

THE EFFECT OF A SCIENTIFIC-BASED APPLIED PHYSICS TEXTBOOK ON STUDENTS' COGNITIVE LEARNING OUTCOMES

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Abstract :

Applied physics is often perceived as difficult by maritime cadets due to low motivation, limited conceptual readiness, and restricted access to non-print learning materials. This study investigates the effect of an Applied Physics textbook on the cognitive learning outcomes of Nautical Technology students at Politeknik Pelayaran Sumatera Barat. Using a quasi-experimental nonequivalent control group design, 24 second-semester cadets were divided into an experimental group using the science-based textbook and a control group using conventional materials. Both groups completed pretests and posttests, and the data were analyzed using the Mann–Whitney U test with $\alpha = 0.05$. The experimental group obtained a higher mean posttest score (82.50) than the control group (80.62), and the difference was statistically significant ($p < 0.05$). These results demonstrate that integrating scientific inquiry steps into printed instructional materials enhances students' conceptual understanding and supports more effective learning. The unique feature of the study is that using a research-based chemical-printed textbook addressing vocational maritime education had not previously been investigated. Implications: As reported by the results, the investigation contributed to maritime physics teaching materials that can be useful as science-based printed resources for enhancing and improving learning outcomes in an accessible way and with context-based specificity.

Keywords: Applied Physics, Scientific Approach, Cognitive Learning Outcomes

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INTRODUCTION

Since the beginning of human civilization, education has been regarded as the foremost instrument for sustaining and advancing human life. The importance of education cannot be denied, as it plays a central role in the intellectual, social, and moral development of individuals and societies. In recent decades, Indonesia has continuously increased its investment in education to ensure equitable access and improved quality across regions. This initiative reflects a national awareness that the country's progress is inseparable from its educational advancement (Kementerian Pendidikan,

Kebudayaan, Riset, dan Teknologi, 2023). Education is a lifelong process aimed at developing human potential to achieve maturity in the spiritual, intellectual, and social dimensions, as mandated by the *National Education System Law No. 20 of 2003* (Departemen Pendidikan Nasional, 2003).

Applied physics is a foundational component of maritime education, equipping cadets with the conceptual and analytical skills necessary to understand fluid dynamics, ship stability, navigation systems, and propulsion mechanisms essential for safe marine operations. In vocational maritime programs, applied physics integrates theoretical understanding with contextualized problem-solving and simulation-based learning to strengthen cadets' operational competencies (Agusti, 2023; Baihaqi, 2024; Sari et al., 2017). Despite its importance, physics continues to be perceived as a complex subject by many students, stemming from internal factors such as low learning motivation and external challenges including teacher-centered instruction, abstract explanations, and limited access to high-quality learning materials (Sumarni & Sudira, 2022; Taslidere, 2020; Tariq & Saeed, 2021). These barriers often hinder students' conceptual development and reduce engagement in physics learning, particularly in vocational contexts where practical relevance is essential.

Instructional materials play a pivotal role in facilitating learning and achieving targeted competencies. The Ministry of Education defines learning materials as a collection of systematically organized content designed to assist teachers and students in the learning process, available in both print and non-print formats (Depdiknas, 2008). That instructional materials help structure content delivery in a logical and progressive manner, supporting competency achievement (Chotimah et al., 2024; Wahyugi, 2025). Further classifies learning materials into two main types: printed materials, such as textbooks, modules, and worksheets, and non-printed media, including videos, audio resources, and digital presentations (Prastowo, 2013; Wahyuni et al., 2024; Assyuza et al., 2024).

In practice, instructors in higher education often rely on non-print materials, such as PowerPoint slides and digital modules. However, this reliance poses challenges, particularly for students with limited access to electronic devices or internet connectivity outside campus settings (Sukarjo et al., 2021). Preliminary observations at the *Politeknik Pelayaran Sumatera Barat* revealed that early-semester students face difficulties reviewing learning materials outside class hours due to restrictions on electronic device use on campus. Consequently, their comprehension of physics concepts remains low, resulting in suboptimal learning outcomes. Learning materials, in principle, should foster student independence, critical thinking, and curiosity-driven exploration (Musniar et al., 2025; Lestari et al., 2023).

