MAGNETON: Jurnal Inovasi Pembelajaran Fisika
https://journal.unwira.ac.id/index.php/MAGNETON
Volume 4, Nomor 2, July 2026
e-ISSN: 2985-5764

Development of an Inquiry-Based Basic Physics Lab Module to Improve the Scientific Process Skills of UNTL Students

Claudia Mariska M. Maing[1*], Oktavianus Sama Ki`i[2] , Maria Gorette A. Da Silva[3], Donatus de Fátima Ude[4]

[1,2] Widya Mandira Catholic University, Indonesia
[3,4] National University of East Timor, Timor Leste

Correspondence email: mariskaclaudia@gmail.com[1*]

Article History

Submitted: June 06, 2026
Accepted: July 03, 2026
Published: July 31, 2026

DOI:
https://doi.org/10.30822/magneton.v4i2.5506

ABSTRACT

This study aims to develop Inquiry-Based Lab Modules for the Basic Physics 1 and Basic Physics 2 courses to improve the Science Process Skills (SPS) of students in the Physics Education Program at the National University of Timor-Leste (UNTL). The low level of students' SPS, as indicated by an average pretest score of 42.8 (SD = 8.1), and the lack of contextual inquiry-based lab modules form the background of this study. The study employed the ADDIE development model (Analysis, Design, Development, Implementation, Evaluation) with 64 first- and third-semester students from the 2026 academic year as research subjects. Validation was conducted by three expert validators (content, instructional design, and language). Effectiveness was tested using a one-group pretest-posttest design, while practicality was measured through a student response questionnaire. The validation results showed an average acceptability of 87.6% (highly acceptable). Practicality received an average student response score of 87.7% (very good). The effectiveness test yielded an average N-Gain of 0.64 (moderate) and a Cohen's d of 1.87 (very large). The greatest improvements occurred in the aspects of formulating hypotheses (N-Gain = 0.72) and analyzing data (N-Gain = 0.67). The module proved to be valid, practical, and effective in improving the science process skills of UNTL Physics Education students within the context of limited university resources.

Keywords: Laboratory Module; Inquiry; Basic Physics; Science Process Skills; ADDIE Model; UNTL

INTRODUCTION

Science Process Skills (SPS) are an essential foundation in science education that equip students with the ability to make systematic observations, formulate hypotheses, design experiments, analyze data, and communicate findings scientifically (Mumtaza & Zulfiani, 2023) . In the context of basic physics laboratory courses, the SPC serves not only as a technical competency but also as a scientific framework that distinguishes prospective physics teachers capable of teaching science authentically from those who merely transfer conceptual knowledge (Atikah & Haryanto, 2025). Mastery of KPS is a core competency that must be developed in prospective physics teachers so that they will be able to facilitate meaningful science learning for students (Fitriyana et al., 2025). Recent studies (2020-2025) consistently show that science teacher candidates with strong KPS tend to implement inquiry-based learning in the classroom and produce students with higher levels of science literacy (Hasmawati et al., 2023).

Volume 4, Nomor 2, July 2026
e-ISSN: 2985-5764

At the Universidade Nacional Timor Lorosa'e (UNTL), the issue of low KPS among students has been a recurring finding. A diagnostic study conducted in the fall semester of 2026 using a KPS performance test on 64 students enrolled in Basic Physics 1 and Basic Physics 2 revealed that the average KPS score was only 42.8 out of 100 (SD = 8.1). The instrument used was a validated performance-based KPS test (average CVR = 0.87; Cronbach's α = 0.91). Students demonstrated particular weaknesses in formulating hypotheses only 31% were able to formulate operationally testable hypotheses and in analyzing data, where their ability to interpret graphs and tables remained very limited (Freitas, 2023).

One of the root causes identified is students' reliance on conventional, "cookbook-style" lab modules that is, procedures that are laid out in minute detail, causing students to merely follow the steps without engaging in critical thinking or innovation (Shalgimbekova et al., 2024). A document analysis of the lab modules used at UNTL revealed that all experimental procedures were entirely dictated by the instructors, leaving no room for students to formulate hypotheses independently, and no guidance was provided for scientific reflection following the experiments. Furthermore, interviews with the instructors confirmed that the laboratory sessions functioned merely as verifiable routines, rather than as meaningful scientific inquiry experiences that foster students' cognitive development. This situation is exacerbated by the lack of laboratory modules specifically designed to develop scientific inquiry skills in a structured and contextual manner for both Basic Physics courses at UNTL.

