DOI: 10.14421/impulse.2024.42-03

IMPULSE: Journal of Research and Innovation in Physics Education
Volume 4, Issue 2, 96 – 106

© ISSN (p): 2798–1762; ISSN (e): 2798-1754
http://ejournal.uin-suka.ac.id/tarbiyah/impulse

Gravitational Acceleration: Its Determination from Gourami Jumping Motion Using Tracker Application

Arina Zaida Ilma[1*], Heru Kuswanto[2]

[1] Natural Science Education Department, Faculty Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, Indonesia
[2] Physics Education Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, Indonesia
*Corresponding author: arinazaida.2024@student.uny.ac.id

ABSTRACT

Jumping out of the water is one of the phenomena of aquatic animals. Analyzing the motions and routines of aquatic animals requires considerable time and is often subjective, making it susceptible to errors caused by observer fatigue. Investigating the motion of objects is a difficult thought, but with the development of technology it becomes easy, one of them is by using the Tracker. This research aims to analyze the Gourami jumping motion using the Tracker in independent experiment activities about animal motion. The materials and tools needed include Gourami fish, Android camera, and Tracker application. The measurement results are the data on time, position, and the graph of motion. Gourami jumping motion is a parabolic motion consisting of uniform linear motion on the x-axis, while uniformly accelerated linear motion on the y-axis. The value of the gravitational acceleration can be determined from the graph and its value is close to the gravitational acceleration constant. Utilizing video analysis of Gourami motion with the Tracker software can be applied in science education, particularly in physics experiments.

INTISARI

Abstrak : Melompat keluar dari air merupakan salah satu fenomena hewan akuatik. Menganalisis gerak dan rutinitas hewan akuatik membutuhkan proses yang memakan waktu dan cenderung subjektif, rentan terhadap kesalahan akibat kelelahan pengamat. Penyelidikan gerak suatu objek adalah suatu hal yang sulit, namun dengan berkembangnya teknologi menjadi mudah, salah satunya dengan menggunakan Tracker. Penelitian ini mempunyai tujuan guna menganalisis gerak melompat ikan gurami dengan Tracker pada kegiatan praktikum mandiri tentang gerak hewan. Bahan dan alat yang dibutuhkan antara lain ikan gurami, kamera android, dan aplikasi Tracker. Hasil pengukuran berupa data waktu, posisi, dan grafik gerak. Gerak melompat ikan gurami merupakan gerak parabola yang terdiri dari gerak lurus beraturan pada sumbu x, sedangkan gerak lurus beraturan dipercepat pada sumbu y. Nilai percepatan gravitasi dapat ditentukan dari grafik dan nilainya mendekati konstanta percepatan gravitasi. Pemanfaatan video analisis gerak ikan gurami menggunakan Tracker dapat diterapkan dalam pembelajaran IPA khususnya pada percobaan fisika.

ARTICLE HISTORY
Received: December 5, 2024
Accepted: March 14, 2025

KEYWORDS:
Gourami fish, Gravitational acceleration, Jumping motion, Tracker application

KATA KUNCI:
Aplikasi Tracker, Gerakan melompat, Ikan gurami, Percepatan gravitasi,

* Corresponding author:
Arina Zaida Ilma, Natural Science Education Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, Indonesia
✉ arinazaida.2024@student.uny.ac.id ✆ +62 89671707601

A. Introduction

Science is a body of knowledge that involves ways of thinking, interactions with people, and the exploration of the universe along with various facts [1]. Science is a method of acquiring knowledge that serves as an approach to understanding natural phenomena. It emerges from our curiosity about ourselves, planets, living organisms, and the universe [2].

Throughout the universe, various animals from five different taxa jumping out of the water to evade their predators, breathing, catching watermelons, communicating, the mechanical motion of swimming fish have become topics of interest for many years [3]. This research emphasizes experimental activities in science learning related to animal motion. Franklin Fearing stated that experiments involving animals attracted the interest of almost all physiologists in the latter half of the 19th century. These experiments were conducted on fish, birds, and dogs [4].

