that the ball hits the wall, it is necessary to measure the average force exerted by the ball on the wall and the length of time the ball hits the wall. Likewise in determining the value of the restitution coefficient on the ball, because the ball moves so that when seen with the naked eye it is not good enough to be able to determine the velocity of the ball before and after the collision. With the help of tracker software and utilizing VBL, it is hoped that it can produce research/experiments with more accurate results on the restitution coefficient material with objects of several types of balls.

This research is important to carry out because research using video analytics as a learning method is needed, not limited to constructivism, direction, and direct instruction (Ilma et al., 2022). Habibulloh et al. (2014) also thinks that the most suitable topic for tracker software is physics material related to kinematics and motion phenomena in general, including the coefficient of restitution.

## Method

The approach used in this research is a quantitative approach, which is one type of experimental research. In the first experiment, a medium-sized bekel ball was used which was hung on the statif, then one of the balls was pulled at a certain angle and then released so that a collision occurred between the two balls. When starting to draw one of the balls, the camera is ready to record the movement of the ball in order to obtain speed data on both balls before and after the collision occurs. Then the video was entered into the tracker software to obtain experimental data. The same was done with the ping pong ball for the second try.

### Research Stage

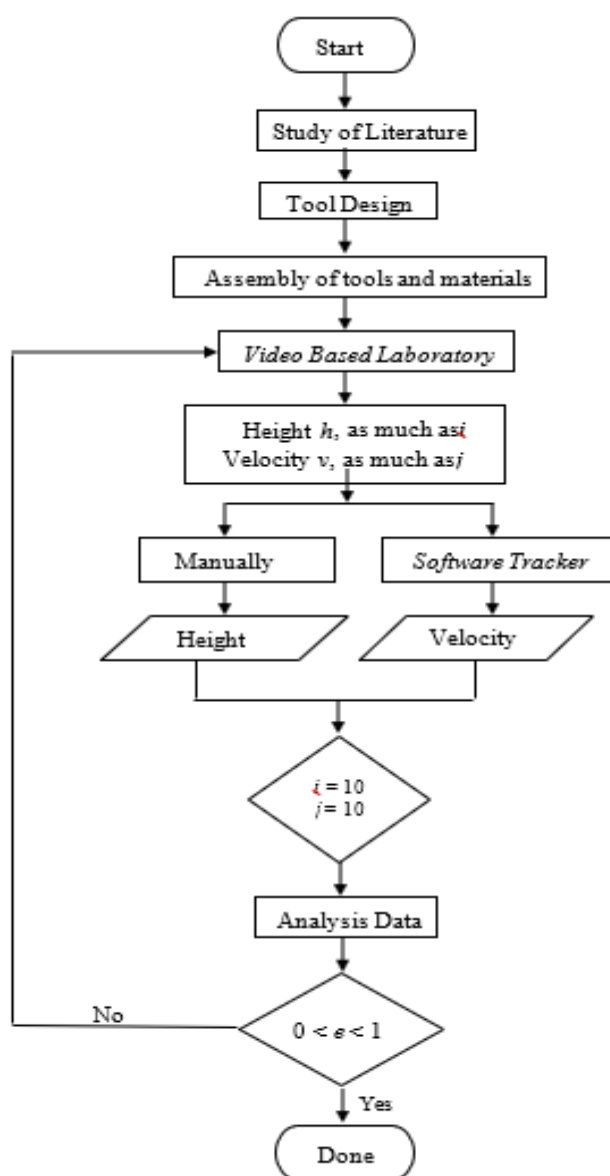


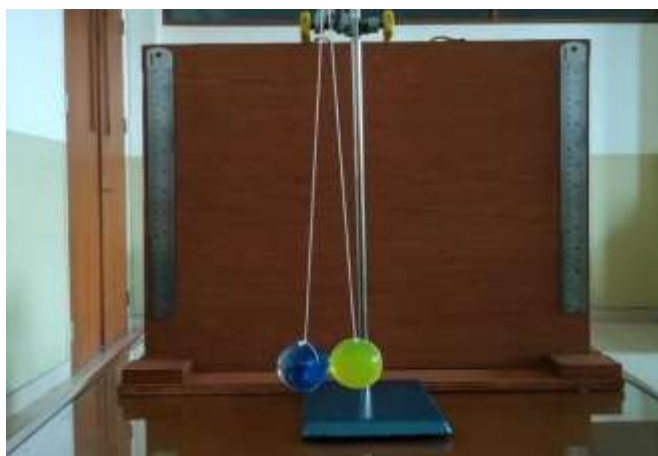
Figure 1. Research flowchart

The first stage, namely the study of literature to design the design of experimental tools and theories that support experiments so that the research carried out is in accordance with existing theories. Then, design the tools that will be used for experiments. Next, namely the assembly of tools and materials to be like a swing with two similar balls with a ruler behind it to measure the height of the ball when it is swung and after a collision occurs and is used as a comparison for calibration tools on tracker software. The first experiment was carried out with two bekel ball types and the second experiment was carried out with two ping pong balls. The fourth stage, namely the process of recording the video swing on the pendulum by using a camera as material to be analyzed at a later