JoTaLP: Journal of Teaching and Learning Physics 11, 1 (2026): 42-53
Website: http://journal.uinsgd.ac.id/index.php/jtlp/index
ISSN 2580-3107 **(online) ISSN** 2528-5505 **(print)**

[Research Article]

DEVELOPMENT OF LITA (LIQUID TILT ACCELEROMETER): AN ALTERNATIVE INSTRUMENT FOR ACCELERATION MEASUREMENT IN LINEAR MOTION EXPERIMENTS

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DOI: http://dx.doi.org/10.15575/jotalp.v11i1.54154
Received: 7 January 2026 Accepted: 10 February 2025 Published: 28 February 2026

ABSTRACT

This study aims to design an alternative instrument for measuring acceleration in linear motion dynamics experiments, named LiTA (Liquid Tilt Accelerometer). The research employed a Research and Development (R&D) method using the ADPT (Analysis, Design, Prototyping, and Testing) approach. The needs analysis stage was conducted using a questionnaire, and the data were analyzed with VOSviewer. The results of the needs analysis revealed that the required experimental instrument should be easily obtainable at an affordable cost, simple in both operation and maintenance, and Integrated technology with digital support is already available. The design of LiTA utilizes the movement of water in a vessel mounted on a dynamics cart. The object's acceleration is determined based on the inclination of the water surface inside the vessel. The prototyping of LiTA used transparent acrylic with black striped transparent stickers attached as a reference to help measure the air slope in the vessel. The testing process was carried out by conducting experiments to measure the acceleration of an object, and the results were compared with the theoretical acceleration values. The experimental data were analyzed using a paired sample t-test and the Bland–Altman plot method. The results of the paired sample t-test showed a p-value greater than 0.05, specifically 0.079, at a 95% confidence level. This indicates that there is no significant difference between the calculated acceleration and the experimental acceleration, when the pulley's moment of inertia is included in the acceleration calculation. All data points fall within the limits of agreement when analyzed using the Bland–Altman plot. The LiTA acceleration measurement instrument can serve as an alternative apparatus for experiments on linear motion dynamics. It provides a feasible solution for measuring acceleration in situations where conventional experimental equipment is limited or unavailable.

Keywords: Liquid Tilt Accelerometer, Linear Motion Dynamics, Acceleration Measurement.

How to cite: Syamsiah, E. N., Taufani, M. R., Aminudin, A. H., Firdaus, H. P., and Putra, A. (2026). Development of LiTA (Liquid Tilt Accelerometer): An Alternative Instrument for Acceleration Measurement in Linear Motion Experiments, *Journal of Teaching and Learning Physics* ***11*** (1), 42-53. DOI: http://dx.doi.org/10.15575/jotalp.v11i1.54154

1. INTRODUCTION

Laboratory activities in physics learning can facilitate students in developing a deeper understanding through direct experiences in observing, measuring, and analyzing physical phenomena. Practicals also help students visualize abstract concepts and build more meaningful understanding, making physics learning more effective and relevant. Consequently, such activities can reduce the potential for the formation of misconceptions (Firmansyah & Suhandi, 2021; Mohana et al., 2023; Putri et al., 2022; Shana & Abulibdeh, 2020; Syamsiah et al., 2024; Wola et al., 2023; Malik et al., 2021; Fathinah et al., 2025; Setya et al., 2021; Masrifah et al,. 2024). In addition, a survey conducted with 42 secondary school physics teachers regarding practical activities related to this concept revealed that the main obstacles in implementing laboratory activities are the limited availability of experimental equipment in schools, restricted instructional time, and difficulties in operating the available instruments. These limitations result in the teaching of Newton's Laws becoming less interactive, focusing primarily on theoretical explanations and mathematical calculations without sufficient conceptual reinforcement through experimental activities.

Considering the importance of laboratory activities in physics learning and the existing challenges, there is a need for an innovation that can facilitate the implementation of experiments on Newton's Laws. The innovation proposed in this study is the initial design of a simple, easy touse, and easily analyzed experimental apparatus. Furthermore, the developed instrument should be applicable not only in laboratory settings but also in classrooms or even at students' homes. Thus, physics learning particularly on the concept of Newton's Laws can become more interactive, engaging, and accessible to all learners.

In linear motion dynamics, acceleration is one of the key quantities that characterizes the motion of an object (Taufiq & Kaniawati, 2023; Tawil & Said, 2022). Measuring acceleration through the inclination of water in a moving vessel is a highly feasible method to be applied in physics learning. This method is simple and intuitive, utilizing the change in the water surface angle caused by the acceleration of the object (Pendrill & Fägerlind, 2015; L'Hote, L. E., 1975). By using a calibrated angular scale, students can calculate the magnitude of an object's acceleration. This method has certain limitations in terms of implementation, particularly in the availability of technology to record the inclination angle of the water. However, with the rapid advancement of smartphone camera technology, this limitation can be overcome. As most teachers and students now possess adequately equipped smartphones, this method can be effectively applied through a practical instrument implemented in physics learning.

