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Students' Lexical Difficulties in Classical Mechanics and Modern Physics Vocabulary: A Survey Analysis

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ABSTRACT

Purpose of the study: The aim of this study is to map undergraduate students' physics vocabulary needs in classical mechanics and modern physics by identifying their levels of familiarity, frequency of use, and perceived difficulty of scientific terms across different physics domains.

Methodology: This study employed a descriptive quantitative survey method. The instrument was a researcher-developed structured questionnaire containing physics vocabulary items, validated by expert review. Data were collected online using Google Forms. Responses were measured with a three-point Likert scale and analyzed descriptively using Microsoft Excel software.

Main Findings: The results show that students demonstrate high vocabulary recognition in classical mechanics and energy-related terms. Moderate recognition appears in laboratory and academic vocabulary. Low recognition is found in thermodynamics and modern physics terms, especially abstract and theoretical concepts. Overall vocabulary familiarity decreases as conceptual abstraction increases across physics domains.

Novelty/Originality of this study: This study introduces a systematic, domain-based mapping of physics vocabulary by integrating familiarity, frequency of use, and perceived difficulty across multiple physics fields. It advances existing research by providing comparative evidence between classical mechanics and modern physics, offering empirical insights that support targeted vocabulary instruction in higher education physics learning.

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1. INTRODUCTION

Scientific language plays an important role in learning physics because many physics concepts depend on the precision of terms and the language structure used. When scientific vocabulary cannot be correctly understood, the process of concept formation is also disrupted [1], [2]. Emphasizes that scientific language is not merely a communication tool but also forms the basis for how students build conceptual understanding [3], [4]. This explains why mastery of scientific vocabulary cannot be separated from success in learning physics.

Several studies have shown that students often interpret physics terms based on their everyday meaning. As a result, terms such as "force", "work", or "energy" are misunderstood, leading to misconceptions [5], [6]. Such findings are consistent with studies on linguistic demands in physics texts, which show that the complexity of language has a direct impact on reading comprehension [7], [8]. Furthermore, when scientific vocabulary is not clearly defined, students tend to construct incorrect arguments because physics terms are used inconsistently [9], [10].

Research on the difficulties of physics vocabulary continues to develop, but most studies only focus on a single topic or specific domain. For instance, some concentrate on thermodynamics, electricity, or a limited number of physics terms [11], [12]. Such a partial approach has yet to provide a comprehensive picture of how students understand vocabulary across the broader physics domain, especially when considered simultaneously in terms of familiarity, frequency of occurrence, and difficulty level [13], [14].

Furthermore, research on physics vocabulary within the context of higher education in Indonesia is still very limited. The majority of studies use small observations or general approaches that have not provided a comprehensive mapping [15], [16]. This situation results in lecturers or curriculum developers not having a clear picture of which domains are most challenging for students [17], [18]. In fact, cross cultural issues such as the mismatch between everyday language and scientific terminology have been highlighted in the context of other countries [19], [20].

Other research gaps also emerge when comparing classical mechanics with modern physics [21]. Show that modern physics is more abstract, more mathematical, and contains technical terms whose initial exposure is relatively low. In other words, students enter this domain with more limited linguistic resources compared to classical mechanics. Until now, there has been little research conducting a systematic comparison of students' vocabulary needs in both domains.Theoretically, this study is based on a lexical approach that considers vocabulary as the primary unit conveying meaning [22], as well as constructivist theory, which views that students interpret new terms based on their prior knowledge. If that prior knowledge is not aligned with the scientific definition, misconceptions can be reinforced rather than corrected. Therefore, a clear understanding of scientific vocabulary becomes the key to overcoming conceptual barriers.

On that basis, this study aims to map the vocabulary needs of students in classical mechanics and modern physics. This mapping is conducted by measuring the level of familiarity , frequency of occurrence, and difficulty of terms. Then, the patterns of both are compared systematically. It is hoped that these findings can provide an empirical basis for improving the teaching strategies of physics vocabulary in higher education in Indonesia.

2. RESEARCH METHOD

This study uses a descriptive survey method to map students' vocabulary needs in classical mechanics and modern physics materials. This design is appropriate as the study does not aim to manipulate variables, but rather to describe the characteristics of a population's perceptions in a standardized manner. Surveys are a commonly used method for collecting quantitative data on perceptions and knowledge in an educational context [23], [24]. The respondents of this study consisted of 50 students from the physics education and pure physics programmes from various universities in Indonesia, ranging from semester 1 to semester 7. A total sampling technique was used because the population was small and all members could be reached, thereby reducing the potential for sample selection bias and increasing representativeness [25], [26].

