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ORIGINAL RESEARCH PAPER

Analyzing Conceptual Misconceptions of Novice Teachers in the Topic of the Kinetic Theory of Gases

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ABSTRACT

The presence of conceptual misconceptions among students and novice teachers remains one of the significant challenges in science education, particularly in teaching topics related to chemistry and physics. Although the kinetic theory of gases is recognized as a fundamental concept in physical chemistry education, research evidence indicates that learners often struggle to fully grasp these concepts and face major difficulties in understanding and articulating the principles and behavior of gases. This study aims to assess the foundational understanding of students and novice teachers regarding key gas-related concepts, such as ideal gases, kinetic energy, and molecular distribution under varying conditions. A set of instructional questions was employed to evaluate participants' knowledge of gas behavior under changes in pressure and temperature, as well as other influencing factors. The results revealed that although more than 50% of students demonstrated familiarity with basic concepts in most topics, a considerable number still made significant errors in understanding more complex issues—such as the effect of temperature on kinetic energy and molecular distribution. The findings highlight the urgent need to enhance instructional strategies and suggest the use of modern educational tools and practical experiences to reinforce the learning of physical chemistry concepts. Furthermore, the results underline the importance of designing effective curricula to improve the teaching quality of fundamental science subjects.

Keywords:
Kinetic Theory of Gases, Misconceptions, Learning Challenges, Science Education

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INTRODUCTION

People engage with the scientific world through formal education in schools, instructional videos, or daily life experiences. Based on these experiences, they develop their knowledge and build connections between new concepts and prior understandings [1]. However, the extent to which these understandings align with scientifically accepted concepts remains questionable and requires careful examination.

Misconceptions are inaccurate or flawed concepts developed from individuals' personal interpretations. While they differ from core scientific ideas, they may seem reasonable due to certain practical experiences or seemingly logical reasoning [2]. Personal and everyday experiences of students with physical phenomena in their surroundings play an important role in the development of their misconceptions [3]. For an incorrect understanding to be considered a misconception, three criteria must typically be met: (1) the individual's scientific knowledge is insufficient; (2) the student provides arguments or evidence to support the incorrect belief; and (3) the individual is confident in the validity of their understanding [4].

The roots of misconceptions may stem from various sources such as textbooks, teaching methods, or students' personal interpretations of scientific content [5]. These scientific misconceptions often result from a combination of factors—from instructional approaches to students' cognitive characteristics—and remain persistent barriers to effective learning. Moreover, misconceptions can be more detrimental than a mere lack of knowledge, as students often subconsciously resist accepting new information that contradicts their prior beliefs. This cognitive dissonance can lead to frustration and disengagement [6].

One of the most important causes of students' misconceptions is their teachers [7-10]. Teachers who have not fully grasped scientific concepts themselves may unintentionally pass along incorrect information or present content in a confusing way. Furthermore, neglecting students' prior knowledge or failing to correct their incorrect assumptions can reinforce these misconceptions. As such, teachers—particularly novice teachers—must be aware of common misconceptions and actively work to address and correct them [11]. Misconceptions are among the most significant obstacles to scientific learning, as they lead to the formation and reinforcement of incorrect ideas, hindering students' proper understanding of scientific principles. This issue is particularly prevalent in foundational sciences such as chemistry and physics, which *often* involve abstract and complex concepts. When such content is not properly understood, it tends to be learned through rote memorization rather than genuine comprehension. In physical chemistry, students frequently encounter misconceptions about scientific theories. For instance, the **kinetic theory of gases** is an abstract concept that many students find difficult to understand. The lack of connection between such theories and students' everyday experiences contributes significantly to this difficulty [12].

Studies show that most research on scientific misconceptions focuses on high school students and university students [13-15]. while less attention has been given to examining misconceptions among teachers. Addressing these issues among novice teachers is particularly important, as they play a pivotal role in the accurate transmission of scientific knowledge to students. Therefore, identifying and correcting misconceptions in this group is essential for preventing the propagation of scientific inaccuracies and for enhancing the overall quality of science education [16-19].

METHODOLOGY

This research employed a descriptive-analytical design and was conducted using a survey-based approach. The statistical population consisted of 36 novice teachers from Farhangian University, who were studied to assess their level of understanding and misconceptions related to the kinetic theory of gases.

To collect data, a multiple-choice test consisting of 17 items (appendix1) was developed and administered. The test was specifically designed to evaluate the conceptual understanding of novice teachers regarding the core concepts of the kinetic theory of gases. The questions focused on key topics such as Boyle’s Law, Charles’s Law, the Ideal Gas Law, and related principles.

educational experts in science education and physics. Content validity was established through expert judgment, where each item was evaluated in terms of relevance, clarity, and alignment with the target concepts.

After administering the test, the collected data were analyzed. Descriptive statistics, including the percentage of correct and incorrect responses, were used to evaluate the responses. Additionally, a qualitative analysis of incorrect answers was performed to identify patterns of misconceptions and common conceptual errors among the participants.

The findings from this analysis provided insight into the major challenges faced in comprehending the concepts of kinetic molecular theory and revealed common trends in conceptual misunderstandings.

RESULTS AND DISCUSSION

Question 1

This question examines novice teachers’ understanding of the general properties of gases. As presented in Table A.2, only 26% of students correctly answered that gases are composed of completely separate particles with no intermolecular forces (Option B). In contrast, approximately 74% of the students demonstrated misconceptions or incorrect assumptions about this concept. A similar study conducted by Köksal (2018) on chemistry students' understanding of gases reported comparable findings [20].

