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SUBJECTIVE EXPERIENCE AND OBJECTIVE MEASUREMENT: INTEGRATING NEWTON'S LAWS AND SMARTPHONE SENSORS IN PHYSICS LEARNING

Nurul Fitria[1*],Ishafit[2], Okimustava[3], Fida Afifah[4], Sri Wahyuni[5], Ermelinda[6], Zellius Ragiliawan[7]
Universitas Ahmad Dahlan Yogyakarta[1]
Universitas Ahmad Dahlan Yogyakarta[2]
Universitas Ahmad Dahlan Yogyakarta[3]
Universitas Ahmad Dahlan Yogyakarta[4]
Universitas Ahmad Dahlan Yogyakarta[5]
Universitas Ahmad Dahlan Yogyakarta[6]
BRIDA Surakarta[7]
[*] E-mail: 2407041003@webmail.uad.ac.id

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Abstract

In today's digital era, physics education demands more contextual and technology-integrated approaches to bridge abstract concepts with real-world experiences. This study aims to develop an innovative approach in physics learning by utilizing smartphone sensors to analyze the vertical motion dynamics of an elevator based on Newton's Laws. The experiment was conducted in a five-story elevator at BRIDA Surakarta using the Phyphox application, which employs the smartphone's built-in accelerometer and barometer. The modes "acceleration without g" and "elevator" were used to record real-time data of acceleration, velocity, and altitude. Data was collected through ten trials—five upward and five downward motion cycles. The recorded data revealed maximum acceleration values of ±8 m/s², aligning with the typical operational range of elevators (6–10 m/s²), while the altitude change was approximately ±18 meters, corresponding to the actual height of the building. The elevator's motion was clearly segmented into three phases: initial acceleration, constant velocity, and deceleration. In each phase, passengers experienced distinct physical sensations—from feeling pressed down, to normal, to weightless—which closely correlated with the recorded acceleration data. These findings strongly validate the application of Newton's Laws in non-inertial systems and the alignment between subjective sensations and quantitative measurements. Beyond reinforcing conceptual understanding through firsthand experience, this approach encourages active student engagement and enables experimentation without reliance on conventional physics laboratories. The study affirms that smartphone-based technologies hold great potential in democratizing access to scientific instrumentation and enhancing the quality of STEM education in a contextual, inclusive, and applicable manner.

Keywords: ***smartphone sensors, elevator motion, Newton's Laws, physics education, accelerometer***

INTRODUCTION

Educational transformation in the era of the Industrial Revolution 4.0 demands the integration of digital technology into the learning process, including in the field of physics education. The main challenge faced today is how to provide contextual, authentic, and meaningful learning experiences, especially when delivering abstract and theoretical physics concepts. Fundamental concepts such as Newton's Laws are often taught in the form of mathematical equations without being accompanied by relevant empirical experiences, which can potentially reduce students' conceptual understanding and active participation in learning (Rakestraw et al., 2023; Vandegrift, 2020). In the context of 21st-century learning, technology-based approaches have become increasingly relevant and important pedagogical strategies. Smartphones, which have become an integral part of young people's daily lives, offer great potential as scientific experiment tools through the use of internal sensors such as accelerometers and barometers (Grouios et al., 2023; Hussain et al., 2023; Wahyuningtyas & Okimustava, 2023). These sensors enable the measurement of motion, acceleration, and air pressure with sufficient accuracy for educational purposes. Applications such as Phyphox (Physical Phone Experiments) allow smartphones to function as portable physics measuring instruments, which can be used in various hands-on experiments (Laeli & Okimustava, 2023). One physical phenomenon relevant to everyday life and rich in mechanical concepts is elevator motion. Elevator systems operate based on Newton's Laws, particularly the relationship between force, mass, and acceleration. Elevator passengers naturally experience variations in normal force during acceleration or deceleration, resulting in physical sensations such as being "pressed down" or "floating." This phenomenon provides an ideal context for linking subjective experiences with objective, sensor-based measurements, thereby delivering more concrete and contextualized learning (Imtinan & Kuswanto, 2023; Wang et al., 2024).