The success of the learning process depends heavily on the alignment between teaching content and students' needs. Unfortunately, many instructors have yet to fulfill their obligation to develop printed teaching materials, as mandated by the *Higher Education Law No. 12 of 2012*. Textbooks and structured printed modules serve not only as instructional tools but also as an alternative communication medium between educators and learners (Arsyad, 2021; Ardianti et al., 2020). Although science-based learning modules have been proven effective in secondary education (Suprihatin et al., 2023; Supu et al., 2022; Azhari et al., 2025), limited research has examined the effect of printed, science-based applied physics textbooks in maritime higher education settings. Sukarjo et al. (2021) compared electronic and printed modules at the vocational high school (SMK) level, but no prior studies have evaluated the implementation of printed science-based textbooks under conditions of limited digital access. This gap highlights the need for innovative, context-sensitive printed materials designed for maritime cadets who require both theoretical understanding and practical applicability.

In summary, the foregoing discussion highlights a clear deficit in accessible, context-relevant instructional resources for maritime students. Addressing this deficit requires an innovative solution, specifically, the development of a science-based applied physics textbook tailored to the nautical context. Such a textbook can integrate structured content with maritime examples, thereby supporting self-guided learning and reinforcing students' understanding. By aligning with curriculum standards and embedding scientific inquiry into its design, this printed resource aims to overcome the limitations posed by reliance on digital materials. Evaluating its effectiveness thus becomes the logical next step in improving cadets' cognitive learning outcomes.

In response to these challenges, this study focuses on developing a printed, science-based applied physics textbook tailored explicitly for the Nautical Technology program. The development of structured, high-quality teaching materials is essential in vocational maritime education, as it supports

the integration of theoretical physics concepts with authentic maritime contexts, such as navigation systems, ship stability, and marine engineering operations (Baihaqi, 2024; Sari et al., 2017). Printed science-based materials also play a critical role in enhancing conceptual understanding, especially in environments where students have limited access to digital resources, a constraint commonly reported in vocational and maritime institutions (Chala et al., 2020; Rahayu et al., 2019). Furthermore, prior studies emphasize that scientific approach learning materials improve students' reasoning, engagement, and cognitive performance by guiding them through systematic observation, experimentation, and evidence-based analysis (Azizah et al., 2024; Hidayati et al., 2020). Therefore, the development of a science-based applied physics textbook is not only academically justified but also pedagogically necessary to strengthen students' mastery of physics concepts within the constraints of maritime vocational education.

Therefore, this research aims to examine the effect of a science-based applied physics textbook on students' cognitive learning outcomes in the Nautical Technology program at Politeknik Pelayaran Sumatera Barat. By developing and implementing a textbook tailored to the maritime context, this study seeks to enhance conceptual understanding, foster independent learning, and improve overall academic performance. Beyond its immediate instructional purpose, the research contributes to the broader discourse on contextualized STEM education and supports Indonesia's ongoing efforts to modernize vocational maritime education in alignment with international standards (International Maritime Organization [IMO], 2014; Fahrudin, 2022).

RESEARCH METHOD

Research Design

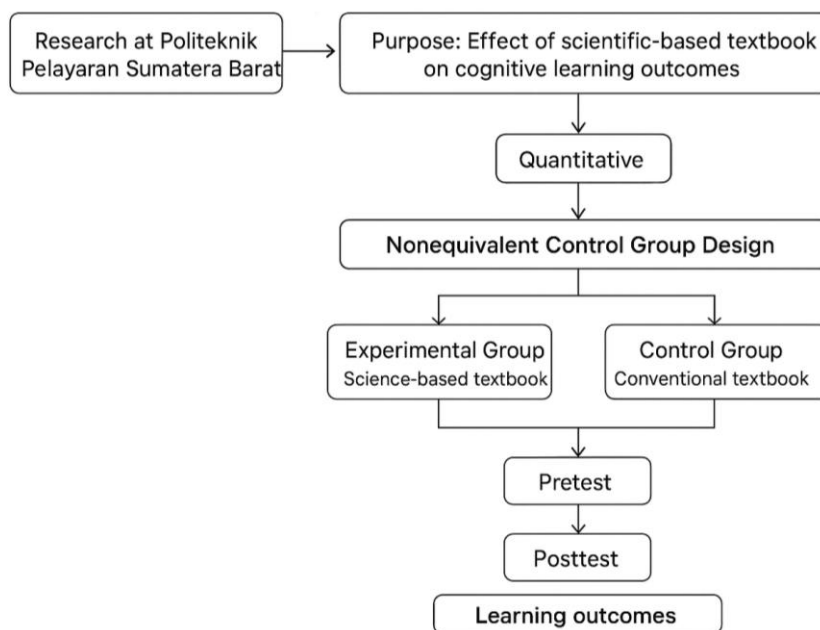


Figure 1. Research Design

This study was conducted at the Politeknik Pelayaran Sumatera Barat from June to July 2025. The purpose of this research was to determine the effect of using a science-based applied physics textbook on the cognitive learning outcomes of students enrolled in the Nautical Technology study program. The research employed a quantitative, quasi-experimental design because not all external variables could be fully controlled. The design used was the Nonequivalent Control Group Design, which involved two non-randomly selected groups: an experimental group using the science-based textbook and a control group using a conventional textbook. Both groups were given a pretest to assess their initial abilities, followed by treatment according to each group, and finally a posttest to measure learning outcomes after the intervention.