Therefore, the aim of this study is to develop an initial design of an alternative acceleration measuring instrument, the Liquid Tilt Accelerometer (LiTA), as an alternative tool for measuring acceleration in linear motion dynamics experiments.

2. METHOD

This study employed a Research and Development (R&D) approach using a development framework adapted from prototyping-based instructional design principles, formulated as the ADPT model (Analysis, Design, Prototyping, and Testing). The model represents a synthesis of the ADDIE and Rapid Prototyping approaches, with a focus on the preliminary development of an acceleration measurement instrument (Syamsiah et al., 2024; Wu et al., 2021; Masrifah et al., 2024).

2.1. Analysis

The Analysis stage was conducted to identify the needs through a literature review and the distribution of questionnaires randomly to secondary school physics teachers. A total of 42 respondents participated, with an average teaching experience of approximately nine years. The questionnaire consisted of three demographic questions and six core questions. The six core questions asked to the respondents were as follows:

a. How is the concept of linear motion dynamics usually taught at your school?

b. What are the main obstacles in conducting experiments related to linear motion dynamics?
c. Are the experimental instruments for linear motion dynamics at your school still functioning properly?
d. In which aspects do the experimental instruments for linear motion dynamics at your school need improvement?
e. In your opinion, what kind of experimental instrument would be ideal for teaching linear motion dynamics?
f. What practical challenges might arise in implementing a digital technology–integrated experimental instrument for linear motion dynamics at your school?

2.2. Design

The Design stage involved the initial planning process, which included deriving the relevant equations, creating the physical design sketches of the instrument, developing the system workflow through a flowchart, writing the technical specifications, and preparing the user manual for the experimental apparatus.

2.3. Prototyping

During the Prototyping stage, an initial prototype of the LiTA acceleration measurement instrument was constructed according to the established design. This process encompassed the selection of suitable materials and the assembly of the experimental device.

2.4. Testing

The Testing stage was conducted to evaluate the functionality of the instrument in measuring the acceleration of an object. The acceleration data obtained from the LiTA instrument were compared with the theoretical acceleration data. The accuracy of the experimental instrument was evaluated through a comprehensive statistical analysis consisting of: (1) a paired sample t-test to examine the significance of differences between the two acceleration datasets, (2) a Bland–Altman plot to analyze measurement agreement and bias, and (3) calculation of the percentage error (Alari et al., 2021; Mansournia et al., 2021; Afifah et al., 2022; Rahayu et al., 2024).

H_0: There is no significant difference between the acceleration values obtained from the experimental instrument and the theoretical calculation results.
H_1: There is a significant difference between the acceleration values obtained from the experimental instrument and the theoretical calculation results.
The overall research methods are presented in Figure 1.

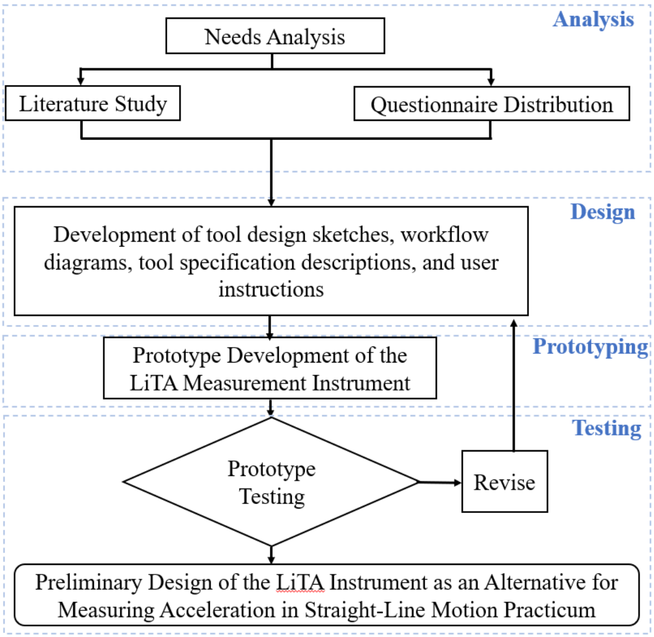


Figure 1. Flowchart of the LiTA Research Process

3. RESULT AND DISCUSSION

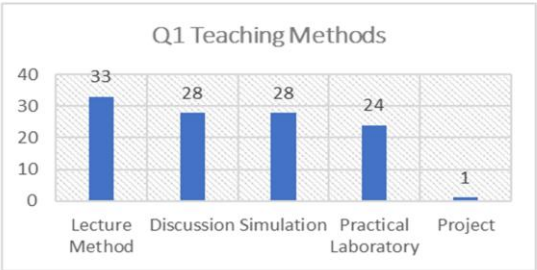
The results of this study are presented according to the stages of the research methodology implemented.