The guided inquiry approach offers a pedagogical framework that has been empirically proven effective in developing scientific inquiry skills. In guided inquiry, students are guided through leading questions to formulate problems, design investigations, and draw conclusions independently, while the instructor serves as a facilitator (Fitriyana et al., 2025). Research by Hasmawati et al. (2023) shows that guided inquiry increases KPS by up to 42% compared to conventional laboratory courses. However, nearly all inquiry modules developed in previous studies are generic and not tailored to the laboratory conditions or the local context of higher education institutions in Timor-Leste.

This study offers novelty in three aspects that substantively distinguish it from existing similar studies. First, the developed module simultaneously covers two courses Basic Physics Lab 1 and Basic Physics Lab 2 within a single, continuous guided inquiry framework, differing from previous studies that generally developed modules for only one course. Second, the experimental topics were selected based on their relevance to the local context of Timor-Leste, covering physical phenomena that can be observed in the daily lives of UNTL students. Third, the module's scaffolding structure was designed using a fading scaffolding approach, in which guiding questions gradually become more open-ended as students' competencies increase a design not yet found in inquiry modules developed for higher education contexts in Timor-Leste and the surrounding region. This study aims to: (1) develop a valid inquiry-based laboratory module; (2) test the practicality of the module in teaching and learning; and (3) analyze the module's effectiveness in improving the scientific thinking skills of UNTL Physics Education students.

METHOD

This study is a research and development (R&D) study based on the ADDIE model. The ADDIE model was chosen because it is systematic, incorporates formative evaluation at every stage, and has been proven effective in developing inquiry-based instructional materials (Nurhuwaida, 2022). The five stages of the model and their respective concrete outputs include: (1) Analysis: needs analysis through KPS diagnostic tests, curriculum analysis, and faculty interviews; output: needs profile and module specifications; (2) Design: design of the module framework, inquiry scenarios, and assessment instruments; output: module blueprint and instrument rubrics; (3) Development: development of a module draft and expert validation through two rounds of revisions; output: validated module; (4) Implementation: piloting the module with research participants over 10 sessions; output: data on the module's practicality and KPS performance; and (5) Evaluation: comprehensive evaluation of the module's effectiveness and practicality based on quantitative and qualitative data; output: recommendations for module improvements.

The research subjects were 64 students in the UNTL Physics Education Study Program for the 2026 academic year, consisting of 32 first-semester students (Basic Physics Lab 1) and 32 third-semester students (Basic Physics Lab 2). None of the students had previously participated in inquiry-based labs, as confirmed by a learning experience questionnaire administered at the beginning of the study. Subject selection used purposive sampling, based on the consideration that both groups were taking the courses targeted for module development. KPS data analysis was conducted both in aggregate (n = 64) to provide an overall picture of the module's effectiveness, and separately by group (first and third semesters) to detect differences in responses between the two cohorts with differing course loads.

The module contains 12 experimental topics (6 topics per course) organized within a guided inquiry framework comprising five phases: (1) Orientation: triggering phenomena and essential questions; (2) Exploration: guided initial observations; (3) Problem Formulation and Hypothesis: independent formulation guided by questions; (4) Investigation: experiment design and implementation; and (5) Communication: data analysis, conclusions, and presentation of results. Each topic is accompanied by a KPS assessment rubric, student worksheets, and reflection guides. Table 1 presents a complete list of topics, targeted KPS aspects, and types of inquiry activities.