One of the phenomena of various aquatic animals is jumping out of the water [5]. Several fish jump out to catch insects on and off low altitudes or escape from external stimuli [6]. Previous research explained an empirical study of the Silver Carp when swimming and jumping motion [7]. The results obtained are the influence of disturbing variables, intrinsic factor (size and morphology of fish), and extrinsic factor (temperature and water depth).

Several factors affect animal motion, including foraging behavior, human interference, and topography, all of which can be incorporated into mechanistic models [8]. Numerous studies assess hormonal or behavioral changes as direct responses to human disturbances but do not further explore their potential impacts on population size, demographic levels, or species resilience from a biological perspective [9], [10]. However, this phenomenon has not yet been studied based on physics experiment.

Analyzing the motions and routines of aquatic animals requires considerable time and is often subjective, making it susceptible to errors caused by observer fatigue [11]. In conducting an investigation of natural phenomena of motion is a difficult think, but with the development of technology, it can become easy. Currently, automated and semi-automated video-based tracking methods, such as D-Track [11], GroupTracker [12], idTracker [13], and Tracker [14], are used to reduce errors and biases in manual analysis

Tracker is an open-source software designed for video modeling and analysis. [15]. It allows to record videos on their mobile phones and analyze the video from the objects motion [16]. Tracker functions makes students easier to investigate speed, changes in position, the center of mass, and acceleration for time, and visualize the motion in a real-time [17], [18]. Tracker is related to real world models based on Newton's laws, for example in learning it is used to solve various physics problems

that are already known in everyday life including pendulum motion, parabola, free fall motion [19]. Tracking methods can analyze the various animals motion, namely fish [13], [20], [21], cats [22], primates [23], and mouse [24]. It also transforms video data into positional trajectories over time.

The use of tracker applications in learning can optimize the use of experimental devices, one of which is the use of trackers to determine the gravitational acceleration through free-fall motion [25], anomaly of Earth through solar eclipse [26], investigate the uniform motion of the straight line and determine the moon's gravity [27] and determining fluid viscosity coefficient [28]. The difference in this research is applying the Tracker application to the Gourami jumping motion.

Practice in science learning is expected to be a means for students to learn independently, around nature, and solve existing various challenges [29]. The nature of science is essential in informal science education. Scientists understand how science operates through experimentation and intuition. It makes sense to add science traits to the intended curriculum at producing faster and better [30].

The problem that arises from learning science is a phenomenon that can be seen directly, but there is also something that cannot be observed easily by students like difficulty reading graphs, analyzing problems and applying them in equations of motion [31]. This research aims to analyze the phenomena from Gourami jumping motion using the Tracker application in independent experiment activities in science learning.

B. Method

The materials and tools needed are Gourami fish, Android phone camera, and also Tracker application. The results from the measurement are graphs of the motion of the Gourami jumping, the value of the distance traveled with Tracker application and then compared with constant value.

The procedure of this research is as follows, namely:

1. The phenomenon of Gourami jumping motion in the environment was recorded using an Android camera.
2. Gourami motion is analyzed using the Tracker through importing recorded videos with the file menu, then importing videos, the videos to be analyzed are then selected by clicking open
3. If the video is available in the Tracker, the frame is set from beginning to end using the track menu, and the new option is clicked and then the calibration tools stick is selected.
4. After the y and x coordinates are obtained, then select the axes for analysis.
5. Then the Gourami mass point is determined for analysis using the track menu by selecting point mass and new.

6. Finally, the Gourami motion is analyzed by auto-track or manually placing frame points on the gourami jump out. The data was obtained in the form of motion vertically and horizontally in two dimensions (x, y). The components that are calculated on the Gourami jumping out of the water using the Tracker are the x(t), y(t), and t (s).