The research instrument consisted of a structured questionnaire containing a list of physics vocabulary from two domains, namely classical mechanics and modern physics, with three assessment indicators: level of familiarity, frequency of use, and difficulty of vocabulary. Each item was rated using a 1-3 likert scale, commonly used to measure perception or mastery in educational research [27]. To ensure language clarity, item suitability, and instrument readability, the questionnaire was validated through expert judgment by an English lecturer. Feedback from the validator was used to revise the structure and wording of the items before distribution.

Data collection was conducted online over a three-week period through several systematic stages. First, the researcher developed the questionnaire, which included a list of vocabulary items, assessment indicators, completion instructions, and scale definitions. The instrument was then reviewed and validated by an English lecturer to ensure the clarity of terms and the suitability of the items with the research objectives. After validation, the questionnaire was uploaded to an online survey platform and equipped with an informed consent page outlining the purpose of the study, respondent anonymity, estimated completion time, and the researcher's contact information. The survey link was subsequently distributed through class group channels and private messages, accompanied by a brief explanation of the study's purpose and the submission deadline. To maximize the response rate, two periodic reminders were sent to participants. All submitted responses were checked for completeness, and incomplete responses were recorded and excluded from the analysis. The valid data were then exported in spreadsheet format and securely stored in encrypted storage to maintain confidentiality. Prior to analysis, data cleaning was carried out to identify and remove duplicate entries, out-of-range values, and input errors.

This structured procedure refers to the survey data collection principles recommended by [23], particularly in ensuring clarity of instruction, respondent accessibility, and data quality. Content validity was obtained through expert evaluation by English lecturers who assessed the clarity of wording and suitability of items with the research objectives. The internal reliability of the instrument was tested using Cronbach's Alpha based on data obtained from 50 respondents. The calculating results showed a value of α = 0.976, indicating that the instrument has an internal consistency acceptable for survey research in the educational context [23].

Data were analyzed descriptively to illustrate students' perception patterns toward vocabulary items within a non-experimental survey design [25], [23]. Frequencies, percentages, and mean scores were calculated for each item using a three-point Likert scale (1–3), with item means derived from three indicators: familiarity, frequency of use, and perceived difficulty. Domain averages were then computed by aggregating item means within each material domain and interpreted using predetermined categorization ranges (see Table 1). To support comparison, vocabulary items were ranked based on their mean scores, the five highest and lowest items in each domain were identified, and bar charts were used to visualize domain averages and rating distributions.

Table 1. Categorization of Mean Scores

Mean Score Range	Category
1.00 – 1.66	Low
1.67 – 2.33	Medium
2.34 – 3.00	High

3. RESULTS AND DISCUSSION

The results of study survey analysis will be discussed based on three main aspects: Identifying unfamiliar or frequently misunderstood physics vocabulary, examining the frequency of these terms encountered by students, and comparing the relative difficulty of physics domains based on linguistic and conceptual characteristics.

In the classical mechanics domain, analysis results show that the five words with the highest average Velocity (2.9) Acceleration (2.8) Force (2.8) Mass (2.7) and Momentum (2.6). This vocabulary has the same meaning in learning basic physic material and widely used in examples and learning questions, so the level of familiar is high among respondents. In contrast, the five words with the lowest frequency are Trajectory (1.8) Inertia (1.9) Net Force (2.0) Displacement (2.1) and Friction (2.2) show a low level of recognition. Although these terms belong to the same domain, they are often introduced implicitly or receive less explicit emphasis during instruction. This suggest that vocabulary recognition is influenced not only by topic familiarity but also by how explictly the terminology is highlighted during the learning process. The relatively consistent scores across respondents indicate that. Overall Classical Mechanics vocabulary is more familiar than vocabulary in other domains (see Table 2).

Table 2. Vocabulary recognition in the Clasical Mechanics domain

Top 5	Bottom 5
Velocity (2.9)	Trajectory (1.8)
Acceleration (2.8)	Inertia (1.9)
Force (2.8)	Net Force (2.0)
Mass (2.7)	Displacment (2.1)
Momentum (2.6)	Friction (2.2)

In the Energy and Rotational Motion domain, the top five vocabulary words are Energy (2.7) Power (2.7) Work (2.6) Kinetic Energy (2.5) and Potential Energy (2.4). These terms frequently appear in learning and are easily associated with real world phenomena which supports higher levels of vocabulary recognition among student. Meanwhile vocabulary words with the lowest frequency such as angular momentum (2.0) Torque (2.1) Moment of Inertia (2.1) Rotational Motion (2.2) and Centripetal Force (2.2). The lower scores for these terms suggest that rotational concepts present greater linguistic and conceptual challenges. Unlike linear motion and energy concepts, rotational motion requires abstract reference frames and vector based reasoning which may reduce students' familiarity with the associated vocabulary. However the difference between the highest and lowest scores in this domain is less pronounced than in Classical Mechanics (Table 3).