3.1 Analysis

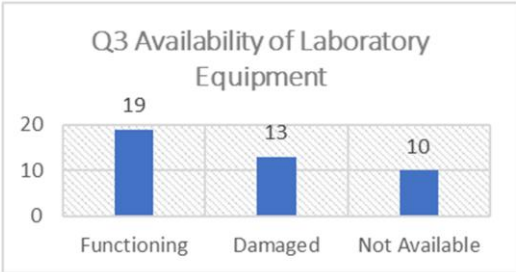
The first step in analyzing the respondents' answers to the distributed questionnaire was to assign codes to each response. The analysis was divided into two sections: (1) analysis of the answers to questions 1, 2, and 3, and (2) analysis of the answers to questions 4, 5, and 6.

Table 1. Response codes for questions 1, 2, and 3.

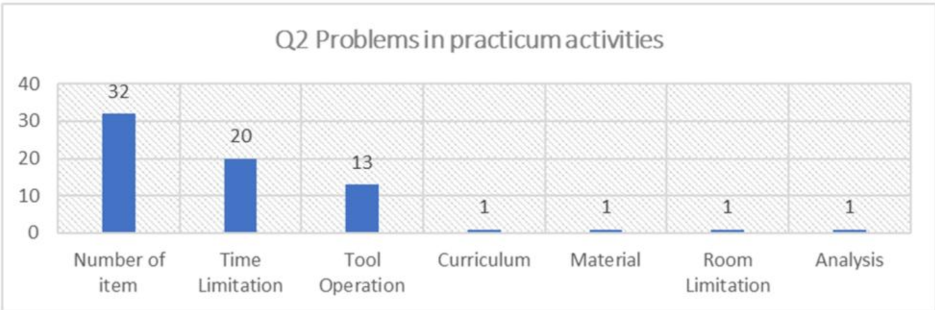
Question 1		Question 2		Question 3	
Response Codes	**Number**	**Response Codes**	**Number**	**Response Codes**	**Number**
Lecture Method	33	Number of item	32	Functioning	19
Discussion	28	Time Limitation	20	Damaged	13
Simulation	28	Tool Operation	13	Not Available	10
Practical Laboratory	24	Curriculum	1		
Project	1	Material	1		
		Room Limitation	1		
		Analysis	1		
		Number of item	32		



(a)



(b)



(c)

Figure 2. (a) question 1 answer diagram, (b) question 3 answer diagram, (c) question 2 answer diagram

The results of the survey for question number 1 indicate that the most commonly used teaching method is the lecture method, while laboratory experiments rank third after classroom discussions. The main challenges faced by physics teachers in conducting experiments are the limited number of available apparatus and the restricted instructional time. For question number 3, which concerns the condition of the experimental equipment, 19 respondents reported that their schools still have functioning experimental tools for linear motion dynamics. However, when combining the number of respondents who stated that the equipment is not functioning with those who reported having no equipment at all, the total amounts to 23 respondents. Thus, it can be concluded that 55% of the schools represented by the 42 respondents do not have functional equipment for conducting linear motion dynamics experiments. When examining the relationship among questions 1, 2, and 3 using VOS Viewer, as illustrated in Figure 3, and focusing on respondents who selected "functioning" (indicating that the equipment is still operational), several issues were identified: (1) difficulties in analyzing experimental data; (2) challenges in operating the equipment; (3) limited instructional time; and (4) insufficient quantity of available apparatus to adequately support experimental activities.

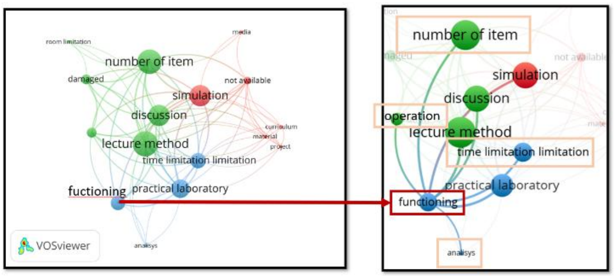


Figure 3. VOS Viewer Analysis Results for Respondents' Answers to Questions 1, 2, and 3

Table 2. Responses code for questions 4, 5, and 6.