Question 2

This question aimed to evaluate students’ understanding of gas behavior under compression. According to the ideal gas law, the pressure of a gas in a sealed container depends on the number of molecular collisions with the container walls and the kinetic energy of the molecules. During compression, volume decreases, intermolecular distances shorten, and the number of collisions increases, leading to a rise in pressure. The correct response is that the average kinetic energy of gas molecules increases, which in turn increases the pressure (Option C). However, incomplete conceptual models and misconceptions—such as focusing solely on increased molecular density or frequency of collisions without considering kinetic energy—led some students to select incorrect options.

Data from Table A.2 shows that only 43% of students provided the correct answer, meaning that 57% failed to identify the correct reasoning. These results suggest that while many students possess a basic understanding of pressure and kinetic energy, a significant portion still struggles to fully grasp the physical processes involved in gas compression.

Question 3

This item was originally part of the 1996 national university entrance chemistry exam in Turkey [21]. It was designed to assess students' ability to apply the ideal gas law and compare properties of two gases composed of identical atoms. In this question, students were asked to identify the incorrect statement. According to the data in Table A.2, only 31% of the students selected the correct answer (Option B), indicating that this question posed considerable difficulty for a significant portion of the participants. Approximately 23% of students believed that the kinetic energies of the two gases were different. However, given that the temperature was the same for both gases, their average kinetic energy should also be equal. In addition, 31% chose Option C, which relates to the number of moles—despite the fact that equal numbers of molecules imply equal mole counts. Furthermore, 14% of students assumed that the densities of the two gases were equal, which is incorrect because differences in molecular mass result in different densities. This highlights a misunderstanding of how various properties—such as kinetic energy, mole quantity, and density—relate to one another in gas behavior.

Overall, these results show that a substantial portion of the students had conceptual difficulties in accurately understanding fundamental ideas related to kinetic energy, mole count, and density, emphasizing the need for more targeted instruction and clarification of these concepts in science education.

Question 4

This question required students to identify the correct molecular distribution of air in a bottle after placing it in hot water. According to the response data (Table A.2), 60% of the students selected the correct option (Option D), which reflects a sound understanding of gas expansion and the uniform dispersion of molecules following heating. However, 40% of the respondents answered incorrectly, indicating a partial misunderstanding among novice teachers regarding the effect of temperature on gas molecules. Interestingly, 23% of them chose Options A or C, confusing the process of gas expansion with convection—the upward movement of warm air and the replacement by cooler air. These are fundamentally different processes with distinct physical bases.

In summary, although more than half of the participants chose the correct response, a significant proportion still require deeper conceptual clarity regarding gas behavior—particularly the role of heat in increasing molecular spacing and ensuring even particle distribution during expansion.

Question 5

According to the kinetic molecular theory, gas molecules move rapidly, continuously, and in straight lines, colliding with each other and with the container walls. During these collisions, energy may be transferred between molecules, but there is no overall loss of kinetic energy. The average kinetic energy of gas molecules depends solely on temperature and increases as temperature rises. At a given temperature, all gases have the same average kinetic energy, regardless of their molecular mass.

As shown in Table A.2, 49% of students selected Option C, the correct answer, indicating that nearly half of the participants correctly understood the relationship between temperature and average kinetic energy. However, 31% selected Option D, suggesting that they mistakenly associated kinetic energy with molecular mass, a relationship that does not exist. Additionally, 11% chose Option B and 9% selected Option A, showing even more confusion about how mass and energy relate. These students may have believed that lighter gases move faster and therefore have more energy—or vice versa—when in fact average kinetic energy depends solely on temperature, not mass or speed.

Although nearly half of the students answered correctly, the other half exhibited conceptual misunderstandings about the meaning of average kinetic energy in gases. These findings indicate the need for greater emphasis on the role of temperature in determining kinetic energy and for clear distinctions to be made between kinetic energy, molecular mass, and molecular speed in instructional practices.

Question 6

In this question, a container is divided into two chambers, I and II, separated by a porous membrane, and each is filled with gases X_2 and Y_2, respectively. The system is connected to a manometer, which initially shows equal mercury levels in both arms. After some time, the mercury level rises in arm "a" [21], indicating that gas X_2 has diffused more quickly through the membrane than gas Y_2.

According to Graham's Law, the diffusion rate of a gas is inversely proportional to the square root of its molar mass. Therefore, if X_2 diffuses faster than Y_2, it implies that Y_2 has a greater molar mass than X_2. Additionally, as gas X_2 enters chamber II, it contributes to the overall pressure increase in that chamber. Based on Table A.2, 54% of students selected Option C (statements 2 and 3), which suggests that most of them understood the relationship between molar mass and pressure. However, they failed to correctly identify the role of molecular speed in diffusion.

32% of students (9% chose Option A and 23% chose Option B) demonstrated partial understanding, correctly interpreting only one of the two key concepts. These students may have recognized the link between speed and molar mass but overlooked the pressure change—or vice versa. Only 14% of the participants selected the fully correct answer (Option D), showing a comprehensive understanding of Graham's Law and how molar mass affects both diffusion rate and pressure dynamics. These findings highlight the need to strengthen students' conceptual grasp of gas behavior, particularly the simultaneous effects of molar mass on speed and pressure during diffusion.

