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ORIGINAL RESEARCH PAPER

A Statistical Analysis of Misconceptions Regarding Challenging Concepts in Chapter One of the 10th-Grade Physics Textbook

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ABSTRACT

This study aimed to investigate and analyze the misconceptions among 10th-grade students regarding fundamental physics concepts, including physical phenomena, scientific modeling, the distinction between laws and principles, scalar and vector quantities, the accuracy of measuring instruments, units, and density. The statistical population consisted of 85 tenth-grade students from the Experimental Sciences and Mathematics-Physics majors, selected through cluster random sampling. Data were collected using an 8-question questionnaire with a reliability coefficient of 0.91 (Cronbach's alpha). The findings revealed that over 50% of students had misconceptions in understanding modeling, distinguishing laws from principles, and identifying scalar and vector quantities. Approximately 45% showed misconceptions in the concepts of density, measurement accuracy, and physical phenomena, while about 30% had misconceptions regarding units. These results highlight the necessity of revising teaching methods and employing concrete examples to address these misunderstandings. To address these misconceptions, the study concludes with recommendations regarding teaching methods, the use of diverse learning styles, and the application of specific examples.

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INTRODUCTION

A proper understanding of fundamental physics concepts, which form the cornerstone of learning in experimental sciences and engineering, has always been a fundamental challenge for educational systems. International studies indicate that students worldwide, regardless of their country's development level, face profound misconceptions when encountering basic physics concepts [1]. These misconceptions not only make learning more complex topics difficult but can also lead to lifelong misunderstandings. Focusing on 10th-grade students in Iran, the present research systematically investigates this educational challenge [2].

Based on the proposed theoretical definition [3], misconceptions are beliefs contradicting established scientific theories, which are systematically supported by seemingly valid though ultimately flawed empirical or logical reasoning, and arise from incomplete evaluation processes during information interpretation; for instance, the prevalent misconception that "heavier objects fall faster" stems from limited everyday observations (e.g., comparing falling leaves and stones), employs seemingly logical arguments ("greater weight implies stronger gravitational pull"), and reflects a fundamental misinterpretation of Newton's second law, thereby highlighting their characteristic reliance on rationalized yet incorrect prior knowledge and the necessity to distinguish them from transient errors, despite their inherent limitations in encompassing all empirical aspects or fully explaining belief persistence [4,5].

Misconceptions are often reinforced by seemingly obvious and self-evident reasoning. The origin of these misconceptions predominantly stems from limited and incomplete practical experiences. Students, particularly at lower educational levels, heavily rely on these incorrect beliefs. Interestingly, many of them already possess these misconceptions even before beginning formal physics instruction [6].

The role of early experiences in forming these incorrect beliefs is highly prominent and determinative in the physics education process. In contrast, misconceptions that emerge at higher educational levels may stem from arbitrary reasoning and can even form part of a complex, multi-faceted cognitive system. These findings emphasize the necessity for early educational intervention and the reconstruction of students' practical experiences [7,8].

The characteristics of these physics misconceptions include resistance to change, meaning they typically demonstrate low cognitive flexibility and may persist even when confronted with compelling scientific evidence, as well as a hierarchical structure where these incorrect beliefs often appear as interconnected conceptual networks, allowing a fundamental misconception to generate secondary incorrect beliefs [9]. Proposed corrective strategies involve implementing refutational experiments designed to directly confront students with contradictions between their predictions and experimental outcomes, and utilizing concept mapping tools to reveal cognitive gaps. Elementary misconceptions, which are linear and one-dimensional in complexity, originate from direct sensory experiences and can be addressed through simple experimental demonstrations. In contrast, advanced misconceptions, which are systematic and multi-layered, stem from abstract reasoning and require structured cognitive challenges for effective correction [10,11].