Table 3. Vocabulary Recognition in the Energy and Rotational Motion Domain

Top 5	Bottom 5
Energy (2.7)	Angular Momentum (2.0)
Power (2.7)	Torque (2.1)
Work (2.6)	Moment of Inertia (2.1)
Kinetic Energy (2.5)	Rotational Motion (2.2)
Potential Energy (2.4)	Centripetal Force (2.2)

And the next domain is Thermodynamics. The five frequently used words in the Thermodynamics domain are Temperature (2.9) Heat (2.8) Pressure (2.8) Volume (2.3) and Internal Energy (2.2). There terms are terms that frequently appear in laboratory activities and basic physics lessons, so they are quite familiar to most respondents. In contrast,more advanced thermodynamics the five least frequently used words are Entropy (1.6) Adiabatic (1.7) Isothermal (1.8) Specific Heat (1.9) and Thermal Equilibrium (2.0). Showed significantly lower recognition scores. These results indicate that abstract and unobservable thermodynamics concepts are less familiar to students. The substantial difference between basic and advanced vocabulary suggest that students' understanding of thermodynamics is unevenly distributed and that linguistic abstraction plays a significant role in learning difficulties in this domain (Table 4).

Table 4. Vocabulary Recognition in the Thermodyamics Domain

Top 5	Bottom 5
Temperature (2.9)	Entropy (1.6)
Heat (2.8)	Adiabatic (1.7)
Pressure (2.8)	Isothermal (1.8)
Volume (2.3)	Specific Heat (1.9)
Internal Energy (2.2)	Thermal Equalibrium (2.0)

So in the Modern Physics domain, the top five vocabulary words are Electron (2.8) Proton (2.6) Photon (2.6) Nuclear (2.4) and Radioactivity (2.3). These five vocabulary words are generally introduced at the secondary school and relate to the basic concepts of atomic structure thus their familiarty level is relatively high. However the five least recognized terms the uncertainly Principle (1.5) Quantum Entanglement (1.6) Spacetime (1.7) Planck Constant (1.8) Quantum (1.9) are highly abstract and theoretical. These concepts are rarely discussed in depth at the school level, resulting in limited exposure. The consistently low recognition scores across these domains indicate that students have a very limited understanding of Modern Physics vocabulary, particularly theoretical terms (Table 5)

Table 5. Vocabulary Recognition in the Modern Physics Domain

Top 5	Bottom 5
Electron (2.8)	Uncertainty Priciple (1.5)
Proton (2.6)	Quantum Entaglement (1.6)
Photon (2.6)	Spacetime (1.7)
Nuclear (2.4)	Planck Constant (1.8)
Radioactivity (2.3)	Quantum (1.9)

The last domain is Laboratory and Academic, the top five vocabulary being Measurement (2.7) Experiment (2.7) Data Analysis (2.6) Graph (2.5) and Observation (2.5). These vocabulary frequently used in laboratory activities and scientific reporting leading to relatively high familiarity among students. Meanwhile the vocabulary words with the lowest scores were Calibration (2.2) Precision (2.3) Accuracy (2.3) Error (2.4) and Hypothesis (2.4). The low scores for these terms indicate that more specific academic vocabulary is not yet fully understood by some students. The difference between the highest and lowest scores is not significant. It can be said that highest vocabulary also has a low average value compared to other domains (Table 6).

Table 6. Vocabulary Recognition in the Laboratory and Academic Domain

Top 5	Bottom 5
Measurement (2.7)	Calibration (2.2)
Experiement (2.7)	Precision (2.3)
Data Analysis (2.6)	Accuracy (2.3)
Graph (2.5)	Error (2.4)
Observation (2.5)	Hypothesis (2.4)

The differences observed across domains suggest that vocabulary recognition is determined not only by term frequency but also by conceptual and linguistic characteristics. Vocabulary related to concrete physical experiences, such as motion, force and measurement is more easily recognized than abstract and symbolic terms like entropy or quantum entanglement. This pattern confirms previous findings that students demonstrate a higher understanding of concrete and experience based concepts than abstract and theoretical concepts [28], [9]. This overall pattern is illustrated in figure 1, which presents the mean recognition scores of the most and least frequently recognized vocabulary items across physics domains showing a clear decline in vocabulary recognition as conceptual abstraction increases.