Question 7

In the initial condition, as more air particles are pumped into the ball, its internal pressure increases. However, the ball's volume also expands, which balances the pressure. As a result, the internal pressure becomes equal to the external atmospheric pressure, maintaining equilibrium (otherwise, the ball would burst). When air begins to escape from the ball, its pressure again aligns with the surrounding air pressure.

According to gas laws, pressure depends on the volume, temperature, and number of gas particles. The more gas particles are present in a given space, the higher the pressure. In the case of the ball, increasing the number of gas molecules leads to an increase in volume, keeping the pressure stable and equal to the ambient pressure.

Based on Table A.2, 31% of the students selected Option A ($P_1 > P_3 > P_2$), which reflects a misunderstanding of pressure relationships. These students likely believed that the internal pressure remains higher than the external pressure even after the valve is opened—an incorrect assumption, as the release of air brings internal and external pressures into balance. 26% of the students chose Option B ($P_3 > P_2 = P_1$), which also reflects an inaccurate interpretation, suggesting that the internal pressure increases after the valve is opened. In reality, once the valve is open, the internal pressure must equal the atmospheric pressure ($P_3 = P_2$).

Another 31% correctly selected Option C ($P_1 = P_2 = P_3$), demonstrating a proper understanding of the scenario. When the valve is opened and air escapes, the internal pressure of the ball adjusts to match the external pressure, achieving equilibrium. 11%

of students selected Option D ($P_1 = P_3 > P_2$), which reflects a flawed understanding, as the internal pressure should not exceed the ambient pressure after the valve is opened. This choice indicates a conceptual error in recognizing how pressure equilibrates in open systems.

Question 8

Avogadro's Law states that two samples of ideal gases with equal pressure, temperature, and volume contain the same number of molecules, regardless of their molecular masses. This means the number of molecules or atoms in a sample of ideal gas is independent of molar mass. According to this principle, molar volume is constant for all ideal gases under identical conditions. In this question, 28% of students selected Options B or C, suggesting they mistakenly believed that lighter gases like hydrogen or heavier gases like carbon dioxide contain more molecules due to differences in mass. In contrast, 71% correctly selected Option D—the right answer—recognizing that under standard temperature and pressure (STP) conditions, all ideal gases contain the same number of molecules, since they occupy the same volume at equal pressure and temperature.

This indicates that a majority of students had an accurate understanding of ideal gas behavior and STP conditions. However, a minority still displayed confusion by incorrectly linking molecular mass to molecular count, highlighting a common misconception that instructional strategies should aim to correct.

Question 9

An analysis of the results presented in Table A.2 shows that only 32% of the respondents correctly selected Option A. In contrast, 68% of the participants provided incorrect responses, indicating the presence of misconceptions about gas behavior.

The most frequently selected incorrect answer was Option C (37%). Those who chose this option may have believed that decreasing the temperature causes gas particles to move toward the center of the container. However, according to the principles of ideal gas behavior, gas particles tend to evenly distribute throughout the available space, and such clustering does not occur.

Option B was selected by 14% of novice teachers. These participants may have mistakenly assumed that gravitational force, combined with lower temperature, would cause lighter gas molecules like helium to accumulate at the bottom of the container. However, under normal conditions and for ideal gases, the effect of gravity on gas distribution is negligible, and molecules remain uniformly dispersed throughout the container. Another 14% chose Option D, reflecting the incorrect belief that decreasing the temperature leads to a reduction in molecular size. Scientifically, temperature affects only the kinetic energy of particles—not their physical size—which remains constant regardless of temperature changes. This pattern of responses suggests that a considerable proportion of novice teachers face conceptual challenges in accurately understanding the behavior of ideal gases, especially regarding the role of temperature in molecular distribution. To enhance conceptual understanding in this area, the use of computer simulations, molecular modeling, and simple, observable experiments is recommended. These tools can be highly effective in addressing misconceptions and strengthening comprehension of gas-related phenomena.

Question 10

At constant temperature, during the phase change of a pure substance from liquid to gas, only the distance between particles increases. The size of the particles remains constant, and average kinetic energy changes only with temperature variation.

Despite this, 54% of participants selected Option D, suggesting that more than half of the students incorrectly believed that both average kinetic energy and particle spacing increase during this transition. This mistake likely stems from a failure to differentiate between temperature change and phase change occurring at constant temperature. Many learners seem to assume that converting a liquid to a gas requires an increase in average kinetic energy, while in reality, if temperature remains unchanged, the kinetic energy stays constant, and only the intermolecular distance increases. Only 29% of students chose the correct answer (Option B), indicating that less than one-third of the novice teachers had an accurate understanding of the concept. Additionally, 17% selected Option C, reflecting another serious misconception—the belief that molecular size changes during a phase transition.

These results highlight the need for clear instruction distinguishing between the effects of temperature and phase changes, as well as better conceptual clarity regarding microscopic particle behavior during state transitions.

Question 11

According to Boyle’s Law, in a closed system at constant temperature, there is an inverse relationship between the volume and pressure of a gas—meaning that as volume decreases, pressure increases, and vice versa. In this question, 69% of novice teachers selected Option D, which is the correct answer. This option reflects the understanding that as water enters the container, the volume of the trapped air decreases, causing the internal pressure to rise, which then resists the further entry of water. This high percentage suggests a good overall awareness among novice teachers of the volume–pressure relationship in closed conditions. In contrast, 9% of the respondents chose Option A, which, although it refers to the entry of water, provides only a superficial explanation and fails to address the core reason—the increase in internal air pressure.