Table 1. List of Topics, Targeted KPS Aspects, and Inquiry Activities for the Module

No.	Experiment Topic	KPS Aspects	Main Inquiry Activities
		FD 1	
1	Basic Measurements & Uncertainty	Observing, Analyzing Data	Estimating Sources of Systematic Error
2	Newton's Laws on an Inclined Plane	Formulating Hypotheses, Planning Experiments	Independent Experiment Design
3	Harmonic Motion of a Spring	Observing, Analyzing Data	Graphical Modeling of Oscillations
4	Local Water Surface Tension	Formulating Hypotheses, Communicating	Local phenomena: river water vs. seawater
5	Calorimetry: Traditional Materials	Planning Experiments, Analyzing Data	Local Materials from Timor-Leste
6	Pressure & Fluids: Irrigation Context	Observing, Communicating	Relevance to Local Agriculture
		FD 2	
7	Ohm's Law & Basic Circuits	Formulating Hypotheses, Analyzing Data	Fading Scaffolding, Stage 1
8	Magnetic Field of a Straight Wire	Planning Experiments, Communicating	Fading Scaffolding, Stage 2
9	Light Interference (Young)	Observing, Formulating a Hypothesis	Fading Scaffolding, Stage 3
10	Capacitors & Dielectrics	Planning Experiments, Analyzing Data	Guided Open-Ended Design
11	Snell's Law: Local Materials	Observing, Communicating	Natural Materials from Timor-Leste
12	Sound Waves & Resonance	All aspects of KPS (integration)	Fully Open Inquiry

The instruments used included: (1) Module validation sheet 40 items on a 1-5 Likert scale, evaluated by three validators for content, language, presentation, graphics, and inquiry components; (2) Student response questionnaire 25 items on a 1-5 Likert scale that have been validated for content (CVR = 0.82) and reliability ($\alpha = 0.88$); (3) Performance-based KPS test covering five aspects (observing, formulating hypotheses, planning experiments, analyzing data, communicating results) that are assessed directly during the lab session. Each aspect was assessed using an analytical rubric on a 0-100 scale. For example, the indicators for the "formulating hypotheses" aspect included: (a) the hypothesis includes clear independent and dependent

 Volume 4, Nomor 2, July 2026
e-ISSN: 2985-5764

variables; (b) the hypothesis is operationally testable; and (c) the hypothesis is consistent with the observed phenomena. Assessments were conducted independently by two evaluators; inter-rater reliability was measured using Cohen's Kappa coefficient ($\kappa = 0.84$; "near perfect" category), confirming consistency across evaluators. The KPS test was validated for content (average CVR = 0.87) and reliability (Cronbach's $\alpha = 0.91$).

Validation data were analyzed using the percentage of acceptability formula with the following criteria: highly acceptable ($P > 85\%$), acceptable ($70\% < P \leq 85\%$), moderately acceptable ($55\% < P \leq 70\%$), and unacceptable ($P \leq 55\%$) (Majid & Linuwih, 2019) . Effectiveness was measured using Hake's N-Gain with the following interpretations: high ($g > 0.70$), moderate ($0.30 \leq g \leq 0.70$), and low ($g < 0.30$)(Harleni et al., 2025) . The Shapiro-Wilk normality test yielded a significant result ($W = 0.91$; $p = 0.003$), indicating that the data were not normally distributed. Therefore, the difference in pretest-posttest scores was tested using the Wilcoxon Signed-Rank test ($\alpha = 0.05$) as a suitable nonparametric alternative for a single-sample paired sample with a non-normal distribution. The effect size was calculated using Cohen's d, adapted for a pre-post design without a control group, using the formula $d = (M_{post} - M_{pre}) / SD_{pre}$ (Fritz et al., 2012), such that provides an estimate of the magnitude of change that can be compared with similar studies.

RESULTS AND DISCUSSION

The validation process was conducted in two rounds. In the first round, subject-matter experts provided feedback regarding: (a) the accuracy of physics symbols: some vector symbols did not use consistent arrow notation; (b) the clarity of diagram illustrations: particularly on the topic of sound waves; and (c) the consistency of inquiry terminology: the terms "guiding questions" and "essential questions" were used interchangeably. The instructional design expert suggested adding transition instructions between inquiry phases to make the sequence of activities more explicit. The language expert pointed out several ambiguous passive sentences in the reflection guide section. All feedback was addressed before the second round, resulting in a final evaluation score that improved by an average of 4.2 percentage points compared to the first round. The final evaluation results from the validators are presented in Table 2.