This study is grounded in the conceptual change theory, a dominant framework for understanding misconceptions pioneered by researchers like Vosniadou (1994) and Chi (2008). This theory posits that students do not enter the classroom as blank slates; instead, they possess well-organized, self-constructed mental models of the natural world derived from limited sensory experience. These naive theories are often coherent and functional in everyday life but are incompatible with established scientific principles, making them remarkably resistant to traditional instruction that fails to directly address and refute them. Our investigation into

concepts like modeling and the law-principle distinction directly engages with this theoretical foundation, as these abstract ideas are fertile ground for the development of such robust, alternative frameworks.
The specific misconceptions targeted in this research are not isolated to the Iranian educational context but are well-documented in the international science education literature. The widespread student difficulty in differentiating scientific models from reality, for example, aligns with the findings of Schwarz et al. (2009), who emphasize the challenge of students viewing models as literal copies rather than conceptual tools. Similarly, the confusion between physical laws and principles reflects a broader global challenge in teaching the nature of science, as discussed by McComas (2003). By explicitly linking our findings to this established body of work, we situate our local study within a global conversation, demonstrating that the identified learning obstacles are universal, yet their manifestation and prevalence may be influenced by specific curricular and instructional practices, thereby highlighting generalizable insights for the field.

STATEMENT OF THE PROBLEM

Physics education, as one of the fundamental disciplines of experimental sciences, plays a crucial role in developing students' scientific thinking and analytical abilities. However, a significant obstacle in this field is the prevalence of common misconceptions arising from the inherent difficulty of the concepts and traditional teaching methods, which can severely impact the learning process. A noteworthy point is that the distortion of a concept does not necessarily equate to a misconception, but it can pave the way for incorrect interpretations. During the process of conveying concepts, an individual might transmit only part of the information, consequently leading the receiver to form erroneous interpretations of that concept in their mind. Below, we review a number of these misconceptions related to the first chapter of the 10th-grade physics textbook [3,12,13].

The concept of "phenomenon" in physics, as the starting point of this research, is often not correctly understood by students. Contrary to the common belief that phenomena are limited to extraordinary events, in physics, any observable and measurable event is considered a phenomenon [14]. Everything that happens around us is a phenomenon. For instance, the Earth's revolution around the Sun, diving into a pool, water boiling in a kettle, and even the audience performing "the wave" in a stadium are all phenomena. This fundamental misunderstanding can affect students' comprehension of the very nature of physics as a science [15, 16].

On the other hand, "modeling" physical phenomena, as one of the cornerstones of the scientific method, is itself a significant source of misconceptions. Many students are unable to distinguish the boundary between physical reality and simplified models. A large number of tenth-grade students do not adequately understand the concept of modeling [17,18]. As we know, modeling is a process where a physical phenomenon is simplified and idealized to such an extent that it can be examined and analyzed. In modeling, minor effects must be neglected, while significant and determining effects are retained. The misconception that occurs here for some students is their inability to distinguish minor effects from significant and determining ones. For example, they think that in kinematics, air resistance is always a minor effect. However, a minor effect is one whose removal does not change the object's path of motion. For instance, in the fall of a stone from a height, air resistance is a minor effect, whereas in the fall of a leaf from a tree, air resistance is a determining effect because if we remove air resistance, the leaf falls straight down, whereas in reality, it moves in a zigzag, irregular, and winding path. Another example of modeling mentioned in the tenth-grade physics textbook is considering objects as particles. Many students assume they can always apply this modeling and treat an object as a particle, whereas an object can only be considered a particle when effects like air resistance, rotation, etc., can be neglected. For example, in the motion of a feather, a skydiver, a balloon, or a sailboat, the object cannot be considered a particle, and effects like air resistance and Archimedes' force (in the case of the sailboat) cannot be disregarded.

Distinguishing between "law" and "principle" in physics presents another educational challenge. Physical laws are based on extensive empirical observations and precise mathematical relationships. A law is a universal and perpetual statement that describes a wide range of diverse phenomena, and many physical laws express the mathematical relationship between certain physical quantities, such as Newton's second law and the law of energy conservation [19]. In contrast, a principle is used to describe a narrower range of physical phenomena that have less generality, such as Pascal's principle, which applies only to confined fluids, or Bernoulli's principle, which is applicable only to moving fluids. Principles are typically assumptions that apply within specific limits. Some students mistakenly believe that a principle is something acceptable that must be taken without proof, similar to axioms in geometry. This subtle distinction, which is not sufficiently emphasized in textbooks, leads to significant confusion among learners. Research conducted in various countries indicates that this problem has a universal nature and is not exclusive to the Iranian educational system [20].