Research Target/Subject

The independent variable in this study was the use of a science-based applied physics textbook, while the dependent variable was the students' cognitive learning outcomes in the Nautical Technology program, measured through pretest and posttest scores. The research population consisted of all second-semester students of the Nautical Technology study program in the 2024/2025 academic year. The sample included 24 students, divided into two classes: Class IIA, the experimental group, and Class IIB, the control group.

Research Procedure

The research process began with the preliminary studies, such as a science-based textbook, test instrument development and validation. In the implementation phase, both the experimental and control groups were instructed under matched conditions, using new materials. The experimental group used the newly published science-based textbook, while the control group used materials at the same level. At the end of the intervention period, posttests were administered to both groups to assess the influence.

Instruments and Data Collection Techniques

Data were collected through an observer in the classroom and through written examinations. The teacher-researcher observed the procedures for instruction, student participation, and involvement during learning activities. The students' cognitive achievement was also assessed using written tests in a combination of pretest and post-test. The test instruments were constructed based on the learning competency indicators of the applied physics syllabus.

The research instruments were validated and tested for reliability to ensure the accuracy and consistency of the measurements. Validity testing was carried out using the Product-Moment Correlation formula, with a test item considered valid if the calculated t-value exceeded the critical t-value. Of the 20 test items evaluated, 17 were found to be valid, while 3 items did not meet the validity criteria and were excluded from further analysis. Reliability testing employed Cronbach's Alpha coefficient. Only the items meeting acceptable validity and reliability thresholds were included in the final instrument. After validation, the data were further tested for normality and homogeneity before statistical analysis.

Data Analysis Technique

The collected data were analyzed through several stages. First, normality testing was conducted using the Shapiro–Wilk test to determine whether the data were normally distributed. Next, homogeneity testing was performed using Levene's Test to verify equality of variances between groups. Since the data were not normally distributed, hypothesis testing was carried out using the non-parametric Mann–Whitney U test. The analysis was conducted with a significance level of 5% ($\alpha = 0.05$). Decisions were based on the obtained p-value from the SPSS output. If $p < 0.05$, the use of the science-based textbook was considered to have a significant effect on students' learning outcomes. Otherwise, if $p > 0.05$, the effect was considered not significant.

RESULTS AND DISCUSSION

This research involved students of the Nautical Technology Study Program at Politeknik Pelayaran Sumatera Barat. Two classes were selected as samples, namely Class TN IIA (control group) and Class TN IIB (experimental group), each consisting of 12 students. The experimental group received treatment using the science-based applied physics textbook, while the control group continued with conventional teaching methods without specific intervention. The selection of control and experimental groups was randomized, regardless of students' prior academic performance. The data obtained from both groups are presented below.

Table 1. Pre-test and post-test scores of control and experimental groups

Class	Score			Mean
	Pre-test/ Post-test	Lowest	Highest	
Control	Pre-test	30	95	76.06
	Post-test	35	100	80.62
Experiment	Pre-test	30	95	76.06
	Post-test	65	100	82.50

As shown in Table 1, both control and experimental groups obtained the same maximum pretest score of 95, with identical mean scores of 76.06. This indicates that both groups had relatively equivalent prior knowledge of applied physics. The mean pre-test score was calculated as the total pre-test score divided by the number of participants ($n = 12$). Thus, there was no significant difference in students' initial understanding of applied physics concepts before treatment.

After the pretest, the experimental group received instruction using the science-based textbook, whereas the control group continued with conventional materials. Following the intervention, posttests were administered to measure learning outcomes. The control group achieved a minimum posttest score of 35, while the experimental group's lowest score increased to 65. The mean posttest score of the control group was 80.62, compared to 82.50 for the experimental group. This increase suggests that the use of science-based textbooks positively affected students' comprehension and cognitive performance in applied physics.

Before hypothesis testing, normality and homogeneity tests were conducted on pretest and post-test data. Based on the Shapiro–Wilk test, the pretest data for both the control and experimental groups were normally distributed, with significance values of 0.479 and 0.345, respectively ($p > 0.05$). The Levene's Test for Equality of Variances showed a significance value of 0.266, indicating that both groups were homogeneous.