Question 4		Question 5		Question 6	
Response Codes	**Number**	**Response Codes**	**Number**	**Response Codes**	**Number**
Equipment procurement	26	Simple to Operate	9	Digital support limitations	12
Quality and Performance	9	Comprehensible	2	Budget	5
Simplicity/Usability	6	Interactive	1	Equipment maintenance	5
Digitalization	6	Educational relevance	12	Human resource capacity	10
Maintainance	5	Experiment kits and tools	6	Tool availability	10
Tools Safety	1	Measuring physical quantities	2	Usage	4
Tools durability	1	Contextual	5	Infrastructure limitation	4
Management	1	Sensor	1	Gadget Distraction	1
Technology	2	Digital Integration	5	Time availability	1
		Computer simulation	1	Accurate data	1
		Automation	1	Concrete	1
		Minimal Friction	1	No Ccallenge	1
		Durable	1	Time efficiency	1
		Efficient	1		
		Prescision	4		
		Safety	3		
		Affordable	1		
		Usable Anywhere	1		

Questions 4, 5, and 6 were designed to explore physics teachers' perceptions regarding the desired improvements to laboratory apparatus and the challenges of digital integration. The majority of respondents expressed the need for experimental tools that can comprehensively explain physical concepts, are easy to use, and are technologically integrated. However, in terms of digital integration, most respondents indicated that digital support limitations remain a major challenge when implementing technology-integrated laboratory instruments. This finding is further supported by the VOS Viewer analysis results presented in Figure 4, which, when focused on the digital integration aspect, highlight digital support limitations as the predominant issue.

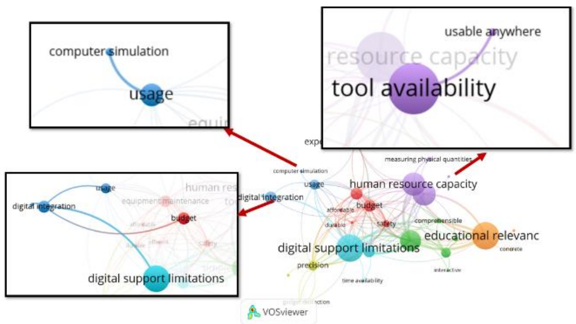


Figure 4. VOS Viewer Analysis Results for Respondents' Answers to Questions 5 and 6

Considering all respondents' answers to the distributed questionnaire, it can be concluded that the laboratory apparatus needed in schools should be affordable and easy to procure, simple to operate and maintain, and integrated with technology that has readily available digital support.

3.2 Design

Based on the results of the needs analysis, the developed experimental apparatus is an acceleration measurement instrument that utilizes the inclination of water as the basis for determining an object's acceleration.

3.2.1. Determining the Inclination Angle of the Free Water Surface Due to the System's Relative Motion

The first approach to determine the equation for the water surface inclination is conducted through an analysis based on Newtonian dynamics. A water vessel (aquarium) that is initially at rest relative to the ground is then accelerated along the *x-axis* with an acceleration a a relative to the ground. When the system is observed from within the vessel, an arbitrary infinitesimal element of water dm on the free surface experiences a fictitious force with magnitude a directed along the negative *x-axis*, as illustrated in the figure below. Consequently, from the perspective of an observer inside the vessel, the system reaches equilibrium with a resultant acceleration a_{res} of magnitude:

$$a_{res} = \sqrt{a^2 + g^2}. \qquad (1)$$

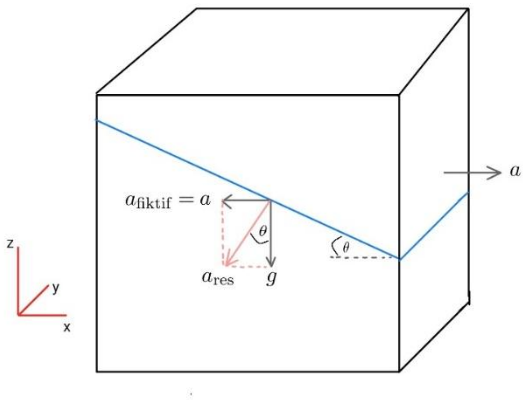


Figure 5. Acceleration diagram

When the resultant acceleration a_{res} occurs, an inclination angle θ is formed along the free surface of the water relative to the horizontal plane. The magnitude of this angle satisfies the relationship derived from the vector composition of vessel's accelerations.

$$a = a_{res} \sin\theta \qquad (2)$$

And local gravitational acceleration

$$g = a_{res} \cos\theta\,. \qquad (3)$$

By taking the ratio of the two previously described vector components, the following relationship can be obtained:

$$\tan\theta = \frac{a}{g}. \qquad (4)$$

The second approach involves using the Euler equation for a non-inertial fluid. The fundamental dynamic equation of the system in fluid mechanics is expressed by the following Euler equation

$$\rho \frac{d\vec{v}}{dt} = \vec{f} - \vec{\nabla} p, \qquad (5)$$

With $\rho, \frac{d\vec{v}}{dt}, f, and\ \vec{\nabla} p$ each term represents the fluid density, the acceleration of the system, the force density vector per unit volume, and the gradient of the absolute pressure in a three-dimensional fluid system. For the case of fluid inside an accelerated vessel, the equation of motion needs to be considered in a non-inertial reference frame, from the perspective of an observer moving with the vessel. In general, Newton's law in a non-inertial frame can be expressed as follows