To understand the influence of various factors on a phenomenon, measurement serves as an essential tool. By precisely quantifying values and analyzing the relationships between them, the role of each factor can be determined. Consequently, the importance of measurement in the sciences, particularly in physics, is undeniable. Some refer to physics as the science of measurement, as this discipline only discusses phenomena that are quantifiable. If something cannot be measured, there is little scientific discourse about it. Anything measurable in physics is termed a quantity. Misconceptions related to physical quantities and measurement are among the issues requiring special attention [21,22].

Many students struggle to distinguish vector quantities from scalar quantities. For instance, the mistaken belief that electric current is a vector quantity challenges the understanding of basic electrical circuit concepts. Students assume that any quantity possessing direction is a vector. Therefore, they think electric current is a vector. However, electric current is a scalar quantity because, for example, under all conditions (regardless of the angle between wires), the sum of currents entering a junction equals the sum of currents leaving it (Figures 1.a and 1.b). In both figures below, irrespective of the angle between the wires, the relation $I_3 = I_1 + I_2$ (Kirchhoff's Current Law) holds true. Thus, electric currents do not follow the rules of vector addition.

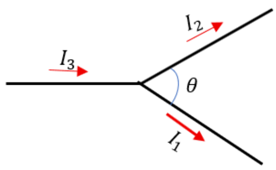


FIG.1.a

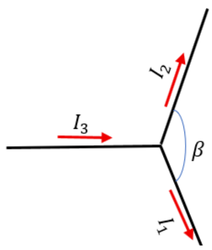


FIG.1.b

On the other hand, an incorrect understanding of the accuracy of measuring instruments and the meaning of significant figures limits students' ability to conduct scientific experiments and interpret results [23]. These weaknesses create more serious problems, particularly in higher educational levels where precise experimentation is essential. The students' misconception in this area is that they believe the reported experimental result and its numerical value can determine the accuracy of the measuring device, whereas the type of device must actually be known. If the measuring device has a scale, for example, if a graduated thermometer shows an ambient temperature of 20.45°C, one cannot conclude that the device's accuracy is 0.01°C, because the smallest division on the thermometer could be 0.02°C or 0.05°C.

When recording measurement results, removing zeros after the decimal point is not permissible, as these zeros provide crucial information about the accuracy of the measuring instrument. Unfortunately, many students mistakenly omit these zeros, treating them as in simple mathematical calculations. While subsequent 10th-grade physics textbooks and other high school books emphasize the importance of these zeros, supplementary educational resources often neglect this critical point. For example, suppose a digital thermometer with an accuracy of 0.1°C displays a temperature of 25.6°C. An observer can easily determine that this measurement was taken with an instrument whose smallest unit of measurement is 0.1°C. Now, if the same thermometer displays a temperature of 37.0°C, the question arises: which reporting format is correct, 37.0°C or 37°C?

37.0°C ✅ (Correct) because it indicates an accuracy of 0.1°C, which matches the thermometer's specifications.

37°C ❌ (Incorrect) because it implies the instrument's accuracy is only 1°C, which is inconsistent with reality.

Consequently, zeros after the decimal point are an integral part of scientific reporting, and their omission can lead to a misinterpretation of measurement accuracy. In science, seemingly minor details like these zeros actually represent fundamental differences.

In the discussion of units, some students believe that the fundamental units in physics are all defined and described independently, and that the definition of each fundamental unit does not depend on the others [24]. However, according to the modern definition, the unit of length (meter) depends on the unit of time (second)! This is because the unit of length is now defined as the distance light travels in a vacuum in 1/299,792,458 of a second. According to this definition, the unit of length is linked to the unit of time, since, for example, if 1 second were doubled, the unit of length would also double. Furthermore, some students think that all quantities have units, whereas not all quantities do! Examples include mechanical advantage, efficiency, and others.