In this experiment, we use three Gourami fish (see Figure 1). Two black Gourami, one with a mass of 0.30 kg and a length of 0.25 m (BG-A), and another with a mass of 0.20 kg and a length of 0.17 m (BG-B), along with an albino Gourami weighing 0.25 kg and measuring 0.20 m (AG), were analyzed. Data from the Tracker were processed using Microsoft Excel to generate graphs of position versus time, altitude versus time, and the trajectory of parabolic motion. The next step is to determine the gravitational acceleration (g) of the Gourami jumping motion using the Tracker application and compare it with the gravitational acceleration constant of 9.8 m/s^2[32], [33], [34].

(a) BG-A (b) BG-B (c) AG

Figure 1. Gourami fish in this experiment

C. Result and Discussion

The use of video analysis of Gourami jumping motion using Tracker application helps students when investigating the center of mass position, acceleration and velocity in a real-time [17] and determines the type of motion. Before analyzing the video, students initially recorded the motion of the Gourami that jumped out of the water. Students can open a digital video file and import it into Tracker. Students can calibrate the scale and set the appropriate coordinate axes. The results obtained after the Gourami jumping motion video were analyzed using Tracker for each fish as presented in Table 1.

Table 1. Data of Gourami Jumping Motion

Type of Gourami	t (s)	x (m)	y (m)
BG-A	0.00	0.02	0.00
	0.03	-0.06	0.03
	0.07	-0.15	0.04
	0.10	-0.22	0.05
	0.13	-0.31	0.04
	0.17	-0.40	0.02
	0.20	-0.48	-0.01
	0.23	-0.56	-0.05
	0.27	-0.64	-0.11
BG-B	0.00	0.01	0.00
	0.03	-0.06	0.03
	0.07	-0.15	0.05
	0.10	-0.25	0.07
	0.13	-0.35	0.08
	0.17	-0.46	0.06
	0.20	-0.54	0.05
	0.23	-0.65	0.01
	0.27	-0.73	-0.02
AG	0.00	0.27	0.19
	0.03	0.23	0.27
	0.07	0.19	0.32
	0.10	0.13	0.37
	0.13	0.07	0.41
	0.17	0.02	0.42
	0.20	-0.05	0.44
	0.23	-0.14	0.45
	0.27	-0.22	0.44

Based on the data (see Table 1), a graph can be created to show the relationship between time and position along the x-axis and y-axis (see Figure 2).

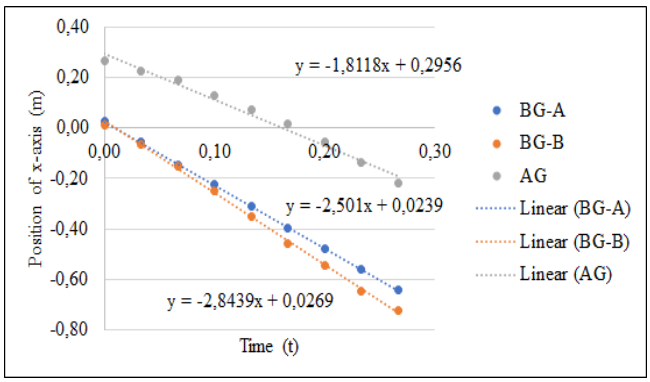

Figure 2. Graph of position versus time on the x-axis of BG A, BG-B and AG.

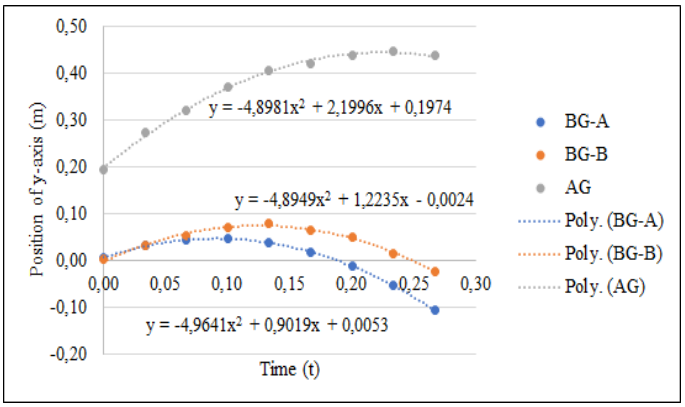

Figure 3. Graph of position versus time on the y-axis of BG A, BG-B and AG.