11% selected Option B, which mentions buoyant force. However, this force—resulting from the difference in density between air and water—does not play a significant role in preventing the entry of water. This response may reflect a conceptual overlap between gas laws and buoyancy effects in the minds of some novice teachers.

Another 11% selected Option C, which, like Option B, focuses on hydrostatic forces. Nevertheless, it should be emphasized that the primary reason water stops entering the container is the increase in internal pressure due to reduced gas volume, not the direct effect of hydrostatic or upward forces from the liquid.

Question 12

According to the kinetic theory of gases, gas molecules move in all directions with random, continuous motion. As a result, gases naturally mix and do not form stable layers. This process, known as molecular diffusion, is the primary mechanism behind gas mixing—even when the gases have different molar masses.

In this question, Option A, which correctly explains diffusion, was selected by 31% of novice teachers. This is the correct answer, as diffusion allows gases to mix regardless of differences in molar mass. However, the relatively low percentage of correct responses indicates a lack of understanding among many novice teachers about actual gas behavior.

Option B, selected by 11% of respondents, is incorrect. While molar mass can influence molecular speed, random motion and collisions are the dominant factors in gas mixing—not molecular mass alone. The most frequently selected incorrect answer was Option C (chosen by 50% of participants). This choice reflects the common misconception that heavier gases tend to settle at lower levels due to having lower pressure. In reality, gas pressure depends on particle number density and temperature, not molar mass. This misunderstanding of the relationship between gas mass, pressure, and position in a closed system is one of the most significant misconceptions identified in this section. Option D, selected by just 6% of participants, is also entirely incorrect, as molecular shape has no effect on the distribution or mixing behavior of gases. This choice likely stems from a misinterpretation of how molecular structure relates to macroscopic gas behavior.

To improve instruction of these concepts, it is recommended to use computer simulations, educational videos, or simple hands-on experiments—such as observing the diffusion of perfume in a room—to provide learners with a tangible understanding of gas mixing. Additionally, comparing the behavior of gases with that of liquids—which do layer due to differences in density—can help clarify the distinct physical behaviors of these two states of matter.

Question 13

According to Dalton's Law of Partial Pressures, the pressure exerted by a gas in a mixture is directly proportional to the number of moles of that gas present and is independent of its molar mass. In fact, the sum of the partial pressures of the individual gases in a mixture equals the total pressure of the system. In this question, Option C was selected by 49% of novice teachers, making it the correct answer. This choice reflects a proper understanding of Dalton's Law—that partial pressure depends only on mole quantity, not molecular mass. The relatively high percentage of correct responses suggests that about half of the participants had a solid grasp of this foundational concept in physical chemistry. However, 14% of students chose Option A, reflecting a common misconception—the incorrect belief that gases with higher molar mass exert greater pressure. In reality, pressure is determined by the number of particles per unit volume, not their mass.

Although approximately half of the students selected the correct response, the presence of a substantial number of incorrect answers—particularly those linked to misconceptions about the role of molar mass—indicates a significant learning gap. To address these misunderstandings, educators should place greater emphasis on the relationship between mole count and pressure in teaching Dalton's Law. The use of concrete examples, visual simulations, and hands-on experiments can greatly aid in reinforcing this principle and correcting incorrect assumptions.

Question 14

Ammonia (NH_3) shows the greatest deviation from the ideal gas law due to its strong hydrogen bonding interactions. In contrast, helium (He) exhibits minimal deviation and behaves almost ideally under most conditions. 57% of novice teachers correctly identified ammonia as the gas with the greatest deviation, demonstrating a good understanding of how intermolecular forces influence gas behavior. However, 20% selected helium, likely due to a misunderstanding of the term "deviation from ideality," since helium actually adheres closely to ideal gas behavior.

Hydrogen and nitrogen, each selected by 11% of students, are relatively ideal gases. Participants who chose these options likely underestimated the role of intermolecular forces, especially hydrogen bonding, in causing deviation from ideal gas laws.

While a majority of the novice teachers correctly recognized ammonia as the gas that deviates most, the selection of less reasonable options like helium by a notable minority indicates an incomplete understanding of what it means for a gas to behave ideally. These results highlight the importance of reinforcing the connection between intermolecular forces and non-ideal gas behavior in chemistry instruction.

Question 15

According to the ideal gas law, the pressure of a gas in a system depends only on the number of moles of gas present. Neither the type of gas nor its molar mass affects the amount of pressure it exerts. In this question, 37% of novice teachers selected Option C, the correct answer, indicating a moderate level of understanding among this group regarding the concept of pressure in ideal gases. However, the relatively low percentage of correct responses suggests that a significant number of participants still face conceptual challenges in grasping this principle. On the other hand, 14% of respondents chose Option A, which reflects the misconception that lighter gases exert more pressure. This belief contradicts the ideal gas law, which states that an increase in the number of moles, regardless of the gas's mass, leads to an equal increase in pressure.

Similarly, 31% selected Option B, indicating the mistaken assumption that heavier gases (like methane) exert greater pressure. In reality, only the number of gas particles per unit volume determines pressure—not their mass.

Finally, 17% of novice teachers selected Option D, further reinforcing the persistence of the incorrect belief that molar mass plays a direct role in determining gas pressure.

Overall, the results from this item show that only about one-third of novice teachers could correctly identify the relationship between pressure and mole count, while over 60% remain entangled in misconceptions about the influence of gas type on pressure. These findings emphasize the need for a pedagogical shift in the way gas behavior is taught—through experimental demonstrations, interactive models, and active learning strategies—to effectively address and correct these conceptual misunderstandings.