For post-test data, the Shapiro–Wilk results showed significance values of 0.578 for the control group and 0.734 for the experimental group, both of which exceeded 0.05, confirming normality. Homogeneity testing also revealed a significance value of 0.203, suggesting equal variances between groups.

Table 2. Paired sample test results (experimental group)

Paired sample test	Sig. (2-tailed)	r
Pre-test – Post-test (Experimental)	0.024	0.61

As shown in Table 2, the paired sample test produced a significance value of 0.024. According to the decision rule, if the p -value (Sig. 2-tailed) < 0.05 , the null hypothesis (H_0) is rejected, and the alternative hypothesis (H_a) is accepted. Therefore, there was a statistically significant difference between pretest and posttest scores in the experimental group, indicating that the science-based textbook contributed to improved student achievement.

Table 3. Independent sample t-test results

Students' learning outcomes	t-test for equality of means	
	Sig. (2-tailed)	r
	0.031	0.44

Table 3 shows that the p -value (Sig. 2-tailed) was 0.031, which is less than 0.05. Consequently, the null hypothesis (H_0) is rejected, and the alternative hypothesis (H_a) is accepted. This indicates a significant difference between the mean learning outcomes of the control and experimental groups. Thus, it can be concluded that the Scientific-Based Applied Physics Textbook significantly enhances students' cognitive learning outcomes compared to conventional methods.

To complement the hypothesis testing, an effect size analysis was conducted using the correlation-based effect size r , which provides a practical interpretation of the magnitude of the observed differences. Using the paired sample results ($p = 0.024$, $df = 11$), the estimated effect size for the *THE EFFECT OF A SCIENTIFIC-BASED...* (Nelfi Erlinda) pp:502-511

experimental group was $r = 0.61$, indicating a significant practical effect. This value reflects great individual improvement among students who used the science-based applied physics textbook. For the comparison between groups, the independent-samples t-test ($p = 0.031$, $df = 22$) yielded an estimated effect size of $r = 0.44$, classified as a moderate effect. This demonstrates that the science-based textbook not only led to statistically significant improvements but also produced a meaningful and educationally relevant impact when compared to the conventional textbook. These results reinforce that the implementation of science-based learning materials in maritime physics instruction contributes substantively to enhancing students' cognitive outcomes.

The findings demonstrate that implementing a science-based applied physics textbook significantly improved students' cognitive learning outcomes in maritime vocational education. This aligns with previous research by Azizah & Sucahyo (2022), who reported that non-print scientific learning materials improved both knowledge and practical competencies in mechanical wave topics, with strong correlation coefficients ($r = 0.83$ for knowledge and $r = 0.50$ for skills). Their results affirm that integrating scientific steps into instructional materials can effectively strengthen conceptual understanding and problem-solving skills.

Furthermore, the validity and practicality of science-based materials are crucial to ensuring effective learning implementation. Physics learning materials embedded with scientific literacy achieved high validity (90.51%), supporting their use as credible instructional tools (Aris et al., 2024). Similarly, Lestari, Ariani, and Gumay (2018) found that science-based textbooks on wave optics received highly positive student responses (83.35%) and significantly improved learning outcomes ($t_0 = 6.53 > t_t = 1.692$). These results confirm the consistency of the scientific approach in enhancing both engagement and conceptual mastery.

From an attitudinal perspective, science-based learning also fosters scientific attitudes and curiosity, and science-based instructional materials were more effective than conventional ones in cultivating students' scientific attitudes in elementary teacher education. This is consistent with the premise that fostering scientific thinking contributes to sustained motivation and deeper engagement in physics learning (Thahir et al., 2020; Fahrurrozi et al., 2023). In addition, recent studies highlight the role of contextual and inquiry-based materials in supporting higher-order thinking skills in physics. Emphasized that contextualized learning materials improved students' critical thinking and self-regulated learning behaviors (Nazifah et al., 2022; Hanifah et al., 2023). It has been demonstrated that integrating scientific and vocational content in physics instruction enhances both conceptual retention and real-world application skills (Ramdani et al., 2019; Desnita et al., 2021).