The graph gets a linear equation (see Figure 2). The equations generated from the data trackers sequentially from BG-A, BG-B and AG are:

$y_{(BG-A)} = -2.501x + 0.0239$ (1)

$y_{(BG-B)} = -2.8439x + 0.0269$ (2)

$y_{(AG)} = -1.8118x + 0.2956$ (3)

The initial velocity from BG-A on the x-axis component (v_{ox}) is 2.501 m/s. The initial velocity from BG-B on the x-axis component (v_{ox}) is 2.8439 m/s. The initial velocity from AG on the x-axis component (v_{ox}) is 1.8118 m/s. The negative sign indicates that the direction of the fish's speed is in the negative x direction.

The graph gets a parabolic equation (see Figure 3). The equations generated from the data trackers sequentially from BG-A, BG-B and AG are:

$y_{(BG-A)} = -4.9641x^2 + 0.9019 + 0.0053$ (4)

$y_{(BG-B)} = -4.8949x^2 + 1.2235x - 0.0024$ (5)

$y_{(AG)} = -4.8981x^2 + 2.1996x + 0.1974$ (6)

The initial velocity from BG-A on the y-axis component (v_{oy}) is 0.9019 m/s. The initial velocity from BG-B on the y-axis component (v_{oy}) is 1.2235 m/s. The initial velocity from AG on the x-axis component (v_{oy}) is 2.1996 m/s. The positive sign indicates that the direction of the fish's speed is in the positive y direction.

In the experiment of fish jumps out of the water using Tracker, it shows that the Gourami fish perform a parabolic motion. The Gourami fish are given a stimulus to jump out of the water when the water is in a small pond, then they are given humans disturbance who seem to be catching it so that the Gourami jumping motion is a parabolic trajectory.

Tracker as a pedagogical tool in learning and teaching effective projectile motion in science (physics) [15]. Parabolic motion is a specific type of two-dimensional

motion in which a particle moves within a vertical plane, utilizing an initial velocity while experiencing constant acceleration due to gravity acting downward [35]. Parabolic motion is basically a combination of uniform linear motion and uniformly accelerated linear motion [36].

In the motion of the fish above, the resulting graph shows a linear line on the y-axis so that it includes uniform linear motion, while on the y-axis a parabolic graph shows that the motion includes uniformly accelerated linear motion. The use of the Tracker software on the Atwood aircraft showed the characteristics of uniform linear motion and uniformly accelerated linear motion so that it was classified as suitable for use in science learning at school [37]. Both have their respective interpretations on the components of the x and y axes. In parabolic motion, vertical and horizontal motion are independent, thus no motion affects each other [35].

The equation that applies to each component is written as the following equation and to find the magnitude of the gravitational acceleration from the resulting graph (see Figure 3).

Equation on the x-axis component:

$$v_{ox} = v_0 \cos\theta \tag{7}$$

Equation on the y-axis component:

$$v_{oy} = v_0 \sin\theta \tag{8}$$

The gravitaty acceleration can be calculate from the experiments using the equation.

$$y = v_0 t - \frac{1}{2} g t^2 \tag{9}$$

The difference in the gravitational acceleration value of Gourami fish jumping out of the water using the tracker application is shown in Table 2.

Table 2. Gravitational Acceleration of Gourami Jumping Motion

Type of Gourami Fish	Gravitational Acceleration	Gravitational Acceleration Constant
BG-A	9.928 m/s^2	
BG B	9.789 m/s^2	9.8 m/s^2
AG	9.782 m/s^2	

From the results (see Table 2), the data using the tracker application is close to the gravitational acceleration constant (9.8 m/s^2), namely in BG-A the results of the gravitational acceleration are 9.928 m/s^2 with level of accuracy is 99,96% , in BG-B is is 9.789 m/s^2 with level of accuracy is 99.15% and error value is 0,0085 and at AG is 9.782 m/s^2 with level of accuracy is 99.75%.