Several studies have shown that sensor-based learning can enhance students' cognitive engagement as well as strengthen their conceptual understanding of basic physics (Kong et al., 2021; Raza et al., 2023). However, the use of such technology in physics learning at both school and university levels remains suboptimal, particularly in integrating quantitative data with students' direct experiences. This represents an important gap that needs to be addressed through learning approaches that can combine cognitive, affective, and psychomotor dimensions in a holistic way. Based on this background, this study aims to explore the use of the Phyphox application on smartphones as an experimental medium to quantitatively analyze elevator motion. The main focus of the research is to examine how acceleration, velocity, and altitude data recorded by sensors can be correlated with passengers' subjective experiences in the context of Newton's Laws. This study is expected to contribute to the development of more innovative, technology-based physics learning strategies that are relevant to students' real-life contexts. From a physics perspective, an elevator is a mechanical system that operates based on fundamental principles of Newton's Laws. The dynamics of elevator motion can be analyzed using all three laws, which explain the relationships among force, mass, and acceleration.

Newton's First Law applies when the elevator is at rest or moving at constant velocity, where the net force acting on the system is zero. In this condition, passengers experience no change in apparent weight because the normal force from the elevator floor equals the gravitational force acting on their bodies.

Newton's Second Law (Law of Acceleration) becomes relevant when the elevator accelerates or decelerates. When the elevator accelerates upward, the normal force experienced by the passenger increases, producing a sensation of increased body weight. Conversely, when the elevator decelerates or accelerates downward, passengers feel a reduction in body weight. This phenomenon can be described using the equation: (1) where N is the normal force, m is the mass, g is gravitational acceleration, and a is the elevator's acceleration.

In the digital era, technological advances in instrumentation and measurement have accelerated through the integration of advanced sensors into smartphones (Rakestraw et al., 2023). Modern smartphones are equipped with various sensors capable of performing physical measurements with high accuracy, opening new opportunities in science education and applied research.

One notable application for utilizing smartphone sensors in physics experiments is Phyphox. This application uses internal smartphone sensors to perform real-time measurements and physics experiments. In the context of elevator motion analysis, Phyphox provides a dedicated menu to measure three main parameters: altitude (h), velocity (v), and acceleration (a). The accelerometer is the primary instrument for measuring a smartphone's motion acceleration in three dimensions. This sensor can detect positional changes and vibrations with high sensitivity (Grouios et al., 2023). In elevator motion analysis, the accelerometer plays a key role in measuring vertical acceleration experienced during the elevator ride. In addition, smartphones are equipped with barometer sensors that measure atmospheric air pressure and determine altitude based on the principle that air pressure decreases as elevation increases from sea level (Grouios et al., 2023). By integrating data from both the barometer and accelerometer, Phyphox can accurately calculate elevator speed, making it a valuable tool for education and research.

The use of smartphone sensors in physics learning has proven to hold great potential in enhancing students' engagement and conceptual understanding (Vandegrift, 2020). This technological integration allows students to conduct authentic experiments using devices already familiar to them. Elevator motion experiments using smartphones provide opportunities to connect subjective experiences—such as passengers' physical sensations—with objective, quantitative measurements and analysis. This approach helps students understand the relationship between theoretical physics concepts and phenomena they experience directly. In contemporary physics education, one of the main challenges is bridging the gap between abstract theoretical concepts and practical applications relevant to students' lives. Experiments using elevators and smartphones offer an effective solution because they present familiar and easily accessible contexts. Several studies indicate that smartphone-based experiments can improve conceptual understanding of fundamental physics principles (Kong et al., 2021). Along with advances in microelectromechanical systems (MEMS) sensor technology, the integration of high-