The novelty of this research lies in its application of a science-based printed textbook within a maritime vocational higher education setting, which has rarely been explored. While previous studies have focused primarily on secondary education (Firman et al., 2018; Sukarjo et al., 2021), this study provides empirical evidence of the model's effectiveness among nautical cadets, whose access to digital resources is limited due to institutional regulations. The integration of a structured, inquiry-driven print textbook not only improved conceptual comprehension but also bridged the gap between theoretical physics and maritime engineering applications. These findings underscore the broader educational implications for STEM and vocational education reform in Indonesia, emphasizing the importance of developing high-quality, context-based, and scientifically grounded learning materials to meet international standards (Kemendikbudristek, 2023; International Maritime Organization [IMO], 2014). Moreover, such initiatives strengthen the alignment between academic instruction and industry demands, promoting a culture of evidence-based teaching and continuous pedagogical innovation in maritime education (Fahrudin, 2022; Deepublish, 2022).

The study's findings have several significant ramifications for the teaching of maritime and vocational physics. In terms of instruction, the results show that in environments where cadets have little access to digital media, a printed textbook with a scientific foundation can be a helpful teaching tool. High-quality printed materials are crucial for promoting independent study and bolstering classroom instruction in maritime institutions that impose stringent restrictions on the use of electronic devices. From a curricular perspective, the incorporation of scientific inquiry steps. Such as observing, questioning, experimenting, and drawing conclusions, applied physics content aligns well with the competency-based frameworks implemented in vocational education. Embedding these elements promotes structured analytical thinking and enhances students' ability to connect theoretical physics

concepts with real maritime operations, thereby strengthening both conceptual mastery and practical decision-making skills.

The research highlights the need for maritime vocational institutions to prioritise providing policy-level guidance on how teaching materials should be developed, grounded in scientific principles and informed by contextual realities. Such programmes are congruent with the current national efforts to enhance the quality, relevance, and responsiveness. For this reason, investing in durable printed textbooks can help to facilitate more standardized and streamlined teaching practices across all maritime curricula. The findings also highlight the importance of educators staying current on their learning. We can create more dynamic, question-led learning communities that will facilitate this. Instructors might benefit from focused training on incorporating scientific inquiry and maritime-contextual examples into printed teaching materials. Enhancing teachers' proficiency in this field can help achieve the broader objective of raising the quality of instruction and ensuring that STEM and maritime vocational training are aligned with modern standards.

Despite the encouraging results, it is important to recognize several limitations of the study. First, the sample size was only 24, which limits the statistical generalizability of the findings and suggests that larger samples from multiple cohorts should be used in future studies. Second, the study was conducted at a single maritime polytechnic, which may not accurately reflect the variety of teaching methods, cadet traits, or resource circumstances found in other maritime establishments. Third, the short duration of the intervention (June–July 2025) made it difficult to assess whether the noted gains in cognitive outcomes are maintained over longer teaching cycles or across different applied physics topics.

Finally, it did not include other important competences of maritime education, such as practical and laboratory skills, navigational problem-solving, or decision-making in operations, focusing only on cognitive learning outcomes. Finally, as the research relies solely on quantitative data, such as questionnaire results (and not on qualitative details, such as student observations or interviews), it is difficult to explain exactly how the textbook appears to work or why students find some issues trickier/more useful than others. These limitations represent critical areas for further inquiry to strengthen the evidence base concerning the use of research-based teaching resources in vocational maritime education. Despite these drawbacks, the study offers a fresh perspective by introducing a printed physics textbook grounded in science in a maritime vocational higher education setting. This area has not received much attention in previous studies. The findings demonstrate that cadets' conceptual grasp of applied physics can be significantly enhanced by inquiry-driven, contextually relevant printed materials, providing a workable and pedagogically sound solution for maritime institutions with limited access to technology.

CONCLUSION

Utilization of a science-based Applied Physics textbook had a significant effect on cognitive Nautical Technology learning outcomes at Politeknik Pelayaran Sumatera Barat. The results suggest that the inclusion of a scientific approach through printed students' material supports marine pre-vocational students in applying their conceptual knowledge to an environmentally relevant topic, such as physics. Nevertheless, this would be the sample size, and being a single maritime institution, this study has some limitations. Accordingly, the generalizability should be viewed critically.

Given these limitations of the study and areas for further research, future studies should consider larger sample sizes to increase statistical power and support results that generalize across more settings. Additionally, participants from multiple maritime or shipping schools should be involved in future studies to account for differences in pedagogical practices and learning environments across contexts. Furthermore, considering other fields of applied physics may help us determine whether the intuitiveness of science-based textbooks is uniform across the material covered. Such comparison studies between printed and digital scientific content are also welcomed, particularly to identify the most suitable format for cadets who face restricted digital access. Furthermore, incorporating qualitative data (such as students' perceptions, engagement, and learning experiences) would provide deeper insights that complement quantitative outcomes and offer a more comprehensive understanding of how science-based learning materials support vocational education.

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