stage, therefore this research utilizes Video Based Laboratory (VBL). Next, determining the measured data. Manually, the data taken is in the form of height as much as *i*, while with the tracker software, the speed data is taken as much as *j*. The sixth stage, namely the process of analyzing data with data obtained manually and data obtained through tracker software. Last, namely if the resulting ball restitution coefficient is between 0 and 1, the research is complete, otherwise it will return to the fourth stage.

*Tools and Materials*

This research requires one set of staves, one scratchpad, 50 cm ruler, digital scales, camera, laptop, Tracker Software, Microsoft Excel, two bekel balls with a diameter of 4.2 cm, two ping pong balls in diameter 4.05 cm and yarn.

*Design Tools*



**Figure 2.** Design of the pendulum swing tool  
(Source: Personal Documentation)

*Data Analysis Technique*

Data analysis techniques with manual experiments using VBL (without the help of tracker software) In the initial state immediately after ball A is released, when

ball A is in the upper position, the upper kinetic energy is equal to zero ( $KE_{upper} = 0$ ) and the potential energy is at its maximum value ( $PE_{upper} = \max$ ) while the potential energy when ball A is currently collide with ball B, namely when ball A is at the lowest/lower point is 0, and the law of conservation of energy applies so that the equation is:

$$v = \sqrt{2gh} \tag{1}$$

According to Chusni (2017), to derive the error equation can be derived from the equation to be measured. With repeated measurements of height, errors in repeated measurements can be formulated as:

$$S_{hx} = \sqrt{\frac{\sum(h_{xi} - \bar{h}_x)^2}{n(n-1)}} \tag{2}$$

By using equation (1), to determine the value of the restitution coefficient on the ball can be formulated as:

$$e = \frac{(v'_B - v'_A)}{v_B - v_A} \tag{3}$$

$$e = \frac{-(\sqrt{2gh_B'} - \sqrt{2gh_A'})}{\sqrt{2gh_A}} \tag{4}$$

Based on equation (4), we can formulate the errorvalue of the obtained restitution coefficient:

$$S_e = \sqrt{\left(\frac{\partial e}{\partial h_B'} S_{h_B'}\right)^2 + \left(\frac{\partial e}{\partial h_A'} S_{h_A'}\right)^2 + \left(\frac{\partial e}{\partial h_B} S_{h_B}\right)^2} \tag{5}$$

Data analysis techniques with experiments using VBL using tracker software. By using equations (3), because the value of  $v_B$  is 0, the equation used becomes:

$$e = \frac{(v'_B - v'_A)}{v_A} \tag{6}$$

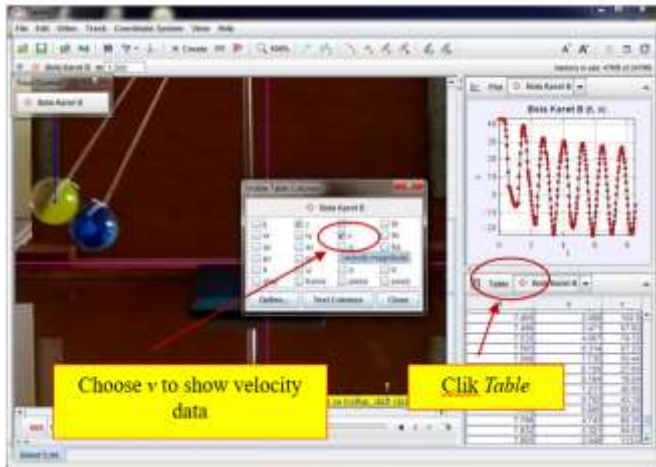
Meanwhile, the error of the restitution coefficientwhen analyzed using tracker software.