The previous study also found the gravitational acceleration with the Tracker application [38]. An experiment to determine the acceleration due to gravity obtained a value of g = 9.63 ± 0.07 m/s^2 with a relative accuracy of RA% = 98.2% and a relative statistical uncertainty of 0.7%. Thus, the high level of accuracy of the Gourami fish jumping out of the water using the Tracker can make it easier for students in

experiment activities to determine the magnitude of the gravitational acceleration. Experimental activities in science learning can foster the independence of students' scientific work [39].

D. Conclusion

Tracker is an open-source application for modeling tools and video analysis to investigate speed, changes in position, center of mass, and the acceleration for time and also visualize the motion concepts in a real-time. By using a Tracker application, it can be make the position versus time graph to determined the gravitational acceleration. Gravitational acceleration resulting from the Gourami jumping motion is always showing a value about 9.782 – 9.928 m/s^2 which is analyzed from the parabolic graph of position y. Therefore, it can be concluded that video analysis of the Gourami's jumping motion using the Tracker can be utilized in physics experiments for science learning about animal motion. It helps students interpret the obtained data through graphs and data tables, making it easier to draw conclusions and accurately identify motion parameters.

References

[1] W. Widodo, D. A. P. Sari, T. Suyanto, M. Martini, and I. Inzanah, "Pengembangan keterampilan pemodelan matematis bagi calon guru IPA," *J. Inov. Pendidik. IPA*, vol. 6, no. 2, pp. 146–155, 2020, doi: 10.21831/jipi.v6i2.27042.

[2] N. A. Campbell, L. A. Urry, M. L. Cain, S. A. Wasserman, P. V. Minorsky, and J. B. Reece, *Biology A Global Approach*, Eleventh E. United States of America: Pearson Education, 2018.

[3] C. Eloy, "Optimal Strouhal number for swimming animals," *J. Fluids Struct.*, vol. 30, pp. 205–218, 2012, doi: 10.1016/j.jfluidstructs.2012.02.008.

[4] A. Klein, "The curious case of the decapitated frog: on experiment and philosophy," *Br. J. Hist. Philos.*, vol. 26, no. 5, pp. 890–917, 2018, doi: 10.1080/09608788.2017.1378866.

[5] B. Chang, J. Myeong, E. Virot, C. Clanet, H. Y. Kim, and S. Jung, "Jumping dynamics of aquatic animals," *J. R. Soc. Interface*, vol. 16, no. 152, 2019, doi: 10.1098/rsif.2019.0014.

[6] B. J. Vetter, A. F. Casper, and A. F. Mensinger, "Characterization and management implications of silver carp (Hypophthalmichthys molitrix) jumping behavior in response to motorized watercraft," *Manag. Biol. Invasions*, vol. 8, no. 1, pp. 113–124, 2017, doi: 10.3391/mbi.2017.8.1.11.

[7] G. R. Parsons, E. Stell, and J. J. Hoover, "Estimating burst swim speeds and jumping characteristics of silver carp (Hypophthalmichthys molitrix) using video analyses and principles of projectile physics," *Report*, no. October 2016, 2016.

[8] H. K. Preisler, A. A. Ager, and M. J. Wisdom, "Analyzing animal movement patterns using potential functions," *Ecosphere*, vol. 4, no. 3, pp. 1–13, 2013, doi: 10.1890/ES12-00286.1.