$$\sum \vec{F}' = \sum \vec{F} + \sum \vec{F}_{fiktif}, \qquad (6)$$

With $\vec{F}', \vec{F}$, and $\vec{F}_{fiktif}$ This includes the forces in the non-inertial frame, the physical forces observed by an inertial observer, and the fictitious forces. Considering that the non-inertial system is caused solely by translational motion, the fictitious force $\vec{F}_{fiktif}$ experienced by a mass m in the system must have the following form

$$\vec{F}_{fiktif} = -ma\hat{\imath}. \qquad (7)$$

By using the density relationship $m = \rho V$, herefore, the Euler equation (5) in a non-inertial reference frame can be expressed as follows

$$\rho \frac{d\overrightarrow{v'}}{dt} = \vec{f} - \vec{\nabla} p - \rho a \hat{\imath}'. \qquad (8)$$

Since the system is influenced only by external forces in the form of gravity, the vector $\vec{f}$ can be expressed as

$$\vec{f} = -\rho g \hat{k}' = -\vec{\nabla}(\rho g z). \qquad (9)$$

As for the pressure gradient $p = p(x', y', z')$ have an expression

$$\vec{\nabla}p = \left(\frac{\partial p}{\partial x'}\right)\hat{\imath}' + \left(\frac{\partial p}{\partial y'}\right)\hat{\jmath}' + \left(\frac{\partial p}{\partial z'}\right)\hat{k}'. \quad (10)$$

The complete form of the Euler equation for the fluid system in a non-inertial reference frame is

$$\rho\frac{d\vec{v'}}{dt} = -\vec{\nabla}\big(\rho g z + p(x',y',z')\big) - \rho a\hat{\imath}'. \quad (11)$$

Now, let us consider the observations made by an observer moving with the vessel. This observer will examine the fluid system in equilibrium, or in other words $\frac{d\vec{v'}}{dt} = 0$ in other words, equation (11) can be expresses in the following form

$$\vec{\nabla}p = -\rho a\hat{\imath}' - \rho g\hat{k}'. \quad (12)$$

By considering the non-zero component terms in equation (12), the horizontal pressure gradient equation can be obtained

$$\frac{\partial p}{\partial x'} = -\rho a, \quad (13)$$

Similarly, the vertical pressure gradient can be expressed as

$$\frac{\partial p}{\partial z'} = -\rho g. \quad (14)$$

It can be observed that the absolute pressure of the fluid does not vary along the *y-axis*, since the following condition applies $\frac{\partial p}{\partial y'} = 0$. The geometric relationship between equations (13) and (14) is ilustrated the foloowing figure

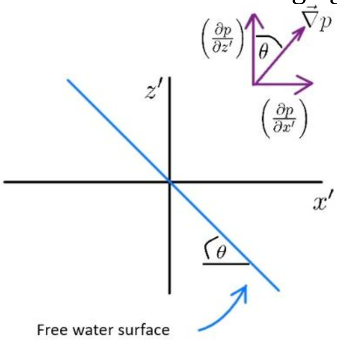


Figure 6. The geometric relationship between equations (13) and (14)

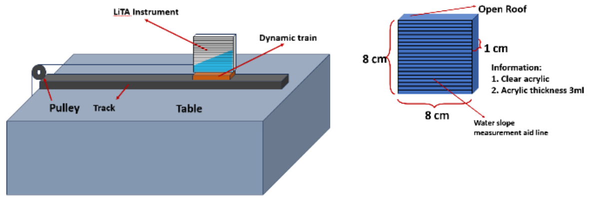
Using the illustration above, the expression for the inclination angle of the free water surface with respect to the-*x'y'* plane can be derived as follows

$$\tan\theta = \frac{\left(\frac{\partial p}{\partial x'}\right)}{\left(\frac{\partial p}{\partial z'}\right)} = \frac{a}{g}. \quad (15)$$

It can be seen that Equation (15) has the same form as Equation (4).
(Nakayama, 2018)

3.2.2. Design of the LiTA (Liquid Tilt Accelerometer) Instrument

The design of the LiTA acceleration measurement instrument can be seen in the following figure 6.



(a) (b)

Figure 7. Physical design of the LiTA instrument

The container used has an internal dimension of 8 cm × 8 cm × 1 cm and is made of transparent acrylic with a thickness of 3 mm. The container is equipped with a transparent striped sticker to facilitate the measurement of the water surface inclination. Initially, a clear protractor sticker was used; however, the protractor lines were difficult to see, and the center point of the protractor did not always align with the water surface.

The LiTA measurement instrument can be attached to the dynamics cart using double-sided adhesive to ensure it remains securely fixed during the experiment. The container is filled with colored water to make the inclination easier to observe. Additionally, it is recommended to place a barrier at the end of the track to prevent the dynamics cart from falling to the floor.

