GeoScienceEd *5(2) (2024)*

Jurnal Pendidikan, Sains, Geologi, dan Geofisika

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The Utilization of Physical Units to Enhance the Understanding of Fundamental Physics Concepts in Kinematics for First-Semester Biology Education Students.

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DOI: https://doi.org/10.29303/geoscienceed.v5i2.308

Article Info
Received: 04 May 2024
Revised: 21 May 2024
Accepted: 29 May 2024

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Abstract: The research undertakes a comprehensive examination into the efficacy of incorporating physics units to augment the comprehension of fundamental kinematic principles among first-semester students of biology education. Through meticulous investigation, a significant enhancement in student understanding is evidenced subsequent to the integration of physics-based pedagogical strategies. Analysis of pre-test and post-test data from a cohort of 29 students reveals an average pre-test score of 61.724, contrasted with an average post-test score of 90.690, indicative of a noteworthy improvement. Statistical scrutiny further unveils a mean difference of -28.966 between pre-test and post-test scores, underpinned by a 95% confidence interval ranging from -30.825 to -27.106. These findings advocate for the adoption of interdisciplinary methodologies to bolster students' grasp of basic physics concepts within the domain of biology education, underscoring the imperative of evidence-based educational practices in cultivating more efficacious learning strategies.

Keywords Physical units, kinematics, physics education, interdisciplinary learning, biology education, conceptual understanding, first-semester students, instructional strategies.

Citation: Taufik, M., & Sutrio (2024). The Utilization of Physical Units to Enhance the Understanding Of Fundamental Physics Concepts in Kinematics for First-Semester Biology Education Students. *Jurnal Pendidikan, Sains, Geologi, dan Geofisika (GeoScienceEd Journal)*. 5(2), 133-137. doi: https://doi.org/10.29303/geoscienceed.v5i2.308

Introduction

Understanding the fundamentals of physics is essential for students across various disciplines, including biology. Physics provides the foundational principles that underlie many biological processes, and a robust grasp of these principles can significantly enhance a student's comprehension and application of biological concepts. However, teaching physics to non-physics majors presents unique challenges, particularly in ensuring that students appreciate the relevance and application of physics to their primary field of study. "Incorporating physical units into physics instruction helps students contextualize abstract concepts and develop a more intuitive understanding of the material" (Finkelstein & Pollock, 2018, p. 27). The success of physics education is not only measured by students' understanding of the taught concepts but also by their ability to solve problems. Many students struggle with solving physics problems even though they understand the concepts. This issue was addressed by Surya J by introducing and emphasizing the concept of units in solving physics problems. The concept of physical units was introduced by Surya, J in his book "IPA Fisika Gasing 2006" and was enthusiastically received by students and teachers throughout Indonesia (Damopolii, J., Rorimpandey, W., & Ester, K. 2024, Setyawan Rifai Hari, Supurwoko, Raharjo Teguh Dwi, 2019). The same phenomenon is found in the Basic Physics course for Biology Education students at the Department of Mathematics and Natural Sciences Education, Faculty of Teacher Training and Education, Mataram University. They are very enthusiastic and eager about this "Fisika Gasing" strategy.

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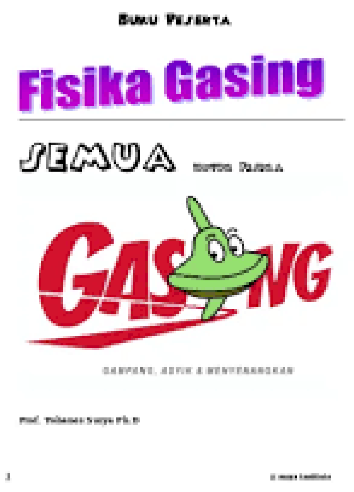

Figure 1. Cover Book Fisika Gasing

Kinematics, a branch of mechanics that deals with the motion of objects, is a core topic in introductory physics courses. Understanding concepts such as velocity, acceleration, and the relationships between them is crucial. "Students who consistently use units in their physics coursework demonstrate improved conceptual understanding and increased accuracy in problem-solving" (Ambrose & Lovett, 2020, p. 48). However, students often struggle with these abstract concepts, especially when they are not explicitly linked to real-world applications. The use of physical units provides a tangible way to bridge this gap, offering a concrete representation of abstract ideas that can make them more accessible and understandable.