Question 16

According to the kinetic molecular theory, the average speed of gas molecules is determined by the following equation:

$$v = \sqrt{\frac{8RT}{\pi M}}$$

where v is the average molecular speed, R is the gas constant, T is the temperature, and M is the molar mass of the gas. The inverse relationship between average speed and molar mass in this formula shows that the lower the molar mass, the higher the molecular speed.

Based on this principle, helium (He) has the fastest moving molecules among the options, making Option C the correct answer. 60% of novice teachers selected this option, indicating that a majority understood the dependency of molecular speed on molar mass. However, 26% selected Option D (CO_2), which is incorrect since CO_2 has the highest molar mass among the given gases and thus the lowest molecular speed. This choice suggests that a significant number of novice teachers still do not fully comprehend the inverse relationship between mass and speed.

Option B (N_2) was chosen by 9% of respondents. While nitrogen is lighter than oxygen and CO_2, it is still heavier than helium. Those who chose this may have recognized the inverse relationship between molar mass and speed but mistakenly assumed nitrogen had the lowest mass.

Option A (O_2) received 6% of responses. Although oxygen is lighter than CO_2, it is still significantly heavier than helium, making this choice clearly incorrect as well. This small group may have incorrectly believed that oxygen is the fastest gas among the choices. A common misconception revealed by this item is the belief among some novice teachers that heavier gases might move faster, whereas the scientific reality is exactly the opposite. These results underscore the importance of emphasizing the mathematical basis and physical interpretation of kinetic theory in instruction, particularly how molecular mass inversely affects particle velocity.

Question 17

This question, like Question 13, evaluates students' understanding of Dalton's Law of Partial Pressures. According to this law, the partial pressure of a gas in a mixture depends only on the number of moles of that gas and the total pressure of the system. Properties such as molar mass or gas type do not influence partial pressure.
In this question, Option B was the most frequently chosen response, selected by 66% of novice teachers. This indicates that a significant proportion of participants had a correct understanding of the law. Option B accurately emphasizes that the partial pressure of each component gas is proportional to its mole fraction in the mixture.
However, 14% of participants selected Option A, reflecting a common misconception—the belief that molar mass affects partial pressure. This is scientifically incorrect, as partial pressure is determined solely by mole count, not the mass of the gas.
Similarly, 14% chose Option C, indicating that some novice teachers mistakenly believed temperature to be the only factor influencing partial pressure, while overlooking the critical role of mole quantity.
Finally, Option D was chosen by 6% of respondents. This response reveals the mistaken belief that all gases in a mixture contribute equally to total pressure. In reality, equal partial pressures only occur when gases are present in equal mole quantities.
Overall, while the majority of novice teachers selected the correct answer, the presence of conceptual errors in approximately 35% of responses indicates that some participants still struggle to clearly distinguish the factors that influence partial pressure. This highlights the need for targeted instructional strategies, including problem-solving activities, conceptual discussions, and hands-on experiments, to help learners solidify their understanding of gas laws and prevent persistent misconceptions.

CONCLUSION

The findings of this study highlight significant conceptual challenges and misunderstandings among novice teachers in comprehending the foundational principles of the kinetic molecular theory of gases. An analysis of the test responses reveals that, while these future educators are relatively familiar with basic concepts, they encounter notable misconceptions when dealing with more abstract or advanced ideas—particularly regarding the relationship between temperature and kinetic energy, gas pressure, and molecular spacing.
This outcome aligns with the findings of Lin et al. (2000), who reported that even high-achieving students and in-service chemistry teachers often hold deep-seated misconceptions about gas laws that are resistant to conventional instruction [22]. In the present study, novice teachers struggled to explain the link between temperature and kinetic energy and to understand molecular distribution, which echoes the results of Köksal (2018) [20]. He found that pre-service teachers often harbored inaccurate beliefs, such as gas particles expanding upon heating or being unevenly distributed in closed containers. A key strength of this research lies in identifying that many of these misconceptions stem from a partial understanding of basic physical and chemical processes. This is consistent with Ivowi (2017), who noted that students' misconceptions often persist despite years of formal education, and that many teachers are either unaware of these misconceptions or unable to anticipate them effectively [5].
It appears that novice teachers may carry these misunderstandings from earlier stages of

learning, and that university-level education has not been fully effective in correcting them.

The findings clearly indicate that a substantial portion of the conceptual errors observed are rooted in an incomplete grasp of fundamental processes that are essential for explaining gas behavior. Furthermore, the study emphasizes the importance of incorporating innovative instructional methods, including digital simulations, interactive molecular models, and AI-based educational technologies, into science education. These tools can significantly aid in visualizing abstract concepts and in correcting misconceptions. In this context, Kuczmann (2017) suggested that the knowledge structures of pre-service teachers may be incomplete, and the absence of "information completion rules" or coherent "chains of reasoning" contributes to the persistence of misunderstandings. Kuczmann recommended emphasizing mastery of basic principles and fostering strong conceptual linkages [23]. Additionally, Kulgemeyer and Wittwer (2022) demonstrated that inaccurate explanations, such as those found in some instructional videos, can lead to an “illusion of understanding,” ultimately hindering genuine learning [1]. This finding underlines the need for using accurate and credible educational tools in teacher training, to prevent the transmission of misconceptions to future students. Consequently, there is a compelling need for a fundamental revision in the pedagogy of science education, particularly in physical chemistry. The use of active learning strategies, the design of concrete experimental situations, and the incorporation of practical and laboratory activities, along with fostering critical thinking and learner engagement, can significantly enhance conceptual understanding.