3.3 Prototyping

The prototyping process began with the selection of tools and materials. The following tools and materials were used to create the LiTA acceleration measurement instrument:

Table 3. Tools and Materials for Making LiTA

No	Name	Utility
1	Acrylic	The main material for making vessels
2	Acrylic Glue	Acrylic adhesive
3	Glass glue	Prevent leaks at each acrylic joint
4	Transparent striped stickers	Helps with water slope measurement lines
5	Food coloring	Make water more visible on camera
6	Double-sided adhesive	To attach the LiTA acceleration measurement instrument to the dynamics train

	Supporting Tools/Materials	
1	Dynamic Train	Moving objects
2	Track + Pulley	Movement director
3	Thread	Dynamic train connection with load
4	Barrier	To prevent the dynamics train and LiTA from falling
5	Load	As a weight

Figure 8. Prototype of the LiTA instrument

The material used to construct the LiTA measurement instrument was transparent acrylic with a thickness of 3 mm. The cutting process should be carried out by an expert or at an acrylic cutting service center to ensure that the vessel is not prone to leakage and can be easily assembled. To address any potential leakage, glass adhesive can be used to seal small gaps that are difficult to cover with acrylic glue.

During assembly, it is important to ensure that the acrylic glue does not drip onto the observation surfaces, as it may leave white streaks that interfere with visibility and cause the water surface to become uneven.

The minimum recommended internal dimensions of the vessel are 8 cm in length and width, as this size allows easier observation of the water’s tilt. The recommended internal thickness is 1 cm; if it is less than 1 cm, the water surface may not remain level. The top cover of the LiTA should be left open to ensure uniform air pressure acting on the water at all points

3.4 Testing.

The instrument testing was conducted to determine how accurately the LiTA instrument could measure an object's acceleration compared to the theoretical calculation results. The following table presents the experimental data obtained:

Table 4. Tools and Materials for Making LiTA

No	m_1 (kg)	m_2 (kg)	a_{Theo1} With I (m/s^2)	a_{Theo2} Without I (m/s^2)	Experiment		Eror	
					θ (°)	a_{Exp} (m/s^2)	With I (%)	Without I (%)
	0,1597	0,1209	4,17926	4,222452	23	4,159853199	0,5%	1,5%
	0,1597	0,1108	3,97162	4,014196	22	3,959457013	0,3%	1,4%
	0,1597	0,1008	3,75034	3,792092	21	3,761867543	-0,3%	0,8%
	0,1597	0,0805	3,24517	3,284346	18	3,184213023	1,9%	3,0%
	0,1597	0,09	3,49169	3,532239	19	3,37441061	3,4%	4,5%
	0,1597	0,0705	2,96396	3,001303	17	2,996160678	-1,1%	0,2%
	0,1597	0,1308	4,36892	4,412530	24	4,363241116	0,1%	1,1%
	0,1597	0,124	4,24006	4,283398	23	4,159853199	1,9%	2,9%
	0,1597	0,1408	4,54792	4,591814	25	4,56981505	-0,5%	0,5%
	0,1597	0,1602	4,86357	4,907659	26	4,779779368	1,7%	2,6%
	0,1597	0,0776	3,16603	3,204720	18	3,184213023	-0,6%	0,6%
	0,1597	0,1708	5,02052	5,064569	27	4,993349405	0,5%	1,4%

The experimental data were analyzed using the Shapiro–Wilk normality test and an accuracy test employing the paired sample t-test. Both analyses were conducted twice: (1) to compare the experimental acceleration data with the theoretical acceleration atheoretical1 that accounts for pulley inertia, and (2) to compare the experimental acceleration data with the theoretical acceleration atheoretical2 that neglects pulley inertia.

3.4.1. The normality test and paired sample t-test for theoretical acceleration data (with pulley inertia) ($a_{theoretical1}$) with the experimental acceleration ($a_{experimental}$) data.

The following are the results of the data normality test obtained:

Table 5. Normality test of theoretical acceleration data with pulley inertia and experimental acceleration

	Shapiro-Wilk		
	Statistic	**df**	**Sig.**
a_theo1	0,962	12	0,814
a_exp	0,048	12	0,614

Based on the results of the normality test for both datasets in table 5, it was found that the significance value (sig) was greater than 0.05, indicating that both datasets were normally distributed.

Table 6. Paired sample t-test of theoretical acceleration data with pulley inertia and experimental acceleration

Mean	Std. Deviation	df	Sig. (2-tailed)
0,02690 25	0,0481581	11	0,079

The paired sample t-test revealed that the difference between the theoretical acceleration, which included the pulley's inertia, and the experimental acceleration was not statistically significant ($p = 0.079 > 0.05$). The mean difference of 0.0227 m/s^2 indicates that the LiTA instrument effectively captures acceleration values consistent with theoretical expectations when pulley inertia is included in the analysis.