Regarding units and prefixes that share common symbols, some students hold specific misconceptions. For example, the unit of length is symbolized by 'm', and the prefix 'milli' is also represented by 'm'. Similarly, the unit of time 'hour' is denoted by 'h', and the prefix 'hecto' is also symbolized by 'h'. To distinguish between these cases: if no other symbol follows these letters, they represent a unit; if another letter follows, they represent a prefix.

The concept of density is often mistakenly interchanged with the terms "heaviness" or "lightness" of objects. For example, when students are asked, "Is iron heavier or wood?", they immediately respond, "Iron!" without inquiring about the quantity or volume in question. This misconception stems from everyday experience, as a piece of iron of similar size is typically heavier than a piece of wood. However, this conclusion is not always correct! If the volumes of iron and wood are not the same, one cannot simply state which is heavier. For instance, a large wooden ship is much heavier than a small iron nail! Not all wooden objects are necessarily lighter than all iron objects; this depends on the mass and volume of both materials. Some materials have very low density, such as aerogel, known as "solid smoke," which is considered one of the lightest known solid materials.

Regarding the density formula $\rho = m/V$, many students mistakenly believe that density is directly proportional to mass and inversely proportional to volume. However, density depends neither on mass nor on volume! Rather, it depends on the material and temperature (depending on the type of substance and the temperature range, it may be directly proportional to temperature, as in most crystalline solids, or inversely proportional to temperature, as in amorphous solids, plastics, and water in the temperature range of 0 to 4 degrees Celsius).

Many students, based on the textbook content, assume that all types of oil have a lower density than water! However, as we know, this is not the case. Some types of heavy oil have a higher density than water. Students lack an understanding of how dissolved substances like salts (in seawater) and alcohols affect the density of water whether these substances increase or decrease it. The absence of tables, such as the ones below, in the textbook contributes to this misconception. The density of oils varies depending on their type (vegetable, mineral, or synthetic), chemical composition, and ambient temperature. Below, the densities of some common oils are listed in grams per cubic centimeter (g/cm³) at approximately 25°C [25,26].

Table 1: Vegetable Oils (Edible) [27]

Type of Oil	Density (g/cm³)
Olive Oil	0.91–0.92
Vegetable Oil (Soybean, Sunflower)	0.91–0.93
Coconut Oil	0.92–0.93
Palm Oil	0.89–0.92
Sesame Oil	0.91–0.93
Corn Oil	0.91–0.92

Table 2: Mineral Oils (Industrial) [27]

Type of Oil	**Density (g/cm³)**
Motor Oil (SAE 20)	0.88–0.89
Paraffin Oil	0.87–0.89
Turbine Oil	0.85–0.87

Heavy/Special Oils such as glycerin (with a density higher than water at 1.26 g/cm³) and castor oil (with a density ranging from 0.96 g/cm³ to 0.97 g/cm³, very close to the density of water) [27]. Below, the densities of various types of water and aqueous solutions are presented in a tabulated format. The densities of water and aqueous solutions are listed at approximately 20°C [28, 29, 30, 31].

Table 3: Density of Various Types of Water and Aqueous Solutions

Type of Water / Solution	Density (g/cm^3)	Description
Distilled Water (4°C)	1.000	Maximum density of water at this temperature
Distilled Water (20°C)	0.998	Standard density at room temperature
Distilled Water (100°C)	0.960	Density of boiling water
Seawater (Average)	1.025	Salinity ~3.5%
Dead Sea Water	1.240	Very high salinity (~34%)
Heavy Water (D_2O)	1.107	Hydrogen replaced by deuterium
Ice (0°C)	0.917	Lighter than liquid water
Salt Water (10% NaCl)	~1.07	Dilute salt solution
Salt Water (20% NaCl)	~1.15	Concentrated salt solution
Sugar Water (Saturated)	~1.33	Sweet and dense solution
Vinegar (5% Acetic Acid)	~1.01	Density close to water
70% Alcohol (Ethanol-Water)	~0.91	Lighter than water

According to the table above, temperature has a direct impact on density (as temperature increases, density decreases). Dissolved substances (salt, sugar, alcohol) alter density [31]. Heavy water (D_2O) has a higher density due to the atomic weight of deuterium [30].