quality sensors into compact devices is increasingly feasible. These advancements expand access to scientific instrumentation that was once limited to laboratories (Rakestraw et al., 2023), reinforcing the relevance of this study in supporting the needs of modern education and industry. Elevator motion analysis provides an ideal context for applying all three of Newton's Laws comprehensively. When the elevator is at rest or moving at constant velocity, Newton's First Law applies ($\Sigma F = 0$), so the normal force N equals the weight W. When the elevator accelerates upward with acceleration a, Newton's Second Law applies:
(2) with the normal force given by:
(3) Conversely, if the elevator accelerates downward, the normal force becomes:
(4) which creates the sensation of feeling lighter or "floating."
Using the Phyphox application in elevator motion experiments enables real-time data acquisition with a high sampling rate. Accelerometer data can be integrated to calculate velocity and displacement, while barometer data provides complementary information on changes in altitude (Hussain et al., 2023). This study contributes to the development of innovative physics learning methodologies by utilizing devices already familiar to students. The integration of subjective experience with objective measurement offers a new dimension in understanding physics concepts (Wang et al., 2024). The significance of this study lies in its ability to bridge the gap between theoretical learning and practical application in the modern technological era. By leveraging widely accessible smartphone sensors, this research supports the democratization of access to scientific instrumentation in education (Rakestraw et al., 2023) and strengthens the potential of such technology in transforming science learning.

METHOD

Research Design:

This study uses a quantitative experimental approach to explore the dynamics of vertical elevator motion by utilizing sensors on smartphones. This approach is designed to integrate theoretical physics concepts with direct experience through technology that is easily accessible to students. Through this method, technology-based learning can be transformed into a meaningful avenue for scientific exploration.

Location and Time of Study:

The research was conducted on Friday, 20 June 2025, at the Regional Research and Innovation Agency (BRIDA) of Surakarta City. The location was chosen because it has a suitable 5-story elevator facility for collecting vertical acceleration data. This site selection refers to standards for vertical motion research that require a minimum height to obtain representative data (Zhou et al., 2020).

Research Instruments

Hardware

The instrument used was a smartphone running the Phyphox application, which functions as an acceleration sensor. A smartphone was chosen because of its accessibility and the sufficiently high accuracy of its accelerometer sensors for physics research purposes (Lăpădat et al., 2021). The smartphone's position was set stably on the elevator wall during data collection.

Software

The Phyphox application was used in the "acceleration without g" mode or the "Elevator" mode to measure vertical acceleration. This application was selected because of its ability to export raw data that can be further analyzed using spreadsheets (Imtinan & Kuswanto, 2023).

Data Collection Procedure

Preparation Stage

Before data collection, sensor calibration and determination of the smartphone's optimal position inside the elevator were performed. The goal was to ensure positional stability and to avoid noise caused by vibration or shifting during measurement.

Data Collection Stage

Data were collected ten times in total, comprising five runs while the elevator went up and five runs while it went down. Each data collection session included:

- Several seconds before the elevator moved,
- During elevator motion,

- Several seconds after the elevator stopped.

Illustration of Elevator Motion:
Data when the elevator goes up

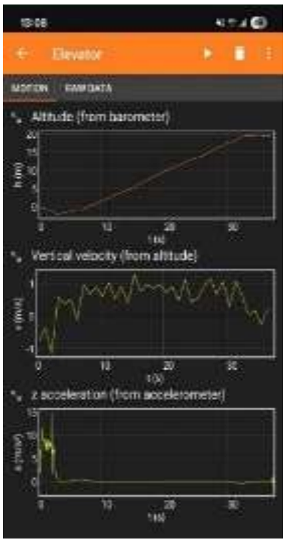

Figure 1. When the Elevator Goes Up
Data when the elevator goes down

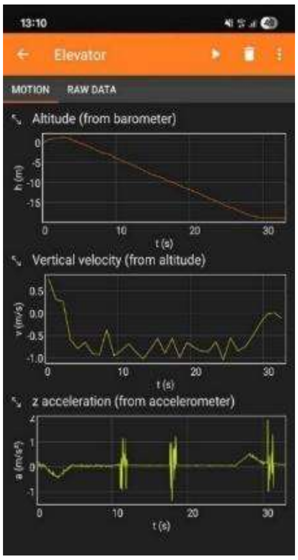

Figure 2. When the Elevator Goes Up
Each measurement recorded data for several seconds before the elevator moved, during the movement, and for several seconds after the elevator stopped. This protocol ensures comprehensive data capture for analysis of the elevator's motion phases (Vincent et al., 2022).