3.4.2. The normality test and paired sample t-test for theoretical acceleration data (without pulley inertia) ($a_{theoretical2}$) with the experimental acceleration ($a_{experimental}$) data.

The following are the results of the data normality test obtained:

Table 7. Normality test of theoretical acceleration data with pulley inertia and experimental acceleration

	Shapiro-Wilk		
	Statistic	**df**	**Sig.**
a_theo2	0,962	12	0,814
a_exp	0,048	12	0,614

The obtained significance levels for both datasets exceeded 0.05, confirming that the data were normally distributed.

Table 8. Paired sample t-test of theoretical acceleration data without pulley inertia and experimental acceleration

Mean	Std. Deviation	df	Sig. (2-tailed)
0,06875 87	0,0486927	11	0,000

The paired sample t-test conducted on the acceleration data that ignored the pulley's inertia and the experimental acceleration data yielded a result smaller than 0.05, indicating a statistically significant difference between the two datasets.

3.4.3. Balnd Altmant Plot for theoretical acceleration data (with pulley inertia) ($a_{theoretical1}$) with the experimental acceleration ($a_{experimental}$) data

The findings from Tests 1 and 2 indicate that the LiTA acceleration measurement instrument performs with acceptable accuracy when the pulley's inertia is taken into account in the reference calculation. A subsequent Bland–Altman analysis comparing the theoretical and experimental acceleration data revealed limits of agreement ranging from –0.0675 to 0.1213 m/s^2, with a standard deviation of 0.04816. These results show that 95% of the measurement differences fall within this range, implying that there is no systematic bias between the theoretical acceleration values and those detected by the LiTA instrument.

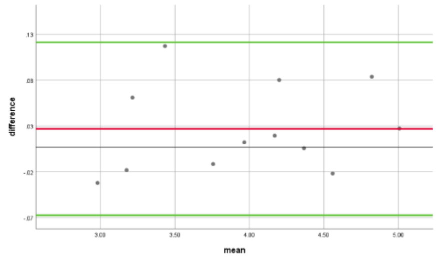


Figure 9. Bland Altmat Plot Diagram for difference and mean theoretical acceleration data with pulley inertia and experimental acceleration

This instrument has a limitation in the variation of mass ratios that can be used during the experiment. This limitation arises because the protractor used in the measurement instrument has the smallest scale of 1 degree. Therefore, a protractor capable of measuring angles with an accuracy of 0.5° or 0.1° is required. This improvement would allow for a greater variety of mass combinations to be used during the experimental process.

Future research could focus on developing a digital protractor application capable of measuring angles with the smallest scale of 0.5° or 0.1°. Such an application is expected to enhance the accuracy of angle measurement in the LiTA instrument and expand the range of mass variations that can be utilized in practical experiments.

4. CONCLUSION

The LiTA acceleration measurement instrument can be used in practical activities on linear motion dynamics as an alternative acceleration measurement tool when there are limitations in the availability of laboratory equipment. This instrument has been proven to possess good accuracy and shows great potential for implementation in laboratory activities, both as an acceleration measuring device and as an interactive learning medium to deepen the understanding of linear motion dynamics concepts.

5. REFERENCES

1. Journal Article

Afifah, S., Mudzakir, A., & Nandiyanto, A. B. D. (2022). How to calculate paired sample t-test using SPSS software: From step-by-step processing for users to the practical examples in the analysis of the effect of application anti-fire bamboo teaching materials on student learning outcomes. Indonesian Journal of Teaching in Science, 2(1), 81-92.

AlArabi, K., Tairab, H., Wardat, Y., Belbase, S. and Alabidi, S., 2022. Enhancing the Learning of Newton's Second Law of Motion Using Computer Simulations. *Journal of Baltic Science Education*, *21*(6), pp.946-966.

Alari, K. M., Kim, S. B., & Wand, J. O. (2021). A tutorial of Bland Altman analysis in a Bayesian framework. Measurement in physical education and exercise science, 25(2), 137-148.

Baring, J.J.A. and Berame, J.S., 2022. Supporting conceptual comprehension of newton's laws of motion of grade 8 students through Kotobee interactive e-module. *Indonesian Journal on Learning and Advanced Education (IJOLAE)*, pp.209-232.

Budiarti, I.S. and Tanta, T., 2021. Analysis on students' scientific literacy of newton's law and motion system in living things. Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education), 9(1), pp.36-51.

Fathinah, N. H., Nurhalim, A. A. F., Aqquilla, R. A., Sari, I. M., Prakoso, A. S., & Zakwandi, R. (2025). Designing a Restitution Experiment Using Smartphone Sound Sensor. *JIPFRI (Jurnal Inovasi Pendidikan Fisika dan Riset Ilmiah)*, *9*(1), 38-45.