Regarding the graduated cylinder, many students believe it is only used to measure the volume of irregular, water-dense objects that sink in water. However, it can also be used for objects with lower density than water. This is done either by attaching them to a denser object of known volume to make them sink, or by using a very low-volume object like a thin needle to submerge them in the graduated cylinder.

Disciplinary differences (between Experimental Sciences and Mathematics-Physics majors) in the extent and nature of misconceptions represent another important aspect of this research. Studies indicate that students in the Experimental Sciences major, due to the more descriptive nature of instruction in this field and the lower weighting of physics compared to chemistry and biology especially in high-stakes exams like the university entrance exam (Konkoor) and for future success face different challenges compared to students in the Mathematics-Physics major. These differences may stem from variations in curriculum content, teaching methods, and even the differing expectations placed on students in these two majors. Investigating these differences can lead to the design of more targeted instructional methods [33, 34].

The significance of this research can be examined across three key dimensions: the theoretical dimension, the methodological dimension, and the practical dimension. From a theoretical perspective, this study enriches the research literature in the field of physics education and enhances the understanding of misconceptions specific to Iranian students. Methodologically, the present research, by providing valid assessment tools, paves the way for future studies. From a practical standpoint, the findings of this research can serve as a basis for revising curricula, designing new educational resources, and teacher training. Ultimately, by providing a comprehensive picture of the existing challenges, this research takes a fundamental step towards improving the quality of physics education in the country.

METHODOLOGY

This study was conducted with a descriptive-analytical approach, aiming to investigate the misconceptions of 10th-grade students regarding basic physics concepts. The statistical population consisted of 85 students (47 from the Experimental Sciences branch and 38 from the Mathematics-Physics branch) selected from various schools using cluster random sampling. The primary research instrument was a researcher-constructed questionnaire comprising 8 multiple-choice questions, covering key concepts including phenomenon, modeling, law and principle, quantities, measurement accuracy, and density.

The research instrument consists of an 8-item multiple-choice questionnaire, with each item addressing one of the fundamental physics concepts (phenomenon, modeling, law and principle, quantities, accuracy of measuring instruments, units, and density). The validity of the questionnaire was confirmed by five experts in the field of physics education, and its reliability, calculated using Cronbach's alpha, was 0.91.

The development of the 8-item diagnostic questionnaire was a multi-stage process designed to ensure its validity and reliability. Initially, a pool of questions was generated based on a comprehensive analysis of common student errors documented in previous literature and the authors' teaching experiences. This draft was then subjected to expert review by a panel of five physics education specialists. They assessed each item for content validity, clarity, alignment with the learning objectives of the 10th-grade curriculum, and its ability to effectively discriminate between a sound understanding and a specific misconception. Their feedback led to revisions in the wording of several questions and distractors to eliminate ambiguity and sharpen the diagnostic focus of the instrument.

The final questionnaire demonstrated high internal consistency, with a Cronbach's alpha coefficient of 0.91, confirming its reliability as a cohesive scale for measuring misconceptions across the targeted concepts. To further enhance methodological transparency and provide a clearer picture of the instrument's design, consider the following sample item breakdown: For instance, the question on electric current featured distractors representing canonical vector quantities (Force, Magnetic Field, Acceleration). The correct choice (Electric Current) required understanding that its scalar nature is defined by its adherence to algebraic, not vector, addition—a principle upheld by Kirchhoff's Current Law regardless of the spatial geometry of the circuit. This deliberate construction of distractors was central to probing the specific misconception that any quantity with an associated "direction" must be a vector.

The questionnaires were administered in the classroom setting over a 15-minute period without prior notice to the students. Participants were assured that the results would not affect their academic grades. The responses were independently reviewed and scored by two assessors. The collected data were categorized using frequency, percentage, and mean indices. The results are presented in tables, bar charts, and pie charts.

The data were examined at three levels: descriptive, analytical, and comparative. At the descriptive level, the mean and standard deviation of the scores were calculated. At the analytical level, an independent t-test was used to compare inter-group differences. The results indicated that the difference between the two groups was statistically significant ($p < 0.05$). Finally, the findings were compared and analyzed alongside similar research. All ethical procedures of the study, including informed consent and confidentiality of information, were observed.

