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*Research Article*

# Medical school students' misconceptions regarding concept of density

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Throughout the years, scientific research has increasingly aimed to identify students' misconceptions and alternative views regarding fundamental concepts and principles of chemistry. Valuable international bibliographic information was created, including details on teaching density and gaining respondent acceptance. The study aimed to explore alternative ideas about density among Lyceum's honours graduate students attending medical school. Moreover, the gender parameters of the participants were examined. A multiple-choice questionnaire was administered to students to collect data on their gender, age, interest in chemistry, and basic knowledge of chemistry concepts, notably density. Furthermore, we analyzed participants' answer accuracy to determine if gender influenced responses or if they were due to statistical fluctuations. In particular, the statistical analysis of the data collected shows that many honours students in the Greek educational system retain a large percentage of the alternative ideas about chemistry concepts. Additionally, the misconceptions recorded in the questions did not correlate with parameters such as grades in the Panhellenic exams, gender, or the student's interest in the chemistry course. Our study's results could improve science teaching by transforming curriculum design and teacher training and enhancing the quality of science instruction in schools.

Keywords: Alternative ideas; Chemistry; Density; Misconceptions

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## 1. Introduction

Students develop their understanding of how the world operates through their interactions with others, their exposure to diverse cultures, and the literature they engage with. These interpretations, ideas, and perceptions enable students to make sense of the various phenomena they encounter daily (Bada & Olusegun, 2015; Panagou et al., 2022).

When students enter classrooms, they frequently bring with them preconceived notions about various phenomena and their workings. These perceptions may diverge from scientific views and can profoundly influence their observations, interpretations, communications, and assimilation of new information. Therefore, it is essential to acknowledge and address these pre-existing ideas, as they exert a significant impact on the learning process (Driver, 1989; Talanquer, 2006; Kotsis & Panagou, 2023). Understanding and engaging with students' initial understandings can enhance instructional strategies and foster deeper conceptual understanding in educational settings.

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Physics, chemistry, biology, geology, astronomy, meteorology, and environmental sciences are dedicated to observing and studying physical and chemical natural phenomena. Scientists in these fields aim to determine the principles behind these phenomena through experiments and observations. Physics, for example, focuses on natural phenomena, while chemistry is concerned with chemical phenomena. Conversely, biology deals with chemical and biological phenomena directly related to life.

Therefore, according to the Greek and International literature, several researchers have conducted empirical studies on students', even teachers', perceptions and knowledge in the field of physics, particularly in mechanics, electricity, thermodynamics, and magnetism (Gavrilas & Kotsis; Kotsis & Panagou, 2022; Kostis et al., 2023; Mbonyiryivuze et al., 2019; Panagou & Kotsis, 2022; Panagou & Kotsis, 2023; Panagou et al., 2024a; Suyatna, 2019). Similarly, studies have been conducted on fundamental concepts and principles of biology, such as evolutionary theory (Fisher et al., 2022; Panagou et al., 2024b; Pazza & Penteado, 2010). However, there is a lack of research regarding chemistry and density. Therefore, further studies are needed to explore this physical phenomenon in greater detail.

Hence, we conducted this research study to enrich the existing literature on students' alternative perceptions and generate new insights regarding density.

## 2. Literature Review

Based on international literature, chemistry is a subject that deals with microcosms, which is not familiar to students before they enter school (Onwu & Randall, 2006; Thompson et al., 2023). Consequently, students often develop misconceptions about Chemistry due to the curriculum, teaching methods, imprecise language, and the abstract and symbolic nature of the course content (Gilbert & Treagust, 2009; Sevian & Talanquer, 2014).

Quantity Density is a fundamental characteristic of matter and is defined as the quotient of mass per unit volume, i.e., density shows how dense the matter is in a body (Koch & Holthausen, 2015). It expresses the amount of mass per unit volume. Density is a characteristic property of any material and is an intensive property of matter; that is, it does not depend on the size of an object or the amount of its matter (Edsall & Wyman, 2014; Silverman, 2018).