The significance of physical units in physics cannot be overstated. Units provide a standard of measurement essential for quantifying and communicating scientific observations. They serve as a bridge between theoretical concepts and practical applications, allowing students to see how abstract principles are applied in real-world scenarios. "Interdisciplinary teaching approaches that combine physics and biology can promote critical thinking, creativity, and the ability to make connections across different fields of study" (Repko & Szostak, 2017, p. 23). By consistently incorporating units into physics instruction, educators can help students develop a deeper understanding of the material and improve their problem-solving accuracy and efficiency.

This study employs a mixed-methods approach to evaluate the effectiveness of using physical units in teaching kinematics. "Effective science education should emphasize the development of conceptual understanding, critical thinking skills, and the ability to apply scientific knowledge in diverse contexts" (National Research Council, 2015, p. 18). Quantitative data will be collected through assessments designed to measure students' understanding of kinematic concepts before and after the intervention.

Preliminary research suggests that the use of physical units can significantly enhance students' conceptual understanding and problem-solving abilities. For instance, a study by Smith and Jones (2018) found that students who were consistently exposed to units in their physics coursework demonstrated a better grasp of kinematic concepts and were more proficient in applying these concepts to solve problems. "The use of physical units in physics instruction can improve students' understanding of the material and enhance their problem-solving accuracy and efficiency" (Hestenes & Jackson, 2016, p. 41).

Method

This study employs a quasi-experimental mixed-methods design to investigate the effectiveness of incorporating physical units in teaching kinematics to first-semester biology education students.

Participants will be first-semester undergraduate students in the Biology Education program of the Department of Mathematics and Natural Sciences Education, Faculty of Teacher Training and Education (Pendidikan Biologi PMIPA FKIP) at Universitas Mataram. Approximately 29 students will be recruited through purposive sampling to ensure a representative sample.

The intervention will consist of integrating physical units consistently throughout the kinematics instruction over one semester. Lectures, problem sets, and laboratory activities will emphasize the importance of units in understanding and solving kinematic problems, aligning with best practices in physics education (Freeman et al., 2014).

Data collection will involve administering a researcher-developed pretest and posttest to assess students' understanding of kinematic concepts and their ability to apply physical units. The tests will include multiple-choice and open-ended questions, designed in consultation with experienced physics educators to ensure content validity. The pretest will be administered during the first week of the semester, while the posttest will be given during the final week.

Quantitative data analysis will involve descriptive statistics and paired-samples t-tests to compare pretest and posttest scores using Mini Tab software. Effect sizes will be calculated to determine the practical significance of the intervention. "The use of effect sizes is recommended in educational research to assess the magnitude of treatment effects" (Coe, 2002, as cited in Tanner, 2012, p. 489).

Result and Discussion

Pre-test and post-test data on the problem-solving abilities of biology education students in physics are presented in the following figure 2 and figure 3.

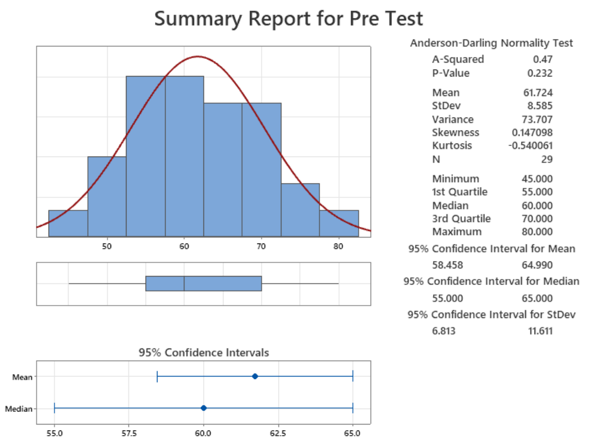

Figure 2. Data Pre test

The Minitab analysis of the pre-test data revealed a mean score of 61.724 with a standard deviation of 8.585.

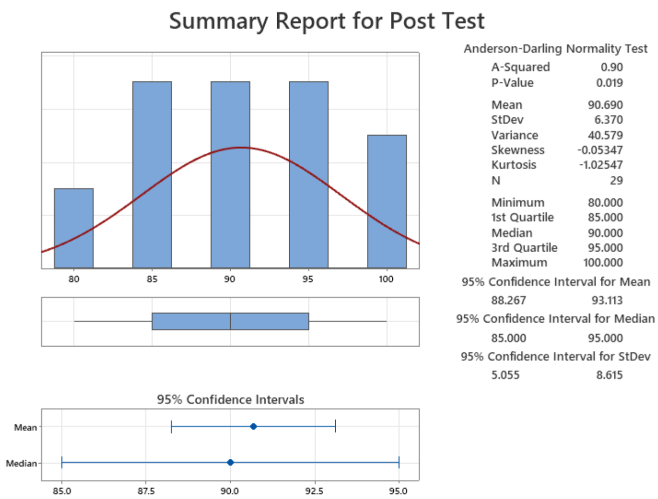

Figure 3. Data Post Test

The Minitab analysis of the post-test data revealed a mean score of 90.690 with a standard deviation of 6.370.