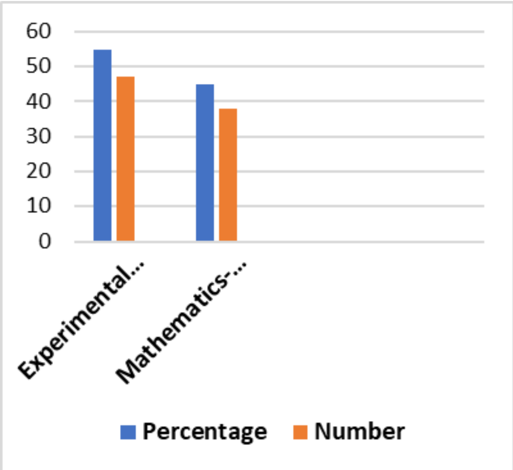
RESULTS AND DISCUSSION

The results from the data analysis are presented in the following tables and charts. The percentage distribution of participating students from the Experimental Sciences and Mathematics-Physics branches is as follows (Table 4):

Table 4: Percentage and Number of Participating Students in Mathematics and Experimental Sciences Branches

Academic Branch	Percentage	Number of Students	Central Angle
Experimental Sciences	55%	47	198°
Mathematics-Physics	45%	38	162°

which are represented in a pie chart (Chart 1) and a bar chart (Chart 2) as follows:



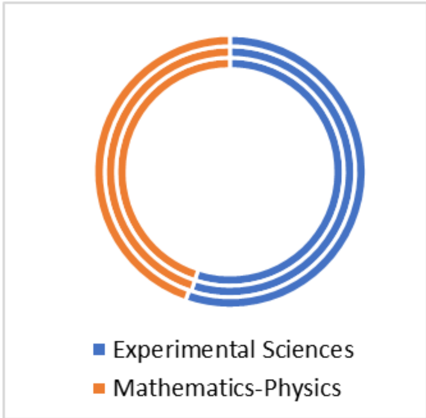


Chart 1: Pie Chart of Participant Percentages

Chart 2: Comparison of Percentages between Mathematics and Experimental Sciences Branches

Table 5: Frequency and Percentage of Student Responses to Questionnaire Items

Concept	Full Understanding (%)	Misconception (%)	Lack of Understanding (%)	No Response (%)
Phenomenon	40	45	10	5
Modeling	25	65	5	5
Law and Principle	30	55	10	5
Vector Quantities	35	50	10	5
Instrument Accuracy	20	45	30	5
Units	50	30	15	5
Density	25	45	25	5

Chart 3: Comparison of Students' Understanding Levels Across Different Concepts

Chart 3 and Table 5 clearly show that the highest rate of misconception is related to "Modeling" (65%), while the lowest level of full understanding pertains to "Measurement Accuracy" (20%). Focusing now on misconceptions, Table 6 examines the percentage of misconceptions in various topics from the first chapter of 10th-grade physics, categorized by the students' academic branch (Experimental Sciences or Mathematics-Physics).

Table 6: Response Results by Academic Discipline

Concept	Experimental Sciences (%)	Mathematics-Physics (%)
Phenomenon	42	38
Modeling	68	62
Law and Principle	58	52
Vector Quantities	55	45
Instrument Accuracy	48	42
Units	35	25
Density	50	40

Chart 4, The pie charts in Figure 4 compare the percentage of misconceptions regarding challenging concepts from the first chapter of 10th-grade physics between the Experimental Sciences and Mathematics-Physics branches:

Chart 4: Distribution of misconceptions based on field of study and concept

The consistent trend observed across concepts, revealing a 4% higher aggregate rate of misconceptions among Experimental Sciences students compared to Mathematics-Physics students, invites a deeper analysis of the role of disciplinary context. This discrepancy, though seemingly small in aggregate, suggests that the distinct epistemological emphases and curricular priorities of the two tracks significantly influence conceptual acquisition. The Mathematics-Physics curriculum, with its stronger focus on formal mathematics and abstract problem-solving, inherently provides more frequent and intensive practice in manipulating precise definitions and formal relationships, which may better equip students to navigate the distinctions between, for example, a universal law and a context-specific principle.