Density is a physical property that distinguishes material bodies based on their different density values (Cohen et al., 2012). This property is related to various phenomena, such as the sinking or floating of solid bodies in liquids, the material's purity, and its identification (Sholl & Steckel, 2022). The density of liquids remains almost constant even when there are significant changes in pressure and temperature (Rowlinson & Swinton, 2013; Tyrrell & Harris, 2013). On the other hand, the density of gases varies significantly when there are changes in pressure and temperature because gases are compressible, which means that changes in volume occur without corresponding changes in mass. Conversely, solids are practically incompressible (Xu & Clarke, 2012; Zucker & Biblarz, 2019). Because they are easier to measure and control, liquids and solids are chosen for teaching density.

Density is a complex quantity that cannot be measured directly (Engel, 2011; Koch & Holthausen, 2015). The concept of density is defined with the help of two quantities: the mass and volume of a material (Scott, 2015). Any misunderstandings regarding mass and volume can lead to misunderstandings regarding density (Allen, 2019). The volume of a body is a three-dimensional function and can be interpreted as size, quantity, capacity, or the amount of liquid matter displaced (Primas, 2013).

The literature has meticulously documented several prevalent misconceptions that both male and female students hold regarding density and its fundamental concepts of mass and volume. Among these misconceptions is the tendency to conflate mass with volume, leading to the erroneous belief that objects with large volumes must necessarily possess large masses, and conversely, that objects with smaller volumes must inherently have smaller masses. Moreover, students frequently misunderstand density as an extensive property, wrongly assuming it depends solely on the distances between molecules. This misconception overlooks the intrinsic nature of density, which is, in fact, an intensive property that does not vary with the amount of substance. Additionally, there is a widespread but incorrect notion that density correlates with an object's hardness, further complicating students' understanding of this concept. These misconceptions have been consistently identified in studies conducted by various researchers, including Almuntasheri et al. (2016), Laurillard (2013), and Llewellyn (2012), highlighting the need for more effective educational strategies to address and correct these fundamental misunderstandings.

Students find it challenging to connect mass with the amount of matter (Kind, 2004), confusing it with weight and volume. In her work, Hewson (1983) mentioned that the word dense, which refers to the number of particles per unit area, contributes to misconceptions about density. After interviews with high school students, he found that despite being taught density twice traditionally, most responded with alternative concepts for density, mass, and volume (Hewson, 1983). When a particle model is used, high school students associate density only with the arrangement of atoms and molecules and not with their mass. At the same time, they consider that it is also related to an object's hardness. Students attribute the density to the character of an expansive quantity, as they do with pressure and temperature. At the same time, it is known that density is an intensive quantity; that is, it is independent of the amount of material. According to Kloos' (2010) research, it was found that children often fail to understand that density is an intensive property that results from the combination of mass and volume. As a result, they tend to believe that the size of an object also plays a role in determining its density.

Similar are the findings of other recent studies (Becke, 2014; Kiray & Simsek, 2021) in which it seems that children have difficulty understanding density because, on the one hand, it is expressed by the ratio of mass to volume and this assumes that children can manage the mathematical concepts of fraction and ratio and on the other hand because the concept of mass is confused with that of volume. Smith's (1985) research shows that children mainly approach the concept of density qualitatively rather than mathematically, perhaps because they need to familiarize themselves with volume measurement units. Also, they do not distinguish the concept of "heavy for its size" and include it in the concept of weight.

Additionally, studies show difficulties distinguishing density from weight (Fox & Hackl, 2006), while in the research of Snir (1993) and his colleagues, students need help distinguishing density from the concept of mass. Rowell and Dawson (1977) designed an innovative teaching approach to density with experimental tests. Nevertheless, many 3rd High School students needed help understanding that the density is constant and characteristic of different objects made of the same material. Snir et al. (1993), proposed in their paper to approach the concept of density with the help of a software program. Since, on the one hand, the students have difficulty understanding the particle structure of matter, the software program did not include concepts related to the microscopic level; on the other hand, they believed the microscopic approach to density was not necessary to separate the concepts of density from weight (Snir et al., 1992). The research showed that some students needed help understanding the logic in the software program (the density represents the number of dots per square).