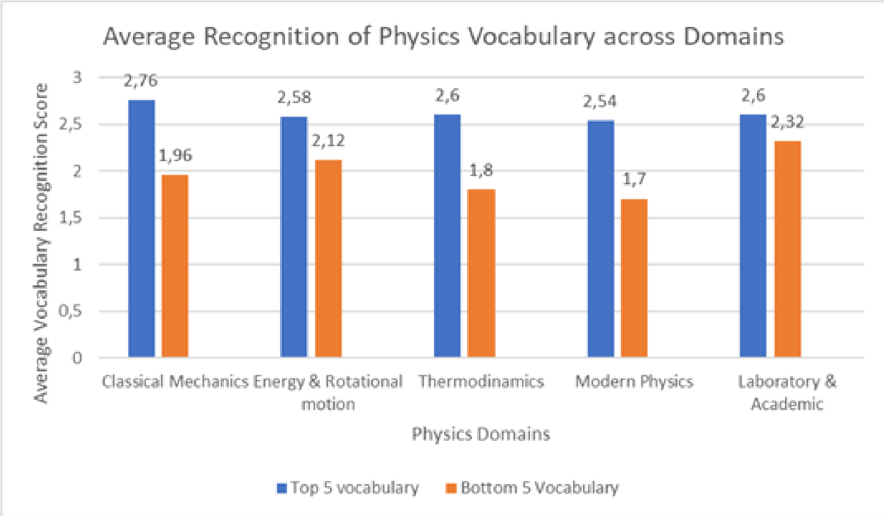

Figure 1, average recognition of physics vocabulary across domains. Blue bars represent the five most frequently recognized vocabulary items, while gray bars indicate the five least recognized terms

Further domain specific distributions are presented in figures 2-5 show vocabulary recognition patterns within each physics domain with more pronounced gaps observed in Thermodynamics and Modern Physics. This study extends previous research by providing a systematic domain based mapping of physics vocabulary recognition, highlighting how linguistic and conceptual difficulties vary across different physics subfields. When scientific terms lack direct experiential references or differ substantially from everyday usage, student are more likely to have difficulty understanding remembering them consistent with previous observations on scientific language learning [21].

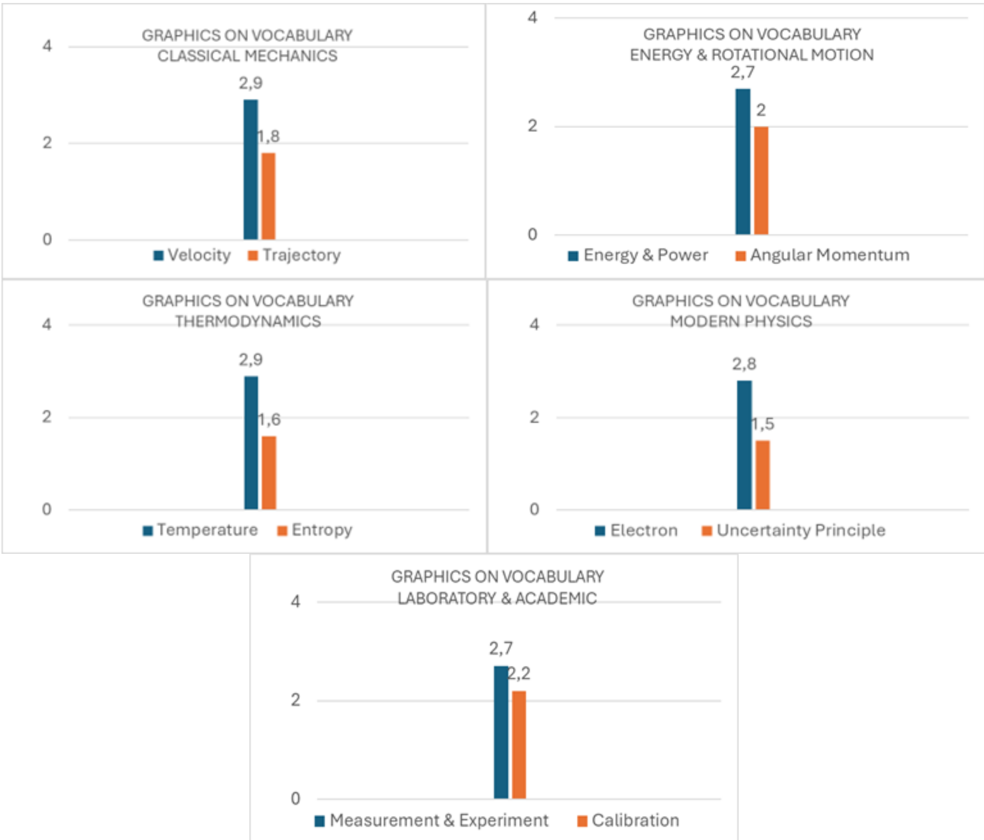

Figure 2. Comparison of Highest and Lowest Vocabulary Scores Across Physics Domains