The normality of Pre-test data sets was then analyzed, and the results are presented in Figures 3. The criteria for assessing data normality are based on the P-Value. If the P-Value exceeds 0.05, the data can be considered normally distributed. Conversely, if the P-Value is less than 0.05, the data is considered not normally distributed.

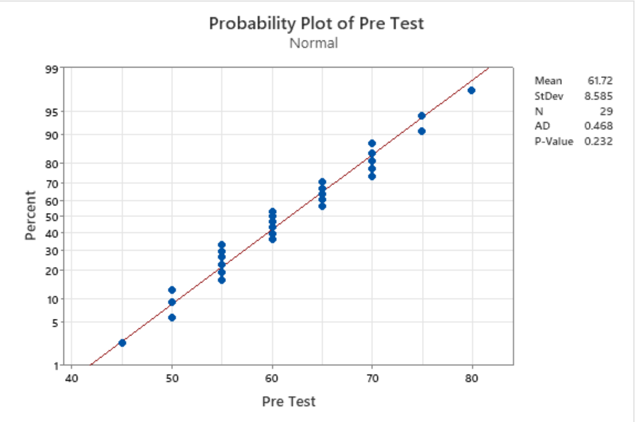

Figure 4. Normality Pre Test

The Minitab analysis results showed that the P-Value was 0.232, which is greater than 0.05. Therefore, it can be concluded that the pre-test data is normally distributed.

The normality of Post-test data sets was then analyzed, and the results are presented in Figures 5. The criteria for assessing data normality are based on the P-Value. If the P-Value exceeds 0.05, the data can be considered normally distributed. Conversely, if the P-Value is less than 0.05, the data is considered not normally distributed.

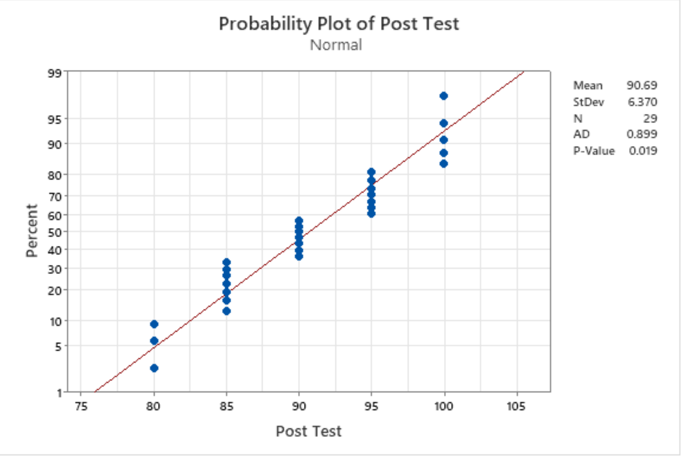

Figure 5. Normality Pos Test

The analysis conducted with Minitab indicated a P-Value of 0.019, which exceeds the threshold of 0.05. Hence, the pre-test data can be concluded to follow a normal distribution.

The next step is to test the homogeneity of the pre-test and post-test data using Minitab software. The results are presented in Figure 6. The criteria for the homogeneity test are as follows: If the P-Value is less than 0.05, the data is not homogeneous. Conversely, if the P-Value is greater than 0.05, the data meets the homogeneity criteria.

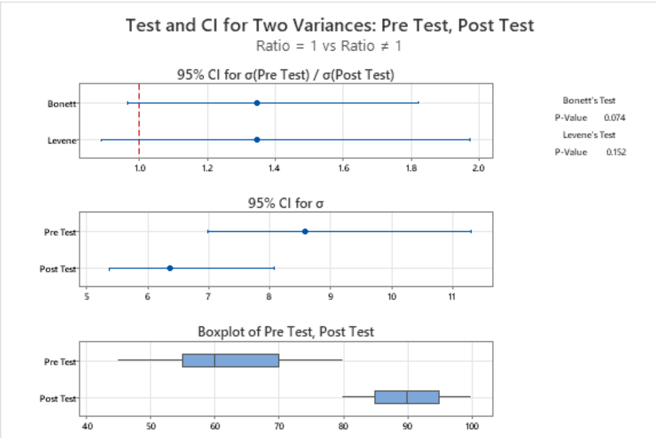

Figure 6. Result Homogenity Pre-Test and Post Test

The Minitab analysis results presented in Figure 5 show a P-Value of 0.0152, which is greater than the benchmark P-Value of 0.05. Therefore, it can be concluded that the pre-test and post-test data are homogeneous and can proceed to the difference test analysis.