[9] Z. Tablado and L. Jenni, "Determinants of uncertainty in wildlife responses to human disturbance," *Biol. Rev.*, vol. 92, no. 1, pp. 216–233, 2017, doi: 10.1111/brv.12224.
[10] M. R. Baker, K. S. Gobush, and C. H. Vynne, "Review of factors influencing stress hormones in fish and wildlife," *J. Nat. Conserv.*, vol. 21, no. 5, pp. 309–318, 2013, doi: 10.1016/j.jnc.2013.03.003.
[11] P. Rachinas-Lopes, R. Ribeiro, M. E. Dos Santos, and R. M. Costa, "D-Track—A semi-automatic 3D video-tracking technique to analyse movements and routines of aquatic animals with application to captive dolphins," *PLoS One*, vol. 13, no. 8, pp. 1–12, 2018, doi: 10.1371/journal.pone.0201614.
[12] T. Fukunaga, S. Kubota, S. Oda, and W. Iwasaki, "GroupTracker: Video tracking system for multiple animals under severe occlusion," *Comput. Biol. Chem.*, vol. 57, pp. 39–45, 2015, doi: 10.1016/j.compbiolchem.2015.02.006.
[13] A. Pérez-Escudero, J. Vicente-Page, R. C. Hinz, S. Arganda, and G. G. De Polavieja, "IdTracker: Tracking individuals in a group by automatic identification of unmarked animals," *Nat. Methods*, vol. 11, no. 7, pp. 743–748, 2014, doi: 10.1038/nmeth.2994.
[14] A. Rossouw, M. Hacker, and M. J. De Vries, "Concepts and contexts in engineering and technology education: An international and interdisciplinary delphi study," *Int. J. Technol. Des. Educ.*, vol. 21, no. 4, pp. 409–424, 2011, doi: 10.1007/s10798-010-9129-1.
[15] L. K. Wee and T. K. Leong, "Video Analysis and Modeling Performance Task to Promote Becoming Like Scientists in Classrooms," *Am. J. Educ. Res.*, vol. 3, no. 2, pp. 197–207, 2015, doi: 10.12691/education-3-2-13.
[16] D. H. Nichols, *Physics for Technology*, Second Edi. Boca Raton: Taylor & Francis Group, 2019.
[17] P. Hockicko, "Forming of physical knowledge in engineering education with the aim to make physics more attractive," in *Physics Teaching in Engineering Education (PTEE)*, 2011, pp. 1–5.
[18] E. Yusuf, "Using tracker to engage students' learning and research in physics," *Pertanika J. Sci. Technol.*, vol. 24, no. 2, pp. 483–491, 2016.
[19] A. Anissofira, F. Dzar, and E. Latief, "Analisis Gerak Roller Coaster Menggunakan Tracker dengan Pendekatan Multi Modus Representasi Sebagai Sarana Siswa Memahami Konsep Kinematika," *Pros. SKF 2016*, pp. 26–32, 2016.
[20] O. Mirat, J. R. Sternberg, K. E. Severi, and C. Wyart, "ZebraZoom: An automated program for high-throughput behavioral analysis and categorization," *Front. Neural Circuits*, vol. 7, no. June, pp. 1–12, 2013, doi: 10.3389/fncir.2013.00107.
[21] A. Z. Ilma, H. Kuswanto, and A. Hujatulatif, "Jumping Motion of Gourami Fish Using Tracker Software as a Mechanical Energy Conservation Practicum," *J. Penelit. Pendidik. IPA*, vol. 8, no. 5, pp. 2154–2158, 2022, doi: 10.29303/jppipa.v8i5.2071.
[22] D. Ramadhanti, H. Kuswanto, H. Hestiana, and A. Azalia, "Penggunaan Analisis Video Gerak Kucing Melompat Berbantuan Aplikasi Tracker Sebagai Kegiatan Praktikum Mandiri Materi Gerak pada Peserta Didik SMP," *J.*