Measurement Instructions

a. Measure acceleration while the elevator is going up or down (a).
b. Choose an elevator that can be used for measurement.
c. Use the "acceleration without g" mode in the Phyphox app or select Elevator.
d. Place the phone in a stable position on the elevator wall during the trip.
e. Collect data while the elevator goes up/down. Make sure to record several seconds before and after the elevator moves. → Export the final data for analysis.

Data Analysis Techniques

Primary Data Processing
Raw data from the Phyphox app are exported to a spreadsheet for further analysis. This process involves:

- Moving the time and acceleration data to a new worksheet,
- Creating an acceleration versus time graph,
- Identifying the elevator motion phases based on acceleration patterns.

Acceleration Graph Analysis
Graph analysis is carried out by identifying three main phases:

- Initial acceleration phase (elevator begins to move),
- Constant velocity phase (acceleration ≈ 0),
- Deceleration phase (elevator is about to stop).
  Each phase is analyzed in relation to Newton's Laws, particularly Newton's Second Law concerning the relationship among force, mass, and acceleration (Imtinan & Kuswanto, 2023).

Velocity Calculation
Velocity at each time point is calculated by numerically integrating the acceleration data with respect to time. Numerical methods are used to convert acceleration data into velocity, producing combined acceleration–velocity graphs that enable a comprehensive analysis of the elevator's motion (Kong et al., 2021).
Observation Data
Steps for Creating Graphs and Analyzing Acceleration Data:

a. Open the spreadsheet containing the raw data and create a new worksheet.
b. Copy the time and acceleration data into the new sheet.
c. Create an acceleration vs. time graph.
d. Explain how each segment of the acceleration graph relates to the elevator's motion. Discuss what happens when acceleration changes, and what occurs when acceleration = 0 at various points during the trip.
e. Compute velocity at each time point based on the acceleration and time data. Create a graph that displays both acceleration and velocity together.

RESULTS AND DISCUSSION
Altitude Profile

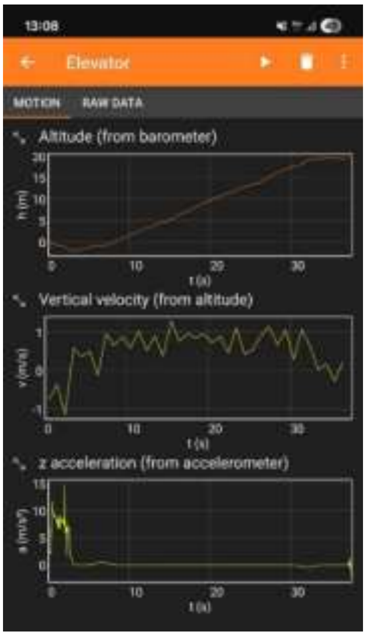

Figure 1. Altitude Graph During Elevator Ascent
Based on the altitude graph obtained from the smartphone's barometer sensor, the elevator experienced an upward vertical displacement of approximately 18 meters during the trip. The pattern of altitude change shows a linear and consistent increase, indicating that the elevator moved upward steadily from the starting position until it reached the destination floor. The barometer sensor was able to detect changes in air pressure proportional to changes in altitude, where each decrease of 1 hPa corresponds to an altitude increase of about 8.3 meters under standard conditions (Kusuma et al., 2023). The Y-axis of the graph represents altitude in meters, while the X-axis represents time in seconds. The stable upward line from about 0 m to 18–19 m shows that the elevator moved upward at a

constant rate without significant fluctuations. This linear change in altitude indicates that the elevator system functioned well in maintaining a constant speed after passing the initial acceleration phase.

Vertical Velocity

The vertical velocity vs. time graph provides highly informative insight into the elevator's motion characteristics. In the initial phase of the trip, fluctuations in velocity are observed due to sensor noise and system stabilization. After this phase, vertical velocity shows a constant pattern in the range of 0.5–1 m/s, indicating that the elevator ascended at a constant speed after the initial acceleration (Kusuma et al., 2023). Analysis of the velocity graph allows identification of three key phases in the elevator's journey.