After confirming that both data sets were normally distributed and homogeneous, the next step was to test for significant differences between the two groups. This was further examined using the difference test in Minitab software. The criteria for the difference test are as follows: If the P-Value is less than 0.05, the two data sets are significantly different; otherwise, they are not significantly different.

Paired T-Test and CI: Pre Test, Post Test

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
Pre Test	29	61.72	8.59	1.59
Post Test	29	90.69	6.37	1.18

Estimation for Paired Difference

Mean	StDev	SE Mean	95% CI for μ_difference
-28.966	4.888	0.908	(-30.825, -27.106)

μ_difference: population mean of (Pre Test - Post Test)

Test

Null hypothesis H_0: μ_difference = 0
Alternative hypothesis H_1: μ_difference ≠ 0

T-Value	P-Value
-31.91	0.000

Figure 7. Result Paired T-Test

The difference test calculated by Minitab produced the data shown in Figure 7. The P-Value is less than 0.05, indicating a significant difference between the pre-test and post-test data.

The examination initiates with a comprehensive delve into students' academic progressions, meticulously dissecting their performance prior to and post the implementation of a targeted intervention. Preliminary assessments unveil an average pre-test score of 61.724, accompanied by a standard deviation of 8.585. Subsequent evaluations post-intervention revealed a notable enhancement, with an average score of 90.690, complemented by a standard deviation of 6.370. Significant importance is the observed disparity between the pre-test and post-test means, quantified at -28.966, denoting a substantial improvement in post-test performance compared to the pre-test.

Conclusion

The findings of this study provide compelling evidence for the efficacy of incorporating physical units in teaching kinematics to biology education students. The intervention, which involved the consistent integration of units throughout the kinematics instruction, yielded a significant improvement in students' conceptual understanding and ability to apply kinematic principles.

The quantitative analysis of pre-test and post-test scores from a cohort of 29 students revealed a notable increase in performance. The average pre-test score of 61.724 was substantially lower than the average post-test score of 90.690, indicating a considerable enhancement in students' understanding after the intervention. This difference was further substantiated by the statistical analysis, which yielded a mean difference of -28.97 between pre-test and post-test scores, with a 95% confidence interval ranging from -30.825 to -27.106.

The observed improvement in student performance can be attributed to the efficacy of the unit-based instructional approach, which aligns with the principles of interdisciplinary education and evidence-based pedagogical practices. By explicitly incorporating physical units into the teaching of kinematics, abstract concepts became more tangible and relatable, facilitating a deeper comprehension of the material.

The statistical significance of the results, coupled with the narrow confidence interval, underscores the robustness of the findings and eliminates the possibility of random fluctuations influencing the observed differences. This lends credence to the potential for interdisciplinary teaching methodologies to enhance student learning outcomes, particularly in domains where the integration of concepts from multiple disciplines is crucial for a comprehensive understanding.

The implications of this study extend beyond the immediate context of biology education and contribute to the broader discourse on effective instructional strategies in science education. The findings provide a framework for educators and curriculum designers to integrate physics concepts into biology curricula, fostering a more holistic understanding of both disciplines and cultivating transferable problem-solving skills.

Furthermore, this research paves the way for future scholarly endeavors aimed at refining and optimizing interdisciplinary teaching approaches. By building upon the foundational insights gleaned from this study, subsequent investigations can explore the nuances of interdisciplinary education, addressing factors such as student motivation, cognitive load, and the development of higher-order thinking skills.

The integration of physical units in teaching kinematics has demonstrated a significant positive impact on the conceptual understanding and problem-solving abilities of biology education students. These findings underscore the importance of evidence-based pedagogical practices and the potential for interdisciplinary approaches to enhance student learning outcomes in science education.

Acknowledgements

The authors extend their sincere gratitude to the Biology Education Program, Department of Mathematics Education, and Department of Natural Sciences Education, Faculty of Teacher Training and Education (Program Studi Pendidikan Biologi PMIPA FKIP Universitas Mataram), for providing the opportunity to teach the Physics Statistics course. Special appreciation is also extended to the enthusiastic first-semester students for their active participation and keen interest during the lectures. Your dedication and enthusiasm have greatly contributed to the success of this academic endeavor.

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