Ultimately, the results of this study underscore that effective science learning is not merely a process of information transfer, but requires the cultivation of learners’ abilities to reason, analyze, and explain scientific phenomena. Thus, the development of more effective instructional approaches and a reconsideration of current curricular content are essential to fostering deep and lasting understanding of complex scientific concepts among students.

In light of the conceptual challenges identified in this study—particularly novice teachers’ misconceptions regarding abstract concepts in the kinetic molecular theory of gases—it is recommended that more innovative and active teaching approaches be incorporated into the instruction of physical chemistry and related topics. The key instructional strategies proposed are as follows:

1. Utilize interactive 3D simulations and models to visually demonstrate molecular behavior under various conditions (e.g., increased pressure, temperature changes, and volume shifts) in order to enhance students’ conceptual visualization.
2. Design simple, hands-on classroom experiments, such as those using syringes, balloons, or basic laboratory tools, to enable students to directly observe changes in pressure, volume, and particle spacing.
3. Integrate artificial intelligence technologies and educational software based on virtual or augmented reality, particularly for conveying complex and abstract scientific ideas.
4. Implement problem-based learning (PBL) approaches, creating opportunities for students to analyze real-life situations and engage in problem-solving during class, with the aim of fostering critical and analytical thinking.

5. Revise and redesign textbook and curriculum content, focusing on the gradual and scaffolded presentation of abstract concepts, while linking them to learners' real-world experiences and prior knowledge.
6. Employ formative assessment techniques to identify misconceptions during the teaching–learning process and provide timely feedback and correction.
7. Create opportunities for group work, discussion, and scientific dialogue in the classroom to promote scientific reasoning and dispel incorrect beliefs through peer interaction and collaborative inquiry.

References

[1] Kulgemeyer, C., & Wittwer, J. (2022). Misconceptions in physics explainer videos and the illusion of understanding: An experimental study. International Journal of Science and Mathematics Education, 21(2), 417–437. https://doi.org/10.1007/s10763-022-10265-7

[2] Kuczmann, I. (2024). The structure of knowledge and students' misconceptions in physics. Nádasi Ferenc Gimnázium Budapest.

[3] Neidorf, T., Arora, A., Erberber, E., & Tsokodayi, Y. (2020). Student misconceptions and errors in physics andmathematics: Exploring data from TIMSS and TIMSS. Springer. https://doi.org/10.1007/978-3-030-30188-0

[4] Niğde Ömer Halisdemir University. (2018). Faculty of Education, Science Education, Niğde, Turkey, July 2018, Vol: 3, Issue: 3.

[5] Ivowi, U. M. O. (2017). Students' misconceptions about conservation principles and field. Research, Science and Technology Education, 4(2), 127-137 https://doi.org/10.1080/0263514860040203

[6] Chen, C., Sonnert, G., Sadler, P. M., Sasselov, D., & Fredericks, C. (2019). The impact of student misconceptions on student persistence in a MOOC. Journal of Research in Science Teaching, 1–32. https://doi.org/10.1002/tea.21616

[7] Arends, R. I. (2012). Learning to teach (9th ed.). McGraw-Hill. http://onlinelibrary.wiley.com/doi/10.1002/cbdv.200490137/abstract

[8] Resbiantoro, G., & Nugraha, A. W. (2017). Miskonsepsi mahasiswa pada konsep dasar gaya dan gerak untuksekolah dasar. Jurnal Pendidikan Sains (JPS), 5(2), 80–87. https://doi.org/10.26714/jps.5.2.2017.80-87

[9] Skamp, K. (2012). Teaching primary science. Australian Academy of Science.

[10] Soeharto, S., Csapó, B., Sarimanah, E., Dewi, F. I., & Sabri, T. (2019). A review of students' common misconceptions in science and their diagnostic assessment tools. Jurnal Pendidikan IPA Indonesia, 8(2), 247–266. https://doi.org/10.15294/jpii.v8i2.18649

[11] Nakiboğlu, C. (2006). Fen ve teknoloji öğretiminde yanlış kavramalar. İçinde M. Bahar (Ed.), Fen ve Teknoloji Öğretimi (s. 190–217). Ankara: Pegem A Yayıncılık.

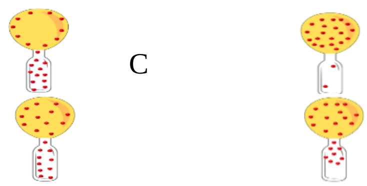
[12] Nik Syaharudin, N., Abd Karim, M. M., Wan Noraini, S. W., & Abdul Rahman, N. (2015). Misconception and difficulties in introductory physics among high school and university students: An overview in mechanics. EDUCATUM - Journal of Science, Mathematics and Technology, 2(1), 34–47. https://doi.org/10.12345/edumath.2015.2.1.34

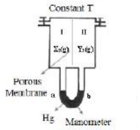
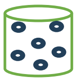
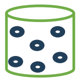
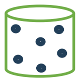
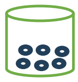
[13] Neidorf, T., Arora, A., Erberber, E., & Tsokodayi, Y. (2020). Student misconceptions and errors in physics andmathematics: Exploring data from TIMSS and TIMSS. Springer. https://doi.org/10.1007/978-3-030-30188-0