Firmansyah, J. and Suhandi, A., 2021, March. Critical thinking skills and science process skills in physics practicum. In *Journal of Physics: Conference Series* (Vol. 1806, No. 1, p. 012047). IOP Publishing.

Ha, S. and Kim, M., 2020. Challenges of designing and carrying out laboratory experiments about Newton's second law: The case of Korean gifted students. *Science & Education*, *29*(5), pp.1389-1416.

L'Hote, L. E. (1975). Large scale use of a liquid–surface accelerometer. The Physics Teacher, 13(2), 100-101.

Malik, A., Utami, N. F., Rizaldi, M. F., Sarah, S., Nursetia, S., Mauli, T., ... & Mulhayatiah, D. (2021, April). Development of an Atwood aircraft practicum tool based on automatic timers to explain Newton's second law. In *Journal of Physics: Conference Series* (Vol. 1869, No. 1, p. 012172). IOP Publishing.

Mansournia, M. A., Waters, R., Nazemipour, M., Bland, M., & Altman, D. G. (2021). Bland-Altman methods for comparing methods of measurement and response to criticisms. Global Epidemiology, 3, 100045.

Masrifah, M., Samsudin, A., Amiroh, D., and Costu, B. (2024) development of newton's law physics e-book on motion based on technological pedagogical content knowledge (TPACK), Journal of Teaching and Learning Physics 9(1), 1-12. DOI: http://dx.doi.org/10.15575/jotalp.v9i1.31637

Mohzana, M., Murcahyanto, H., Fahrurrozi, M. and Supriadi, Y.N., 2023. Optimization of management of laboratory facilities in the process of learning science at high school. *Jurnal Penelitian Pendidikan IPA*, *9*(10), pp.8226-8234.

Nugraha, A.M., 2019. Graphic User Interface (GUI) untuk materi dinamika gerak sistem katrol berbasis matlab. *Navigation Physics: Journal of Physics Education*, *1*(2), pp.51-58.

Pendrill, A.M. and Fägerlind, C.O., 2015. Liquid in accelerated motion. *Physics Education*, *50*(6), pp.648-650.

Putri, A., Lengkana, D. and Jalmo, T., 2022. Teacher's perceptions of electronic multi representation stem based worksheet to improve student's metacognitive ability. *Jurnal Pendidikan Sains Indonesia*, *10*(3), pp.606-622.

Radiyono, Y., Fauzi, A., Surantoro, S. and Wirdiyatusyifa, W., 2022. Pembuatan alat percobaan Hukum II Newton dengan sensor cahaya Photodioda. *Jurnal Materi dan Pembelajaran Fisika*, *12*(1), pp.1-5.

Rahayu, N. I., Muktiarni, M., & Hidayat, Y. (2024). An application of statistical testing: A guide to basic parametric statistics in educational research using SPSS. ASEAN Journal of Science and Engineering, 4(3), 569-582.

Setya, W., Agustina, R. D., Putra, R. P., Prihatini, S., Hidayatulloh, R., Isnaeni, P. S., & Malik, A. (2021, November). Implementation of higher order thinking laboratory (HOTLAB) on magnetic field with real blended virtual laboratory to improve students critical thinking skills. In *Journal of Physics: Conference Series* (Vol. 2098, No. 1, p. 012019). IOP Publishing.

Shana, Z. and Abulibdeh, E.S., 2020. Science practical work and its impact on high students' academic achievement. *JOTSE*, *10*(2), pp.199-215.

Sumarni, R.A., Juliardi, M., Widiyatun, F., Astuti, I.A.D., Okyranida, I.Y. and Bhakti, Y.B., 2021, March. MATLAB-based physics calculator: Alternative for learning media for work and energy concept. In *Journal of Physics: Conference Series* (Vol. 1806, No. 1, p. 012022). IOP Publishing.

Syamsiah, E.N., Taufani, M.R., Aminudin, A.H., Pamungkas, R.S., Fadilla, R.M. and Nabilah, F.N., 2024. Development of the Physics Practicum Apparatus based on Microcontroller: A Prototype Constructed from Misconceptions of Basic Kinematics Concepts. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, *10*(2), pp.367-380.

Taufiq, M. and Kaniawati, I., 2023. Mekanika Newtonian dan Signifikansi Filosofisnya. *Jurnal Filsafat Indonesia*, *6*(2), pp.246-257.

Tawil, M. and Said, M.A., 2022. Understanding the newton's motion concept through qualitative and quantitative teaching. *JPPPF (Jurnal Penelitian dan Pengembangan Pendidikan Fisika*, *8*(1).

Wola, B.R., Rungkat, J.A. and Harindah, G.M.D., 2023. Science process skills of prospective science teachers' in practicum activity at the laboratory. *Jurnal Inovasi Pendidikan IPA*, *9*(1), pp.50-61.

2 Book

Nakayama, Y., 2018. *Introduction to fluid mechanics*. Butterworth-Heinemann.