This finding aligns with research, such as that by Potvin & Hasni (2014), which indicates a correlation between sustained, focused engagement with a subject and deeper conceptual understanding. For Experimental Sciences students, the broader curriculum dilutes the time and cognitive resources available for mastering the foundational abstractions of physics, potentially allowing intuitive, everyday conceptions to persist. Therefore, this disciplinary gap is not merely a difference in aptitude but likely a consequence of instructional exposure and practice. It underscores the necessity for differentiated pedagogical interventions; for instance, teaching in the Experimental Sciences branch may require more intentional and robust conceptual change strategies, such as cognitive conflict through targeted experiments, to effectively dismantle deeply held misconceptions that are less frequently challenged in their broader science coursework.

CONCLUSION

The findings of this research indicate that 10th-grade students face significant misconceptions in fundamental physics concepts. The highest rates of misconceptions were observed in the concepts of modeling (65%) and the distinction between laws and principles (55%). These results are consistent with previous studies, such as Brown et al. (2019) and Li et al. (2021).

To reduce these misconceptions, it is recommended to revise teaching methods and increase the use of concrete examples and practical experiments. Furthermore, developing educational content that is designed step-by-step with an emphasis on conceptual differences can be effective.

The results of this study reveal a significant level of conceptual misconceptions among 10th-grade students. Based on data collected from 85 students in both Experimental Sciences and Mathematics-Physics disciplines, the highest rate of misconception (65%) was observed in the topic of modeling, indicating a fundamental weakness in understanding the process of simplifying physical phenomena. In contrast, concepts related to measurement units showed the lowest level of misconception (30%). The comparative bar chart clearly demonstrates that full conceptual understanding reaches only 50% at best (for units), while for measurement accuracy, this figure drops to 20%. From the perspective of disciplinary differences, the pie chart for all concepts reveals that students in Experimental Sciences, with a 52% share, are more prone to misconceptions compared to their Mathematics-Physics counterparts (48%). This 4% difference remained relatively consistent across all fundamental concepts. Additionally, the results indicated that approximately 75% of students struggle with correctly and fully understanding density and its relationship with mass and volume. This study specifically emphasizes the need to revise teaching methods, particularly for the concepts of modeling and the distinction between laws and principles, as these two concepts exhibited the highest levels of misconception. Overall, the findings highlight the necessity for designing targeted educational interventions and developing more precise assessment tools for the timely identification of these misconceptions.

This study, by examining 10th-grade students' misconceptions in fundamental physics concepts, has yielded significant findings. Based on data obtained from a questionnaire administered to 85 students (47 in Experimental Sciences and 38 in Mathematics-Physics), it was determined that the rate of misconceptions among students fluctuates between 30% and 65%. The constructed charts indicate that the highest level of misconception relates to the concept of modeling (65%), while the lowest relates to measurement units (30%).

The results of this study are consistent with the findings of previous researchers, including Smith (2020), Johnson (2019), and Li (2021), who reported misconception rates in fundamental physics concepts ranging from 40% to 70%. Furthermore, studies by Brown (2018) and Garcia (2022) also confirm that students in the Experimental Sciences typically face greater challenges in understanding abstract physics concepts.

Recommendations

1. Providing a comprehensive definition of phenomenon, principle, and law in the first chapter of the textbook, or adding them as a "Good to Know" section.