1. **Initial acceleration phase** – velocity starts from a negative value toward zero, then increases. This suggests that the elevator experienced a slight downward motion or initial fluctuation before moving upward.
2. **Constant speed phase** – velocity stabilizes near a peak of about 1.3 m/s, indicating uniform upward motion.
3. **Deceleration phase** – velocity decreases back toward zero as the elevator slows to a stop.

Vertical Acceleration

The vertical acceleration graph obtained from the accelerometer sensor shows significant changes in the three main phases of the elevator's journey: beginning, middle, and end.

- **Initial phase (0–2 s)**: A sharp acceleration spike exceeding 8 m/s^2 is observed. This represents the elevator motor's thrust overcoming gravity to initiate upward motion. Physically, this indicates a positive net acceleration, so the normal force on the passenger's body is greater than usual. Subjectively, passengers feel pressed downward, as if their weight has increased.
- **Middle phase (2–25 s)**: Acceleration approaches zero, indicating motion at constant speed with no additional acceleration. This reflects a state of equilibrium where the net force is zero. Passengers feel no change in weight, experiencing sensations similar to standing still on solid ground.
- **Final phase (25–30 s)**: Negative acceleration appears, indicating deceleration as the elevator approaches a stop. This reduces the normal force, causing passengers to feel lighter or "floating." Theoretically, this occurs because the net force acts opposite to the initial direction of motion, consistent with Newton's Second Law.

These results show that each phase of the elevator's motion can be quantitatively analyzed and explained using fundamental mechanics. Passengers' subjective sensations of changing forces align with the real-time sensor data, providing empirical validation of acceleration concepts in non-inertial systems.

Analysis of Elevator Downward Motion

Altitude Profile During Descent

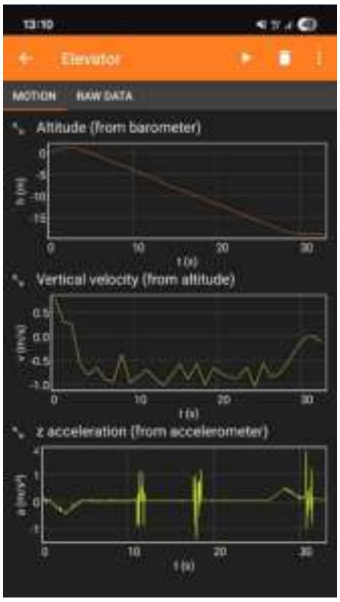

Figure 2. Altitude Graph During Elevator Descent

The altitude graph during descent shows a gradual drop from 0 m to -18 m over about 30 seconds. This linear, consistent pattern indicates steady downward motion in the direction of gravitational acceleration. The barometer detects increased air pressure as altitude decreases, shown as negative values on the graph (Chang et al., 2020). A closer look shows that in the first 0–3 seconds, altitude briefly rises, suggesting stabilization or slight upward motion before descent. From 3 s to about 30 s, altitude decreases steadily. In the final seconds (30–34 s), the line flattens, indicating deceleration and stopping.

Vertical Velocity During Descent

The vertical velocity graph during descent displays three main phases: initial acceleration, constant speed, and final deceleration.

1. **Initial phase (0–5 s)**: Velocity changes from slightly positive (~+0.5 m/s) to negative, indicating a shift from being stationary or slightly ascending to descending. This reflects downward acceleration due to a net force in the negative vertical direction.
2. **Constant speed phase (5–25 s)**: Velocity remains steady between -0.8 m/s and -1.1 m/s. This uniform motion means driving force balances drag and gravity, so acceleration is nearly zero. Passengers feel no significant change in force.
3. **Final deceleration phase (25–32 s)**: Velocity gradually returns toward zero from the negative direction, indicating upward acceleration opposing the downward motion.

The smooth transitions between phases confirm precise motion control, matching the principles of vertical dynamics and supporting the accuracy of smartphone sensor measurements.

Vertical Acceleration During Descent

The acceleration graph during descent also shows three phases:

- **Phase 1 (0–5 s)**: Light negative acceleration (~-0.5 m/s²) as the elevator begins to move downward. Passengers feel slightly lighter.
- **Phase 2 (5–25 s)**: Near-zero acceleration, indicating uniform motion. This aligns with Newton's First Law no net force means constant velocity.
- **Phase 3**: Occasional spikes in acceleration (e.g., at 10 s, 18 s, 30 s) correspond to motor adjustments during motion or braking. According to Newton's Second Law, sudden acceleration changes reflect rapid changes in net force.