Pendidik. Sains Indones., vol. 9, no. 3, pp. 459–470, 2021, doi: 10.24815/jpsi.v9i3.20547.
[23] S. Ballesta, G. Reymond, M. Pozzobon, and J. R. Duhamel, "A real-time 3D video tracking system for monitoring primate groups," *J. Neurosci. Methods*, vol. 234, pp. 147–152, 2014, doi: 10.1016/j.jneumeth.2014.05.022.
[24] F. De Chaumont *et al.*, "Computerized video analysis of social interactions in mice," *Nat. Methods*, vol. 9, no. 4, pp. 410–417, 2012, doi: 10.1038/nmeth.1924.
[25] L. K. Kanga, R. B. Astro, Y. E. Ika, P. Education, and S. Program, "Analysis of Vertical Movements on Freedom and Bullet," vol. 4, no. 1, pp. 19–25, 2021.
[26] A. H. Setyadin *et al.*, "Optimalisasi Bandul Matematis Menggunakan Tracker dalam Penentuan Perubahan Percepatan Gravitasi Permukaan Bumi (G) Akibat Gerhana Matahari Sebagian (GMS) 9 Maret 2016," in *Seminar Nasional Fisika*, 2016, pp. 167–170. doi: 10.21009/0305020132.
[27] D. P. Sari, W. Widodo, and Madlazim, "Sciences Practicum in The Covid-19 Pandemic Era by Using a Video Tracker," *J. Inov. Pendidik. dan Sains*, vol. 2, no. 3, pp. 75–81, 2021.
[28] R. B. Islami, L. A. Didik, and B. Bahtiar, "Determine of the nira water viscosity by using video based laboratory falling ball method with tracker software," *Gravity J. Ilm. Penelit. dan Pembelajaran Fis.*, vol. 7, no. 2, pp. 8–20, 2021, doi: 10.30870/gravity.v7i2.10165.
[29] I. Diamond, *Science Education in school, TLRP Institute of Education*. London: University of London, 2011.
[30] W. F. McComas, *Nature of Science in Science Instruction*. Switzerland: Springer Nature Switzerland AG, 2020.
[31] F. Mufit, "The study of misconceptions on motion's concept and remediate using real experiment video analysis," *Asean Comp. Educ. Res. Netw. Conf.*, pp. 1–7, 2018.
[32] D. Halliday, R. Resnick, and J. Walker, *Fundamental of Physics*, 9th Editio. New Jersey: John Wiley & Sons Inc, 2011.
[33] R. . Serway and J. Jewett, *Physics for Scientists and Engineers with Modern Physics*, Ninth Edit. United Stated of America: Books/Cole, 2014.
[34] Giancoli and C. Douglas, *Physics Principles with Application*, Sixth Edit. New Jersey: Upper Saddle River, 2005.
[35] J. Halliday, D., Resnick, R., Walker, *Fundamentals of Physics*, 9th Editio. New Jersey: John Wiley & Sons, Inc, 2011.
[36] T. S. Tuhusula, B. Pattana, E. Randai, D. . Wateriri, and A. . Walukow, "Experiments Usingbased Virtual Lab Phet Simulation in Learning Physics on Parabolic Movement Materials," *J. Pendidik. fIS*, vol. 9, no. 2, pp. 128–135, 2020.
[37] M. G. Nugraha, K. H. Kirana, F. Nugraha, E. A. Nurinsani, and F. N. Sholihat, "Optimization of Rectilinear Motion Experiments using Tracker Application," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 288, no. 1, 2018, doi: 10.1088/1757-899X/288/1/012096.
[38] M. Anni, "Quantitative comparison between the smartphone based experiments for the gravity acceleration measurement at home," *Educ. Sci.*, vol. 11, no. 9, pp. 1–20, 2021, doi: 10.3390/educsci11090493.

[39] P. Parmin, E. N. Savitri, and Y. N. Ifriza, “Scientific work independence application for various education levels referring to Piaget’s theory to support the implementation of science integrated learning model,” *J. Penelit. dan Pembelajaran IPA*, vol. 8, no. 2, pp. 175–191, 2022, doi: 10.30870/jppi.v8i2.17442.