Literature from the past and present reveals, that students persistently harbor alternative misconceptions regarding the concept of density. This indicates that the issue is not confined to any particular era but is, in fact, a timeless problem that continues to challenge educators. It underscores the necessity for ongoing research and a collaborative effort to develop and implement effective strategies to address and rectify these fundamental misunderstandings.

## 3. The Aim

This research aims to investigate diverse perspectives on density, a concept within the concept of chemistry, among medical students at the University of Ioannina. Additionally, the study seeks to explore potential correlations between students' understanding of density and gender dynamics within this academic context.

The research was meticulously crafted to address the following overarching inquiries:

RQ 1) To what extent do medical school students exhibit consistency in their comprehension of density, encompassing both scientific and alternative conceptualizations?

RQ 2) What level of interest do distinguished honours students demonstrate towards the Chemistry course, particularly regarding the topic of density?

RQ 3) Does a discernible and statistically significant discrepancy exist in the academic performance of students based on their gender, particularly concerning their responses regarding density comprehension?

This study seeks to provide valuable insights into the nuanced understanding of density among medical students through systematic investigation and thorough analysis. Furthermore, it aims to elucidate potential gender-related disparities in academic performance within chemistry education.

## 4. Method

### 4.1. Participants

Study participants were 300 first-year students from the Department of Medical School at the University of Ioannina (54% of the population were men, and 46% were women). Greek Medical Students are among the highest achievers in the educational system. Meanwhile, medical schools are in high demand and only accept a few students. Consequently, students must perform very well on the university entrance examinations to be able to access them. Chemistry is one of the subjects students will be examined on, which means they need to study hard to succeed.

Additionally, Greek students must choose between sciences and technology and social sciences and humanities as their education orientation. Usually, students who follow the scientific education direction score high in science subjects such as physics, mathematics, biology, and chemistry. The 313 respondents followed a scientific education in the Lyceum, while only 3 followed a technological one. The research was carried out in the first semester of their academic studies.

### 4.2. Pilot Study

A necessary condition for collecting the research material is evaluating the content of the questionnaires with a trial application on people like the final sample. A pilot study was conducted for this purpose, which revealed the following:

a. What words, phrases, or concepts are not understood or lead the subjects to misinterpretations?

b. How interesting and valuable are the answers to each question?

c. What questions do subjects have difficulty with, or what additional information are they asking for?

d. How much time is required to complete the questionnaire?

e. What are the subjects' reactions, and how can they be overcome?

### 4.3. Instrument

The questionnaire includes nine questions, of which the first four are related to the demographic data of the students (age and gender) and questions regarding the knowledge background for the chemistry course, i.e., these questions are related to gender, age, interest in the subject of chemistry on a five-point scale (1=not at all, 2=little, 3=moderate, 4=very much, 5=very much), and the score in the subject of chemistry in the Panhellenic Entrance Examination for Higher Education. The last five questions described below investigate whether there are alternative ideas or perceptions of the students about the concept of density.

### 4.4. Main Study

Participating students responded to the items in their classrooms at the beginning of their first lecture at the university under the authors' supervision. The process was completed in two steps. First, the study was introduced to the students, and instructions for completing the instrument were given. Second, following a scripted, standard protocol for introducing the study, the research assistants obtained informed consent, explained associated assurances, gave instructions for responding to the test, and monitored the students throughout the process.

### 4.5. Statistical Analysis of the Data

The selection of a quantitative research methodology is based on its widely recognized characteristics, which include its structured and steadfast nature (Walter & Andersen, 2013). This approach allows for the examination of correlations among multiple attributes across a substantial dataset, thereby revealing overall patterns and trends within the studied phenomena (Flick, 2015). Additionally, the quantitative framework enables investigations on a sizable and representative sample of the population, making it possible to identify correlations among variables and discern prevailing trends (Queirós et al., 2017). Consequently, the practices inherent in quantitative research are geared towards scrutinizing theoretical hypotheses through meticulous exploration of targeted inquiries, ultimately identifying associations among specific variables (Pandey & Pandey, 2021).