**Result and Discussion**

The restitution coefficient is a physical factor employed to quantify the extent to which a collision between two items represents their flexibility (Wang et al., 2021; Zhu et al., 2021). This factor demonstrates the capacity of two items to preserve a portion of their kinetic energy following a collision (Hosseini et al., 2023; Kundrák et al., 2019). The utilization of the restitution

coefficient is typically observed in scenarios involving the collision of solid objects, such as rebounding balls or interactions among other solid entities. The value of the restitution coefficient can fluctuate based on the properties of the colliding items and the specifics of the collision itself.

In this research, velocity data is generated in tracker software shown in the image below:



**Figure 3.** Visible table columns on software tracker source: personal documentation

The results of the value of the restitution coefficient on the bekel ball with data taken manually are  $e = 0.5136 \pm 0.004214$  while the restitution coefficient value on the bekel ball with data taken through the tracker software is  $e = 0.5397 \pm 0.0008731$ . Based on the results obtained, we can see that the errors obtained from the data taken manually are greater than the errors obtained from the data taken through the tracker software. So it can be said that data retrieval through tracker software is much more accurate than data retrieval that is taken manually with an error percentage ratio (Hwang et al, 2016) of  $0.4214\% : 0.08731\%$ .

Meanwhile, the results of the restitution coefficient value on the ping pong ball with data taken manually are equal to  $e = 0.4707 \pm 0.01736$  and the value of the restitution coefficient on the ping pong ball with the data taken through the tracker software is  $e = 0.5115 \pm 0.001154$ . From the results obtained, it can also be seen that errors with data taken manually are greater than errors taken using tracker software. So it can also be said that data retrieval through tracker software is much more accurate than data retrieval that is taken manually with an error percentage ratio of  $1.736\% : 0.1154\%$ .

A significant difference error is more visible in bekel balls, because the bekel balls are made of rubber so that their reflection is greater than the ping pong balls. Besides that, when taking the data it is much easier because the movement is more obvious at the time after

the collision. The value of the restitution coefficient depends on the constituent material, if the material is softer, the elasticity is greater so that the value of the restitution coefficient is greater. In accordance with the theory that the value of the restitution coefficient is closer to the value of 1, the collision that occurs is also more perfect.

In manual data collection, the value of the restitution coefficient on the bekel ball is greater than the restitution coefficient value on the ping pong ball with a difference of 0.05035, while data collection using tracker software also shows that the value of the restitution coefficient for bekel ball is greater than that of ping pong ball, namely by the difference amounting to 0.0282.

## Conclusion

Utilizing tracker computer program for examination can improve the unwavering quality of created information and make strides proficiency in explore execution. Manual information investigation of marbles come about in compensation coefficient values of  $e = 0.5136 \pm 0.004214$  and  $e = 0.4566 \pm 0.01736$  for ping pong balls. In differentiate, utilizing tracker computer program yielded  $e = 0.5397 \pm 0.0008731$  for marbles and  $e = 0.5115 \pm 0.001154$  for ping pong balls. This outlines the software's capability to upgrade the exactness of test comes about, hence making strides the generally research facility prepare.

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## Author Contributions

D.A.P as the drafter and author of the initial draft of the article. D.L.S as supervision, instrument validator and final revision of the article.

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## Conflicts of Interest

In this article the author declares that there is no conflict of interest.

## References

- Agusti, H. A., Sari, P. A., & Desnita. (2023). Meta-Analisis Pengaruh Model Pembelajaran Discovery Berbantuan Media ICT Terhadap Hasil Belajar Fisika Siswa. *Compton: Jurnal Ilmiah Pendidikan Fisika*, 9(2), 161-172. <https://doi.org/10.30738/cjipf.v9i2.14833>
- Aouifi, H. El, Hajji, M. El, Es-Saady, Y., & Douzi, H. (2024). Video-Based Learning Recommender Systems: A Systematic Literature Review. *IEEE*