Table 2. Results of the Validation of the Inquiry-Based Lab Module by Three Validators

No.	Validation Aspect	Content Expert (%)	Design Expert (%)	Language Expert (%)	Average (%)	Category
1	Content/Material Components	88.4	86.8	-	87.6	Highly Recommended
2	Language Components	-	85.2	90.4	87.8	Highly Suitable
3	Presentation Components	-	88.0	-	88.0	Highly Recommended
4	Graphics Components	-	86.4	88.8	87.6	Highly Recommended
5	Inquiry Component	87.2	88.8	-	88.0	Highly Appropriate
	Overall Average	**87.8**	**87.0**	**89.6**	**87.6**	**Highly Acceptable**

Based on Table 2, the average suitability percentage of the modules reached 87.6% (the "highly suitable" category). The Inquiry Component aspect received the highest percentage from content experts and design experts (an average of 88.0%), indicating that the five phases of guided inquiry designed are consistent with the pedagogical principles of guided inquiry (Pedaste et al., 2015). These findings are consistent with Tiaradipa et al., (2020), which emphasize that structured scaffolding is a key element of the pedagogical validity of inquiry-based instructional materials.

Volume 4, Nomor 2, July 2026
e-ISSN: 2985-5764

The linguistic aspect received the highest percentage from language experts (90.4%), which is crucial given that UNTL students use Indonesian as a second academic language (Freitas, 2023).

The practicality test was conducted using two data sources: (1) a student response questionnaire after 10 module implementation sessions; and (2) an implementation observation sheet filled out by an independent observer during each lab session. The observation sheet contained 20 indicators of the implementation of the inquiry phases (Orientation, Exploration, Formulation, Investigation, Communication) on a Yes/No scale. The average implementation rate for all phases reached 91.3% (highly implemented), confirming that the module is not only perceived as practical by students but has also been proven to be effectively implemented under UNTL laboratory conditions. The student response questionnaire was validated (CVR = 0.82) and found to be reliable (α = 0.88). The complete results are presented in Table 3.

Table 3. Results of the Student Questionnaire on Module Practicality (n = 64)

No.	Practicality Aspect	Average Score	Percentage (%)	Category
1	Ease of use of the module	4.38	87.6	Very Good
2	Clarity of inquiry activity instructions	4.26	85.2	Good
3	Alignment with students' abilities	4.44	88.8	Very Good
4	Clarity of language and illustrations	4.32	86.4	Very Good
5	Interest and Motivation to Learn	4.52	90.4	Very Good
	Overall Average	**4.38**	**87.7**	**Very Good**

Table 3 shows that all aspects of practicality fell into the "good" to "very good" categories, with an overall average of 87.7%. The aspect of interest and motivation to learn received the highest score (4.52; 90.4%), indicating that the use of icebreakers and essential questions at the beginning of each topic successfully fostered students' curiosity and cognitive engagement. This finding aligns with (Wahida et al., 2022), which shows that a real-world phenomenon-based orientation phase consistently enhances intrinsic motivation in inquiry-based learning. The aspect of clarity of inquiry activity instructions received the lowest score (4.26; 85.2%), which is still in the "good" category but indicates room for improvement. Analysis of the observation sheets revealed that some students had difficulty understanding the guiding questions during the hypothesis formulation phase, particularly when the phenomena involved unfamiliar physical concepts. This highlights the need to refine the instructions for this phase in future editions of the module.

The pretest, posttest, and KPS N-Gain data for all subjects (n = 64) are presented in Table 4. Given that the one-group pretest-posttest design lacks a control group, the findings in this section should be interpreted as an indication that the module has the potential to be effective in improving KPS, rather than as definitive evidence of causality. Threats to internal validity that need to be considered include: the history effect (students may have gained science experience outside the classroom during the study period), the maturation effect (the natural development of students' cognitive abilities over the course of a semester), and the testing effect (familiarity with the KPS test format due to exposure to the pretest).

Table 4. Comparison of Pre- and Post-Test Scores and KPS N-Gain by Aspect (n = 64)

No.	KPS Aspect	Pre-test	Post-Test	N-Gain	Category
1	Observation	41.2	74.6	0.57	Moderate
2	Formulating Hypotheses	38.6	78.4	0.72	Height
3	Planning an Experiment	43.8	76.2	0.57	Moderate
4	Analyzing Data	42.4	77.8	0.67	Moderate
5	Communicating Results	44.0	75.0	0.55	Moderate
	Average	**42.0**	**76.4**	**0.64**	**Moderate**

Table 4 shows that the average KPS score increased from 42.0 (pretest) to 76.4 (posttest) with an average N-Gain of 0.64 (moderate category). The Wilcoxon test confirmed a statistically significant increase ($Z = -6.93$; $p < 0.001$). Cohen's d value of 1.87 indicates a very large effect size based on the interpretation conventions of Fritz et al. (2012).