[14] Daud, N. S. N., Karim, M. M. A., Hassan, S. W. N., & Rahman, N. A. (2015). Misconception and difficulties in introductory physics among high school and university students: An overview in mechanics. EDUCATUM - Journal of Science, Mathematics and Technology, 2(1), 34-47. ISSN 2289-7070.
[15] Achor, E. E., Ellah, B. O., & Omaga, J. O. (2022). Misconceptions and difficult concepts as determinant of students' academic engagement and retention in physics. Jurnal Varidika, 34(1), 42–52. https://doi.org/10.23917/varidika.v1i1.17660
[16] Kumandaş, B., Ateskan, A., & Lane, J. (2019). Misconceptions in biology: A meta-synthesis study of research, 2000–2014. Journal of Biological Education, 53(4), 350–364. https://doi.org/10.1080/00219266.2018.1490798
[17] Kaltakci-Gurel, D., Eryilmaz, A., & McDermott, L. C. (2015). A review and comparison of diagnostic instruments to identify students' misconceptions in science. Eurasia Journal of Mathematics, Science and Technology Education, 11(5), 989–1008. https://doi.org/10.12973/eurasia.2015.1369a
[18] Resbiantoro, G., Setiani, R., & Dwikoranto. (2022). A review of misconception in physics: The diagnosis, causes, and remediation. Journal of Turkish Science Education, 19(2), 403–427. https://doi.org/10.36681/tused.2022.128
[19] Theobald, M., & Brod, G. (2021). Tackling scientific misconceptions: The element of surprise. Child Development, 92(5), 2128–2141. https://doi.org/10.1111/cdev.13582
[20] Köksal, E. A. (2018). Students' understanding of gas concepts. Journal of Scientific Perspectives, 3(3). https://ratingacademy.com.tr/journals/index.php/jsp/
[21] Yalçınkaya, E. (2010). Effect of case-based learning on 10th grade students' understanding of gas concepts, their attitude and motivation (Doctoral dissertation, Middle East Technical University). Middle East Technical University Institutional Repository
[22] Lin, H. S., Cheng, H. J., & Lawrenz, F. (2000). The assessment of students and teachers' understanding of gas laws. Journal of Chemical Education, 77(2), 235.
[23] Kuczmann, I. (2017, December). The structure of knowledge and students' misconceptions in physics. In AIP Conference Proceedings (Vol. 1916, No. 1). AIP Publishing.

Appendix A:

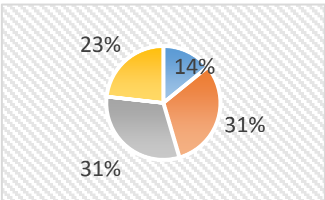
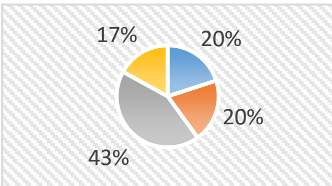
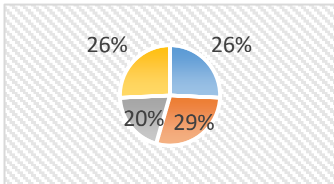
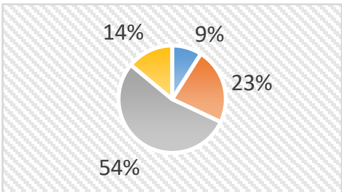
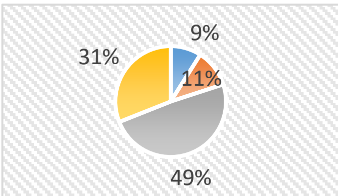
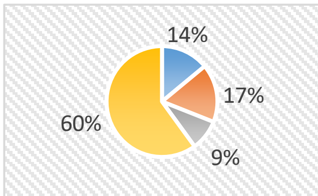
Table A.1: Questionnaire

No.	Question	Options	Correct Answer
1	Which of the following is true about gases?	A) The volume a gas occupies depends on the type and number of atoms in the gas molecules. B) Gases consist of completely separate particles with no forces between them. C) The pressure of a gas depends on its type and molecular mass. D) The smaller the gas particles, the higher their kinetic energy.	B
2	At a constant temperature of 25°C, an ideal gas is placed in a sealed syringe. If the piston is slowly pushed inward, which of the following statements is incorrect?	A) Molecules strike the walls more frequently, increasing pressure. B) The distance between particles decreases, leading to increased pressure. C) The average kinetic energy of particles increases, increasing pressure. D) The number of particles per unit volume increases, increasing pressure.	C
3	Ideal gases X_2 and X_3 have equal temperature, volume, and number of molecules. Which of the following comparisons is incorrect?	A) Densities are different. B) Pressures are different. C) Number of moles is the same. D) Average kinetic energy is the same.	B
4	A balloon is attached to the neck of a bottle full of air and placed in hot water. After some time, the balloon inflates. Which of the following diagrams best represents the distribution of air molecules?	 C A D B	D
5	Which statement is correct about the comparison of average kinetic energy of oxygen, carbon dioxide, and hydrogen gases at 25°C?	A) $H_2 < CO_2 < O_2$ B) $CO_2 < O_2 < H_2$ C) $H_2 = CO_2 = O_2$ D) $CO_2 > O_2 > H_2$	C
6	In the setup shown in Figure (A)... Based on this, which statements are correct? 1) X_2 molecules move faster than Y_2; 2) Y_2 has a higher molecular mass; 3) Pressure in chamber II inc reased.	A) Only 1 B) Only 2 C) 2 and 3 D) 1, 2, and 3	D