Overall, these patterns illustrate vertical motion dynamics effectively and make real-world, sensor-based learning possible.

Correlation with Newton's Laws and Subjective Experience

Application of Newton's Second Law

The observed elevator motion closely matches Newton's Second Law ($\Sigma F = m \cdot a$). Positive acceleration during ascent increases the normal force ($N > mg$), making passengers feel heavier. Negative acceleration during descent decreases the normal force ($N < mg$), making passengers feel lighter. At constant speed, acceleration is zero, net force is zero, and passengers feel normal weight.

Consistency with Kinematics

Measurements align with basic kinematic laws. Linear displacement during constant speed confirms $s = vt$. Velocity patterns match $v = v_0 + at$ for each phase (Raza et al., 2023). Integration of acceleration, velocity, and position data shows consistent relationships, as predicted by calculus-based kinematics.

Subjective Experience vs. Physics

Passenger sensations match sensor data: feeling "pressed down" during positive acceleration, normal at zero acceleration, and "floating" during negative acceleration (Niu et al., 2022). This demonstrates that smartphones can measure forces experienced by passengers accurately, enhancing interactive physics learning.

Implications for Physics Education

Using smartphone sensors to study elevator motion offers an innovative approach to teaching physics, especially Newton's laws and kinematics in real contexts. Combining quantitative sensor data with subjective experience produces a more complete, concrete, and applicable learning process. This approach allows students to

directly observe phenomena usually learned abstractly, strengthening conceptual understanding through empirical experience. With devices familiar to daily life, experiments become more relevant and engaging.
Moreover, this method democratizes physics experiment tools once limited to labs are now widely accessible, enabling experiments outside traditional classrooms. This supports more inclusive, adaptive, and accessible science education without relying solely on conventional lab equipment. In conclusion, integrating sensor technology into physics education enhances learning quality while supporting a shift toward modern, participatory, and technology-based science teaching.

CONCLUSION

Exploration of Elevator Motion Using Smartphone Sensors has successfully demonstrated the effectiveness of MEMS (Microelectromechanical Systems) technology in contextual physics learning. This study shows that the Phyphox application is capable of measuring the acceleration, velocity, and height of an elevator with sufficient accuracy for educational purposes, where the accelerometer sensor successfully detected acceleration variations of up to 8 m/s^2 during the initial acceleration phase, while the barometer sensor was able to measure altitude changes of up to 18 meters with consistent precision. The integration of quantitative sensor data with the subjective experience of passengers has validated the application of Newton's three laws in the context of elevator motion, particularly in explaining the correlation between objective acceleration and the physical sensations experienced by passengers.

The analysis indicates that elevator motion consists of three distinct phases: the initial acceleration phase, characterized by high acceleration values causing passengers to feel pressed downward; the constant motion phase, with near-zero acceleration where passengers feel normal conditions; and the deceleration phase, with negative acceleration that induces a sensation of lightness. The strong correlation between sensor data and subjective experience demonstrates that smartphone technology can serve as an effective physics learning tool, bridging the gap between theoretical concepts and practical applications in everyday life. This research provides a significant contribution to the democratization of access to scientific instrumentation in physics education, where devices already familiar to students can be utilized for authentic experiments without the need for expensive laboratory equipment. The developed methodology has proven effective in increasing student engagement in STEM learning through an approach that integrates modern technology with fundamental physics principles, thereby creating opportunities for developing a more innovative and technologically relevant physics curriculum.

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REFERENCES

Chang, Y., Cui, X., Hou, G., & Jin, Y. (2020). Calibration of the Pressure Sensor Device with the Extreme Learning Machine.

Grouios, G., Ziagkas, E., Loukovitis, A., Chatzinikolaou, K., & Koidou, E. (2023). Accelerometers in Our Pocket: Does Smartphone Accelerometer Technology Provide Accurate Data? Sensors, 23(1), 1–17.