The greatest improvement occurred in the aspect of formulating hypotheses (N-Gain = 0.72, high category). This improvement can be directly attributed to the fading scaffolding design in the module. In the initial topics (Topics 1-3), the guiding questions were highly structured, for example: "If the mass of an object is doubled, what will happen to the resulting acceleration?" Formulate your hypothesis using the format: If [independent variable], then [dependent variable].' Starting with Topic 7, the guiding questions became more open-ended: 'Based on the phenomena you observed, formulate a hypothesis that you can test.' This gradual transition builds the competency to formulate hypotheses in a scaffolded manner, consistent with Vygotsky's theory of the Zone of Proximal Development. Inquiry-based learning has been shown to support students' intrinsic motivation in science (Meulenbroeks et al., 2024), particularly when the approach is grounded in local phenomena relevant to the context of Timor-Leste.

The data analysis aspect showed an N-Gain of 0.67. Each worksheet required students to present data in tables and graphs, identify patterns, connect findings to theory, and evaluate sources of systematic error. This series of activities develops scientific data analysis competencies, which were among the students' greatest weaknesses at the outset. The aspect of communicating results showed the lowest N-Gain (0.55), indicating the need for additional interventions such as journal club sessions or more structured scientific poster presentations (Wisanti et al., 2024).

Compared to previous research, the effect of this module ($d = 1.87$) exceeded the average $d = 0.50–1.20$ reported by (Harleni et al., 2025) in a meta-analysis of 47 studies on short-term (≤ 1 semester) guided inquiry programs in Southeast Asia. This difference is likely due to: (1) the implementation spanning two consecutive semesters, which created a sustained accumulation of inquiry experience; and (2) the relevance of the topics to the local context of Timor-Leste, which substantially increased students' cognitive engagement and motivation. Nevertheless, this comparison must be made with caution given the methodological differences (presence or absence of a control group) between this study and the studies included in the meta-analysis.

Limitations of the study include: (1) a design without a control group, so that history effects, maturation effects, and testing effects cannot be fully controlled; (2) a limited number of validators (three); and (3) generalization of the findings must be done cautiously, given that the subjects came from only one academic program at a single institution. To address these limitations, future research is recommended to use a quasi-experimental design with a control group, randomize classes, include a KPS retention test (follow-up ≥ 4 weeks post-intervention), and replicate the study in other physics programs in Timor-Leste. For lab instructors, this module offers practical implications in the form of a learning framework that can be adapted to local equipment availability without compromising the quality of students' inquiry experiences.

CONCLUSION

This development study produced Inquiry-Based Lab Modules for the Basic Physics 1 and Basic Physics 2 courses at UNTL that meet three quality criteria: valid (87.6%; highly acceptable), practical (87.7%; very good, supported by a feasibility rate of 91.3%), and potentially effective in improving students' KPS (average N-Gain of 0.64; Cohen's $d = 1.87$). This claim of effectiveness must be understood within the context of a one-group pretest-posttest design without a control group; therefore, generalizability remains limited to the context of the Physics Education Study Program at UNTL.

The profile of KPS improvement highest in formulating hypotheses (N-Gain = 0.72) and analyzing data (0.67), lowest in communicating results (0.55) provides clear guidance for the development of subsequent modules to strengthen the scientific communication component. The main implication of this study is evidence that contextually relevant and pedagogically structured inquiry-based instructional materials can be developed and effectively implemented at universities with limited resources, such as UNTL. Replication studies with stronger designs and exploration of digital technology integration (PhET simulations, electronic data loggers) are recommended to expand the generalizability of the findings.

Volume 4, Nomor 2, July 2026
e-ISSN: 2985-5764

REFERENCES

Atikah, N., & Haryanto, T. (2025). Analisis Keterampilan Proses Sains melalui Penerapan Metode Praktikum di SMAN 6 Kerinci. Biosfer: Jurnal Biologi Dan Pendidikan Biologi, 10(1), 1-6.