			
7	Consider an air-filled ball initially at pressure P_1... If the valve is opened and air is released, what is the correct relation between pressures?	A) $P_1 > P_3 > P_2$ B) $P_3 > P_2 = P_1$ C) $P_3 = P_2 = P_1$ D) $P_1 = P_3 > P_2$	C
8	Under STP, we have three 10-liter containers filled with chlorine, hydrogen, and carbon dioxide gases... which contains the most molecules?	A) Chlorine B) Hydrogen C) Carbon dioxide D) All have the same	D
9	Figure (B) shows the molecular distribution of helium gas in a closed container at 25°C and 1 atm. If temperature decreases to -70°C, which distribution is most accurate?  F)	 C  A  D  B	A
10	At constant temperature, during the phase transition of a pure substance from liquid to gas, which particle characteristic changes?	A) Average kinetic energy B) Distance between particles C) Both average kinetic energy and particle size D) Both average kinetic energy and distance between particles	B
11	A funnel is placed inside a sealed container, and water is poured in. As the water level reaches the funnel's end, it becomes harder to pour more water. Why?	A) The opening is blocked by water B) Buoyant force prevents flow C) Upward water pressure resists flow D) Increased internal pressure prevents flow	D
12	Why don't heavier-than-air gases always settle at lower levels?	A) Due to random molecular motion, they mix with other gases. B) Because of their mass, they exert less pressure. C) This statement is incorrect; heavy gases do settle. D) It depends on the molecular shape.	A
13	A container holds a gas mixture of H_2 and O_2 at constant temperature. If their mole numbers are equal, which is true about partial pressures?	A) O_2 has higher partial pressure B) H_2 has higher partial pressure C) Both have equal partial pressure D) Partial pressure depends on molecular mass	C
14	Which gas deviates most from ideal gas behavior under the same conditions?	A) Hydrogen (H_2) B) Nitrogen (N_2) C) Ammonia (NH_3) D) Helium (He)	C

15	If temperature and volume of a container are constant, increasing the number of molecules of which gas increases pressure more? H_2 or CH_4?	A) Only H_2 B) Only CH_4 C) Both equally D) Depends on molecular mass	C
16	Which gas has the highest average molecular speed at the same temperature?	A) Oxygen (O_2) B) Nitrogen (N_2) C) Helium (He) D) Carbon dioxide (CO_2)	C
17	A gas mixture contains O_2, Ar, and CO_2. Which statement about their partial pressures is correct?	A) Depends on molecular mass B) Proportional to mole number C) Depends only on temperature D) All have equal partial pressure	B

Table A.2: Status of Responses to Questions

Option A: Blue color , **Option B**: Orange color, **Option C**: Gray color, **Option D:** Yellow color		
		
Question 3	Question 2	Question 1
		
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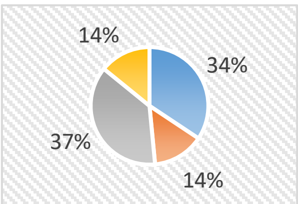	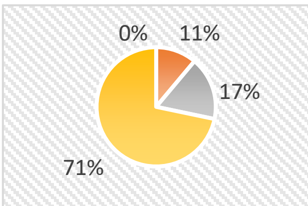	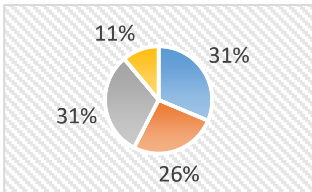
Question 9	Question 8	Question 7

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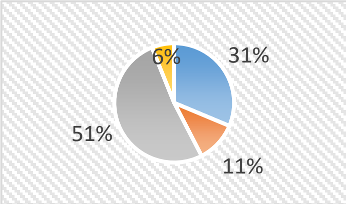
<td>
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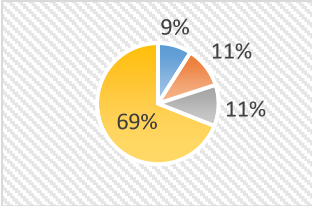
<td>
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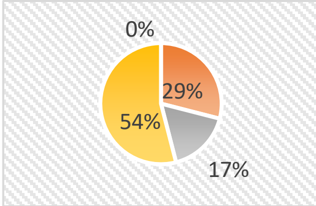
<td>
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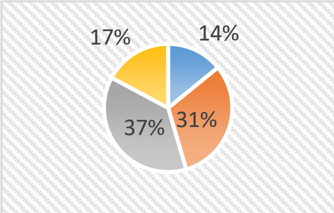
<td>
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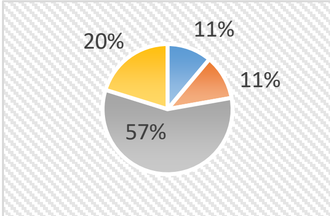
<td>
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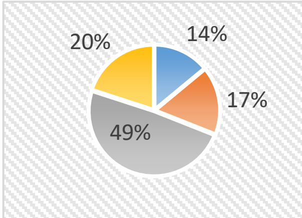
<td>
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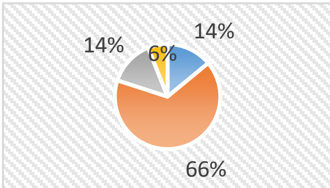
<td>
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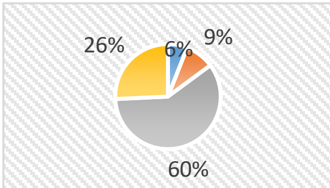
<td>
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