Hussain, F., Gonçalves, N. J., Alexandre, D., Coelho, P., Albuquerque, C., Leithardt, V., & Pires, I. (2023). A smartphone accelerometer data-driven approach to recognize activities of daily life: A comparative study. Smart Health, 30, 100432.

Imtinan, N., & Kuswanto, H. (2023). The Use of Phyphox Application in Physics Experiments: A Literature Review. JIPF (Jurnal Ilmu Pendidikan Fisika), 8(2), 183.

Kong, X., Yang, W., Luo, H., & Li, B. (2021). Application of Stabilized Numerical Integration Method in Acceleration Sensor Data Processing. IEEE Sensors Journal, PP, 1.

Kusuma, H. A., Yuliani, Suhendra, T., Devendra, D., & Setyono, D. E. D. (2023). Evaluating the Accuracy of BMP280 and BME280 Sensors for Sea Level in a Coastal Environment: A Field Study at Tanjung Siambang Pier. Ilmu Kelautan: Indonesian Journal of Marine Sciences, 28(2), 189–202.

Laeli, S., & Mustava, O. (2023). Alternatif praktikum penentuan percepatan gravitasi menggunakan aplikasi phyphox di masa pasca pandemi. Buletin Edukasi Indonesia, 2(02), 61-68.

Lăpădat, A. M., Tiberius, C. C. J. M., & Teunissen, P. J. G. (2021). Experimental evaluation of smartphone accelerometer and low-cost dual frequency gnss sensors for deformation monitoring. Sensors, 21(23).

Niu, D., Guo, L., Zhao, W., & Li, H. (2022). Operation performance evaluation of elevators based on condition monitoring and combination weighting method. Measurement, 194, 111091. Peters, R. (2010). Physics Education using a Smartphone Accelerometer.

Raharja, E. P., Tamsih, I. J. T. R., Triono, M., Sutomo, E., Matonda, K. S., & Supriyatna, S. (2025). Enhancing physics experiment skills using smartphone sensors for teachers in sorong regency. Journal of Community Service and Empowerment, 6(1), 124–132.

Rakestraw, D., Higgins, D., Harris, D., Allen, M., Red, E., Lang, D., Gamez, M., & Strubbe, D. A. (2023). Exploring Newton’s Second Law and Kinetic Friction Using the Accelerometer Sensor in Smartphones. The Physics Teacher, 61(6), 473–476.

Raza, A., Al Nasar, M. R., Hanandeh, E. S., Zitar, R. A., Nasereddin, A. Y., & Abualigah, L. (2023). A Novel Methodology for Human Kinematics Motion Detection Based on Smartphones Sensor Data Using Artificial Intelligence. Technologies, 11(2), 1–17.

Rakestraw D, Higgins D, Harris D, Allen M, Red E, Lang D, et al. Exploring Newton’s Second Law and Kinetic Friction Using the Accelerometer Sensor in Smartphones. The Physics Teacher. 2023;61(6):473–6.

Vandegrift, E. (2020). Smartphone physics on the rise. Physics.

Vincent, A. C., Furman, H., Slepian, R. C., Ammann, K. R., Maria, C. Di, Chien, J. H., Siu, K. C., & Slepian, M. J. (2022). Smart Phone-Based Motion Capture and Analysis: Importance of Operating Envelope Definition and Application to Clinical Use. Applied Sciences (Switzerland), 12(12), 6–10.

Wahyuningtyas, D., & Okimustava, O. (2023). Media Pembelajaran Berbasis Android Guna Penunjang Belajar Siswa Di Era Society 5.0. In Seminar Nasional Riset dan Inovasi Teknologi (SEMNAS RISTEK) (Vol. 7, No. 1)

Wang, Q., Chen, L., Xiao, G., Wang, P., Gu, Y., & Lu, J. (2024). Elevator fault diagnosis based on digital twin and PINNs-e-RGCN. Scientific Reports, 14(1), 1–24.

Zhou, L., Guo, J., Wen, X., Ma, J., Yang, F., Wang, C., & Zhang, D. (2020). Monitoring and analysis of dynamic characteristics of super high-rise buildings using GB-RAR: A case study of the WGC under construction, China. Applied Sciences (Switzerland), 10(3).