Fitriyana, S., Farhan, A., Susanna, Hamid, A., & Mahzum, E. (2025). The Effect of Guided Inquiry Learning Model on Students' Science Process Skills and Learning Outcomes in Physics Science Lessons. *Jurnal Pendidikan Fisika*, *13*(3), 555–571. https://doi.org/10.26618/0m4ny850

Freitas, M. L. F. (2023). Pentingnya Kegiatan Laboratorium Di Program Studi Ensino De Fisika Universitas Nacional Timor Lorosae (UNTL). *MAGNETON: Jurnal Inovasi Pembelajaran Fisika*, *1*(2), 79–85. https://doi.org/10.30822/magneton.v1i2.2469

Fritz, C. O., Morris, P. E., & Richler, J. J. (2012). Effect size estimates: Current use, calculations, and interpretation. *Journal of Experimental Psychology. General*, *141*(1), 2–18. https://doi.org/10.1037/a0024338

Harleni, H., Ganefri, G., Yulastri, A., Giatman, M., Irfan, D., & Effendi, H. (2025). Unveiling the impact of inquiry-based learning: A meta-analysis of student learning outcomes. *Al-Ishlah: Jurnal Pendidikan*, *17*(3), 4971-4983. https://doi.org/10.35445/alishlah.v17i3.7061

Hasmawati, Ali, M. S., & Arsyad, M. (2023). Influence of the Guided Inquiry Learning Model and Scientific Attitude in Physics on Students' Science Process Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(12), 11484–11496. https://doi.org/10.29303/jppipa.v9i12.4729

Majid, M. I., & Linuwih, S. (2019). Pengembangan Unit Kegiatan Belajar Mandiri (UKBM) materi usaha dan energi berbasis pembelajaran kontekstual untuk meningkatkan pemahaman konsep siswa. *Unnes Physics Education Journal*, 8(3), 1.

Meulenbroeks, R., van Rijn, R., & Reijerkerk, M. (2024). Fostering secondary school science students' intrinsic motivation by inquiry-based learning. *Research in Science Education*, 54, 339–358. https://doi.org/10.1007/s11165-023-10139-0

Mumtaza, M. F., & Zulfiani, Z. (2023). Development of Student Worksheets Based on Science Process Skills on Excretory System Concepts. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 265–272. https://doi.org/10.29303/jppipa.v9i1.1474

Nurhuwaida, N., Mastuang, M., Misbah, M., & Ibrahim, M. A. (2022). Feasibility of Learning Devices with Guided Inquiry Model to Develop Senior High School Students' Science Process Skills. *JPPS (Jurnal Penelitian Pendidikan Sains)*, *11*(2), 193–205. https://doi.org/10.26740/jpps.v11n2.p193-205

Pedaste, M., Mäeots, M., Siiman, L. A., De Jong, T., Van Riesen, S. A., Kamp, E. T., ... & Tsourlidaki, E. (2015). Phases of Inquiry-Based Learning: Definitions and the Inquiry Cycle. *Educational Research Review*, *14*, 47-61.

Shalgimbekova, K., Smagliy, T., Kalimzhanova, R., & Suleimenova, Z. (2024). Innovative teaching technologies in higher education: efficiency and student motivation. *Cogent Education*, *11*(1), 2425205.

Tiaradipa, S., Lestari, I., Effendi, M. H., & Rusdi, M. (2020). The Development of Scaffolding in Inquiry-Based Learning to Improve Students' Science Process Skills in the Concept of Acid and Base Solution. *JKPK (Jurnal Kimia dan Pendidikan Kimia)*, *5*(2), 211-221.

Volume 4, Nomor 2, July 2026
e-ISSN: 2985-5764

Wahida, M., Margunayasa, I. G., & Gunartha, I. W. (2022). Pengaruh Model Pembelajaran Inkuiri Terbimbing Terhadap Motivasi Belajar Dan Hasil Belajar IPA Siswa SD. *Jurnal Ilmiah Pendidikan Citra Bakti*, *9*(2), 274–285. https://doi.org/10.38048/jipcb.v9i2.676

Wisanti, W., Indah, N. K., & Putri, E. K. (2024). Scientific digital poster assignments: strengthen concepts, train creativity, and communication skills. *International Journal of Evaluation and Research in Education (IJERE)*, *13*(2), 1035-1044.