Figure 2-6 shows the highest and lowest vocabulary values across domains. In the modern physics domain, both the highest and lowest vocabulary values are the lowest compared to other domains. The results of his study serve as a challenge for educators and prospective educators to incorporate vocabulary more frequently into modern physics chapters so that students will become familiar with the vocabulary in modern physics chapters. This research shows that the problem of understanding physics is not only due to complex mathematics, but also due to the specialized language used in science. To overcome this, students need to learn physics vocabulary deliberately and clearly, especially terms that are difficult to understand or rarely used in everyday life. This method has proven effective in helping students better understand scientific terminology, A 2021 Venida study found that students improved a lot in how they learned and used scientific language. They could explain ideas better by using the right words.

The results of this study show significant variation in mastery of disciplines across physics domains, with modern physics having the lowest average comprehension score compared to other domains. This finding reflects students' difficulties in grasping and comprehending abstract and less common scientific terms, particularly those related to topics such as electrons and the principle of tidying. This aligns with previous research that revealed that understanding physics is specific and often differs significantly from everyday language, thus requiring explicit learning to connect the scientific meaning of these terms to the appropriate learning context [29].

In addition, other studies have highlighted that limited scientific vocabulary knowledge not only impacts conceptual understanding, but also students' anxiety and confidence in dealing with technical terms, which in turn can affect physics learning outcomes [12]. The findings of this study are consistent with the literature stating that vocabulary skills are an important component in scientific literacy and a comprehensive understanding of physics concepts, not just mathematical or manipulative abilities alone [30].

This study makes a unique contribution by quantitatively comparing vocabulary across multiple physics content domains by calculating the highest and lowest scores within each domain, a finding rarely found in physics education literature. Its primary novelty lies in the cross-domain analysis, which identifies modern physics as the domain with the most pressing vocabulary needs for explicit instruction. This study adds to the understanding that vocabulary challenges are not universal across all physics content but have distinct patterns across domains, necessitating tailoring of physics language instruction based on the characteristics of the content domains.

These findings have several important implications for physics education practice. First, physics teachers and prospective teachers need to incorporate vocabulary learning strategies in a planned and explicit manner across all content domains, particularly linguistically challenging topics like modern physics. An increased focus on scientific vocabulary can help students build a stronger mental lexicon for non-intuitive terms. Second, physics curricula need to consider aspects of scientific language as part of core competencies to improve students' overall scientific literacy. Third, learning materials and assessments should be designed to assess not only conceptual understanding but also appropriate scientific vocabulary, so students can more effectively read, write, and discuss physics concepts.

While providing valuable insights, this study has several limitations that warrant attention. First, the vocabulary measurement was based solely on a relatively simple three-point scale, which may not fully capture the nuances of students' vocabulary comprehension. Second, the study was conducted on a specific sample within a general physics context and did not encompass the broader range of language backgrounds or ability levels of the student population. Third, the study did not directly evaluate the relationship between vocabulary mastery and student academic achievement, so the link between vocabulary mastery and success in physics learning requires further study. This lack of a direct link between vocabulary variables and academic outcomes is a limitation that could be a focus for future research.

4. CONCLUSION

This study demonstrates the crucial role of scientific vocabulary in supporting students' conceptual understanding of physics, revealing systematic differences in vocabulary recognition across domains, with higher familiarity in classical mechanics and energy-related topics and lower recognition in thermodynamics and modern physics. These patterns indicate that vocabulary difficulty increases as concepts become more abstract, mathematically intensive, and less connected to everyday experience. The study's main contribution lies in its domain-based mapping of physics vocabulary based on familiarity, frequency, and perceived difficulty, showing that linguistic challenges are unevenly distributed across physics content areas. The findings highlight the need for explicit vocabulary instruction, particularly in abstract domains, to reduce misunderstandings and enhance scientific reasoning and communication. However, the study is limited by its relatively small sample size and reliance on self-reported perceptions. Future research is recommended to employ experimental designs, explore digital learning tools, and examine multilingual contexts to further strengthen understanding of physics vocabulary acquisition and its impact on learning outcomes.

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