As mentioned above, the data collection method used was a sample survey. The sampling design of a representative sample is appropriate for the needs of this study, as the purpose was to explore the level of understanding of the density concept and highlight possible alternative ideas rather than intervene with experimental research on the sample (Lohr, 2021). In addition, the above could be examined over a short period of time by administering an appropriate questionnaire only once, as their possible changes over time were not discussed. Students were given a suitable closed-ended questionnaire, which they were asked to answer in writing during one teaching hour (Patten, 2016). The questions are linked to simple phenomena that occur in everyday life, so students are confronted with situations that show their misunderstandings of the density. The questionnaire does not include questions that would provide a sterile test of the student's knowledge gained during their middle and high school years.

The research data was processed with the IBM SPSS Statistics 29.0 statistical program (Field, 2013; Wagner, 2019) and Microsoft Office Excel spreadsheets (Abbott, 2014). The internal consistency and reliability for the second and third parts of the questionnaire were checked by Cronbach's alpha coefficient (Tavakol & Dennick, 2011) and Kuder-Richardson Formula 20 (KR-20), respectively (Sarmah, 2012). So, the items in the third part of the questionnaire were coded as binary items (incorrect or correct).

Classical Test Theory, a quantitative approach, the reliability and validity of the scale based on its items was tested. Classical Test Theory, referred to as true score theory, posits that each individual possesses a true score. An individual's true score is defined as the expected score over an infinite number of independent administrations of the scale (McDonald, 2013; Suen, 2012).

For the knowledge section, firstly, the 12 items were analyzed for item difficulty (values should range from .30 to .70) and item discrimination index (values should range from .20 and over) (Boopathiraj & Chellamani, 2013; Quaigrain & Arhin, 2017). For educational or cognitive assessments, difficulty refers to the likelihood that examinees will answer the item correctly. Additionally, the item-discrimination index increases with the extent to which an item differentiates among individuals with varying levels of the underlying concept of interest. Secondly, the overall performance was determined. Specific statistical indicators (average, frequency, percentages) were estimated, and the appropriate diagrams and tables were created for visual representation. Histograms were used to test the normality of the data. The statistical criterion $\chi^2$ test was used, with which it is possible to establish whether there is a relationship between the two variables under consideration.

## 5. Results

The population of this study to investigate alternative ideas in chemistry concepts is 300 high school students, namely 162 boys (54%) and 138 girls (46%) aged 18-19 years old. The respondents were asked to mark in the questionnaire the grade they obtained in Chemistry in the National Entrance Examination. The results of the statistical analysis are presented in Table 1.

Table 1
*Respondents' grades in the chemistry course*

| *Grade in Chemistry Direction* | *Frequency* | *Percentage %* |
|---|---|---|
| 19.5-20 | 171 | 57 |
| 19-19.5 | 94 | 31.3 |
| 18.5-19 | 35 | 11.7 |
| 18-18.5 | 0 | 0 |
| <18 | 0 | 0 |
| Total | 300 | 100 |

Participants' responses regarding their interest in the Chemistry course are shown in Table 2. A large percentage of participants showed an extremely high interest in Chemistry, while about 13 % showed a moderate interest.

Table 2
*Respondents' interest in the chemistry course*

| *Interest in Chemistry* | *Frequency* | *Percentage %* |
|---|---|---|
| Not at all | 0 | 0 |
| A little | 2 | 0.7 |
| Moderate | 40 | 13.3 |
| Much | 95 | 31.7 |
| Very Much | 163 | 54.3 |
| Total | 316 | 100 |

In Question 1, participants were presented with a scenario involving two identical containers: one filled with oil (left container) and the other with water (right container), both filled to the same height and placed on a scale, as depicted in Figure 1. The question posed was: "What do you think will happen?". Figure 2 displays the results of the statistical analysis, which are particularly noteworthy. Of the 300 respondents, a substantial majority, 217 individuals (72.3%), hypothesized that the balance would shift to the left. In contrast, 19 respondents (6.3%) anticipated that the balance would shift to the right, and 64 respondents (21.3%) predicted that the balance would remain level.