- Transactions on Learning Technologies*, 17, 485–497. <https://doi.org/10.1109/TLT.2023.3313391>
- Aprilia, M., Lubis, P. H. M., & Lia, L. (2020). Pengaruh Model Discovery Learning Terhadap Pemahaman Konsep Siswa SMA Berbantuan Software Tracker pada Materi GHS. *Jurnal Pendidikan Fisika Dan Teknologi*, 6(2), 320–326. <https://doi.org/10.29303/jpft.v6i2.2286>
- Bancong, H., & Song, J. (2020). Exploring How Students Construct Collaborative Thought Experiments During Physics Problem-Solving Activities. *Science & Education*, 29(3), 617–645. <https://doi.org/10.1007/s11191-020-00129-3>
- Clifford, S., Sheagley, G., & Piston, S. (2021). Increasing Precision without Altering Treatment Effects: Repeated Measures Designs in Survey Experiments. *American Political Science Review*, 115(3), 1048–1065. <https://doi.org/10.1017/S0003055421000241>
- Fadholi, L., Harijanto, A., & Lesmono, A. D. (2018). Analisis Video Kejadian Fisika Dengan Software Tracker Sebagai Rancangan Bahan Ajar Momentum Dan Impuls Untuk Meningkatkan Kemampuan Berfikir Kritis Siswa SMA Kelas X. *Jurnal Pembelajaran Fisika*, 7(3), 263–270. <https://doi.org/10.19184/jpf.v7i3.8598>
- Fahrnunisa, S. A., Rismawati, Y., Sinaga, P., & Rusdiana, D. (2021). Experiments of the law of conservation of mechanical energy using video tracker in high school learning. *Journal of Physics: Conference Series*, 1806(1), 012035. <https://doi.org/10.1088/1742-6596/1806/1/012035>
- Fatmawati, I., & Ishafit, I. (2021). Analisis Pengaruh Bahan Bakar Minyak terhadap Energi Kinetik pada Kapal Otok-Otok berbantuan Software Tracker Sebagai Alternatif Media Pembelajaran Fisika Gerak Melingkar. *Jurnal Penelitian Pembelajaran Fisika*, 12(1), 17–21. <https://doi.org/10.26877/jp2f.v12i1.7177>
- Fitri, A. D., & Mufit, F. (2022). Kepraktisan Bahan Ajar Berbasis Konflik Kognitif Menggunakan Software Tracker Untuk Mengkonstruksi Konsep Momentum Dan Impuls. *EduFisika: Jurnal Pendidikan Fisika*, 7(2), 147–153. <https://doi.org/10.59052/edufisika.v7i2.20372>
- Gamage, K. A. A., Wijesuriya, D. I., Ekanayake, S. Y., Rennie, A. E. W., Lambert, C. G., & Gunawardhana, N. (2020). Online Delivery of Teaching and Laboratory Practices: Continuity of University Programmes during COVID-19 Pandemic. *Education Sciences*, 10(10), 291. <https://doi.org/10.3390/educsci10100291>
- Habibulloh, M., & Madlazim, M. (2014). Penerapan Metode Analisis Video Software Tracker Dalam Pembelajaran Fisika Konsep Gerak Jatuh Bebas Untuk Meningkatkan Keterampilan Proses Siswa Kelas X SMAN 1 Sooko Mojokerto. *Jurnal Penelitian Fisika Dan Aplikasinya (JPFA)*, 4(1), 15. <https://doi.org/10.26740/jpfa.v4n1.p15-22>
- Hidayah, M. D., Ruhiat, Y., & Rusdiyani, I. (2023). Pembelajaran Materi Gerak Benda Untuk Siswa SD Dengan Media Canva Video. *Jurnal Penelitian Pendidikan IPA*, 9(6), 4303–4309. <https://doi.org/10.29303/jppipa.v9i6.3122>
- Hosseini, S. A., & Karlin, I. V. (2023). Lattice Boltzmann for non-ideal fluids: Fundamentals and Practice. *Physics Reports*, 1030, 1–137. <https://doi.org/10.1016/j.physrep.2023.07.003>
- Hujatutatif, A., Jumadi, J., Kuswanto, H., & Ilma, A. Z. (2022). Analyzing and Comparing Frequency of the Birds Sound Spectrum using Audacity Software in Practicum Activity. *Jurnal Penelitian Pendidikan IPA*, 8(6), 2586–2592. <https://doi.org/10.29303/jppipa.v8i6.1697>
- Ilma, A. Z., Kuswanto, H., & Hujatutatif, A. (2022). Jumping Motion of Gourami Fish Using Tracker Software as a Mechanical Energy Conservation Practicum. *Jurnal Penelitian Pendidikan IPA*, 8(5), 2154–2158. <https://doi.org/10.29303/jppipa.v8i5.2071>
- Islami, R. B., Didik, L. A., & Bahtiar, B. (2021). Determine of the nira water viscosity by using video based laboratory falling ball method with tracker software. *Gravity: Jurnal Ilmiah Penelitian Dan Pembelajaran Fisika*, 7(2). <https://doi.org/10.30870/gravity.v7i2.10165>
- Khalil, M., Topali, P., Ortega-Arranz, A., Er, E., Akçapınar, G., & Belokrys, G. (2023). Correction: Video Analytics in Digital Learning Environments: Exploring Student Behaviour Across Different Learning Contexts. *Technology, Knowledge and Learning*, 1–29. <https://doi.org/10.1007/s10758-023-09689-z>
- Khoiri, N., Respayanti, S., Kurniawan, A. F., & Ristanto, S. (2023). Practicum Ticker Timer with Inquiry Approach to Improve Student Learning Outcomes. *Jurnal Penelitian Pendidikan IPA*, 9(2), 838–842. <https://doi.org/10.29303/jppipa.v9i2.3017>
- Kundrák, Mitsyk, Fedorovich, & Markopoulos. (2019). The Use of the Kinetic Theory of Gases to Simulate the Physical Situations on the Surface of Autonomously Moving Parts During Multi-Energy Vibration Processing. *Materials*, 12(19), 3054. <https://doi.org/10.3390/ma12193054>
- Marpaung, R. R., Aziz, N. R. N., Purwanti, M. D., Sasti, P. N., & Saraswati, D. L. (2021). Penggunaan Laboratorium Virtual Phet Simulation Sebagai Solusi Praktikum Waktu Paruh. *Journal of Teaching and Learning Physics*, 6(2), 110–118. <https://doi.org/10.15575/jotalp.v6i2.12213>