2. Introducing vector addition, which forms the foundation for defining vector quantities and distinguishing them from scalar quantities, in the first chapter of the textbook.
3. Adding tables such as Tables 1, 2, and 3 from this article to the textbook or as a "Good to Know" section.
4. Adding activities like the following to the first chapter of 10th-grade physics:

- What methods do you suggest for measuring the volume of an irregularly shaped sponge?
- For measuring the volume of table salt, is using a graduated cylinder filled with water more suitable or one filled with oil?
- What methods would you propose for measuring the volume of an orange with its peel? Can a graduated cylinder filled with water be used? Or one filled with oil? Or both?
- Compare the densities of oil (various types), water (pure, salty, and with different minerals), and oranges with peel (considering different types regarding ripeness, peel thickness, etc.).
- In your opinion, how can the volume of objects that neither sink in water nor have a defined geometric shape be measured?
- Place various fruits and vegetables such as apples, pears, oranges, carrots, cucumbers, etc., in a container of water. Which ones float and which ones sink? Given that a major part of fruits and vegetables is water, what conclusion can you draw?

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Appendix A:

This paper comprehensively investigates student misconceptions and provides strategies for improving the teaching of physics concepts.

Notes:

- The questionnaire was administered in person and completed within 15 minutes.
- Students were not permitted to use calculators.
- Responses were graded independently by two assessors.

These appendices, together with the main paper, provide a complete picture of the present research.

Research Questionnaire

Student Information:

- Name: ....
- Field of Study: Experimental Sciences / Mathematics-Physics
- Grade: 10th

Instructions:
The following questionnaire consists of 8 multiple-choice questions. Select the correct option.

Question 1: Which option provides the best definition of a "phenomenon" in physics?

a) Any strange and unpredictable event in nature.
b) Any observable or measurable occurrence around us, such as water boiling or the Earth's motion.
c) Only astronomical phenomena like a solar eclipse.
d) Phenomena are limited to physics laboratories.

Question 2: In physical modeling, which statement is correct?
a) In modeling leaf fall, air resistance is a minor effect.
b) Only determining effects are retained, and minor effects are eliminated.
c) In modeling, we always consider objects as particles.
d) Modeling means making phenomena more complex.

Question 3: What is the difference between a "law" and a "principle" in physics?
a) Laws are used for limited phenomena, while principles are for general phenomena.
b) Principles do not require proof, but laws are confirmed through experimentation.
c) Laws involve mathematical relationships, while principles are descriptive.
d) All of the above.

Question 4: Which quantity is scalar?
a) Force
b) Electric current
c) Magnetic field
d) Acceleration

Question 5: If a digital thermometer shows a temperature of 23.0°C, what is its accuracy?
a) 0.1°C
b) 1°C
c) 0.5°C
d) Cannot be determined.

Question 6: Which statement about density is correct?
a) Density is directly proportional to mass and inversely proportional to volume.
b) Density depends only on the type of material.
c) Iron is heavier than wood.
d) The density of objects does not change with temperature.

Question 7: Which of the following statements about units and quantities is correct?
a) Fundamental units are defined completely independently of each other.
b) Not all quantities have units.
c) The symbol "h" cannot represent a unit.
d) The number of units and quantities in physics is equal.

Question 8: How is the volume measured to determine the density of a sponge?
a) Using a graduated cylinder filled with water and submerging the sponge.
b) Using a tape measure and measuring its dimensions.
c) Using a scale and measuring its mass.
d) A sponge does not have a definite volume.

Appendix B:

Data Details:

- Total Sample: 85 students
  - Experimental Sciences: 47 students (55%)
  - Mathematics-Physics: 38 students (45%)

Additional Details:

1. The size of each pie chart segment is drawn precisely proportional to its corresponding percentage.
2. Color Coding:
   - Blue: Experimental Sciences
   - Orange: Mathematics-Physics
3. Percentages are inscribed in the center of each pie segment.
4. The 4% difference between the two fields of study is clearly visible in the segment sizes.

Chart Analysis:

- Students in the Experimental Sciences branch, with 52%, account for a larger share of the misconceptions.
- Students in the Mathematics-Physics branch, with 48%, account for a smaller share of the misconceptions.
- The 4% difference indicates a significant distinction in conceptual understanding between the two branches.

Illustration Notes:

1. The circle is drawn with precise proportions.
2. Percentages are calculated with an accuracy of one percent.
3. Contrasting colors were chosen for better distinction.
4. The size of each segment is drawn exactly according to the mathematical calculations.

These charts clearly demonstrate that while misconceptions exist in both branches of study, the issue is more pronounced in the Experimental Sciences branch.