- Melinia, S., Lubis, P. H. ., & Sulistiawati, S. (2021). Pengembangan LKPD Berbasis Discovery Learning Berbantuan Software Tracker Untuk Meningkatkan Pemahaman Konsep Peserta Didik Kelas X di SMA Sriguna Palembang Pada Materi GHS. *Jurnal Pendidikan Fisika Dan Teknologi*, 7(2), 80–86. <https://doi.org/10.29303/jpft.v7i2.2782>
- Peebles, A. T., Carroll, M. M., Socha, J. J., Schmitt, D., & Queen, R. M. (2021). Validity of Using Automated Two-Dimensional Video Analysis to Measure Continuous Sagittal Plane Running Kinematics. *Annals of Biomedical Engineering*, 49(1), 455–468. <https://doi.org/10.1007/s10439-020-02569-y>
- Sudirman, S. (2023). Influence of Volta Element-Based Learning Media on Students' Science Process Skills. *Jurnal Penelitian Pendidikan IPA*, 9(2), 752–756. <https://doi.org/10.29303/jppipa.v9i2.2758>
- Utari, S., & Prima, E. C. (2019). Analisis Hukum Kekekalan Momentum Model Tumbukan Kelereng dengan Gantungan Ganda menggunakan Analisis Video Tracker. *Jurnal Pendidikan Fisika Dan Keilmuan (JPFK)*, 5(2), 83. <https://doi.org/10.25273/jpfk.v5i2.4145>
- Wang, J., Xu, C., Xu, Y., Wang, Z., Qi, X., Wang, J., Zhou, W., Tang, H., & Wang, Q. (2021). Influencing Factors Analysis and Simulation Calibration of Restitution Coefficient of Rice Grain. *Applied Sciences*, 11(13), 5884. <https://doi.org/10.3390/app11135884>
- Weng, X., Ng, O.-L., & Chiu, T. K. F. (2023). Competency development of pre-service teachers during video-based learning: A systematic literature review and meta-analysis. *Computers & Education*, 199, 104790. <https://doi.org/10.1016/j.compedu.2023.104790>
- Yanti, Y., Mulyaningsih, N. N., & Saraswati, D. L. (2020). Pengaruh Panjang Tali, Massa dan Diameter Bandul Terhadap Periode dengan Variasi Sudut. *STRING (Satuan Tulisan Riset Dan Inovasi Teknologi)*, 5(1), 6. <https://doi.org/10.30998/string.v5i1.5885>
- Zhu, C., He, M., Karakus, M., Zhang, X., & Guo, Z. (2021). The collision experiment between rolling stones of different shapes and protective cushion in open-pit mines. *Journal of Mountain Science*, 18(5), 1391–1403. <https://doi.org/10.1007/s11629-020-6380-0>