A deeper analysis of the responses reveals an intriguing detail: among the 217 respondents who predicted a leftward shift of the balance, 123 individuals (41.1% of the total respondents) specified that the balance would shift left, while 94 respondents (31.3%) articulated that it would shift to the left because the left side would be heavier. This subset of respondents appears to be conflating the concepts of weight and mass. Although they correctly predicted the leftward shift of the balance,

Figure 1
*Scale for question 1*

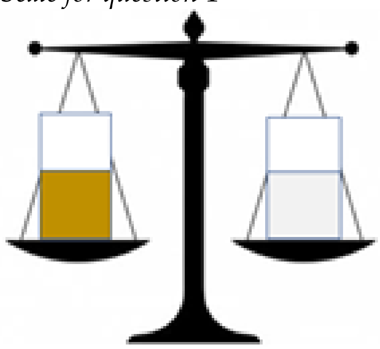
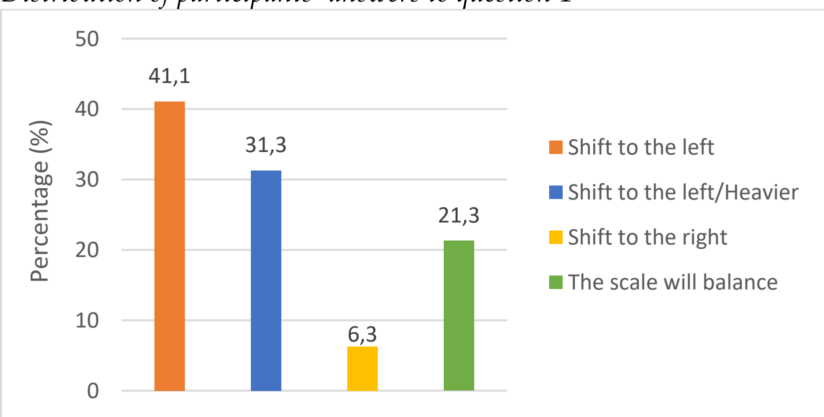


Figure 2
*Distribution of participants' answers to question 1*



their rationale indicates a misconception. They believe that the scale measures weight, whereas it is a well-established fact that scales are designed to measure mass.

This analysis underscores a partial correctness in their responses—acknowledging that the balance will indeed shift to the left. However, it also highlights a fundamental misunderstanding among a significant proportion of respondents regarding the principles of weight versus mass measurement.

Question 2 posed the scenario of two identical opaque containers balanced on a scale, with one container filled with oil and the other with water, as illustrated in Figure 3. Respondents were asked to determine whether the height of the liquid in the oil container would be greater, the same, or less than that in the water container. The statistical analysis of the responses, depicted in Figure 4, reveals that a considerable percentage of respondents, approximately 76% (228 out of 300), correctly identified that the height of the liquid in the oil container would be greater. Meanwhile, 12.3% of respondents believed that the height would be less, and 11.7% thought that the heights would be the same.

It is worth noting that while the majority correctly identified differing heights, their responses may not necessarily reflect an understanding of the underlying density relationship between oil and water. This suggests a potential area for educational intervention. The correct answer hinges on the recognition that oil, having a lower density than water, would indeed occupy a greater volume to balance the mass, resulting in a higher liquid height in the oil container.

Furthermore, only 35 out of 300 respondents (11.7%) posited that the heights would be the same, indicating a limited awareness of the fundamental principles governing density and mass. These findings highlight a partial correctness in recognizing that the liquid heights will differ, yet they also point to a common misconception regarding the density relationship between oil and water. This suggests the necessity for more comprehensive education on the principles of density and buoyancy to correct these misunderstandings.

Figure 3
*Scale for question 2*

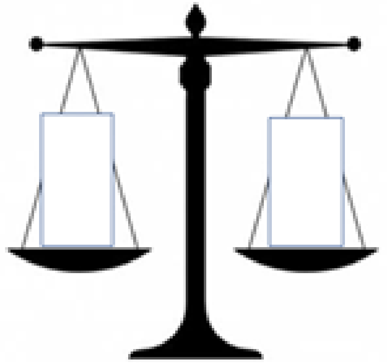
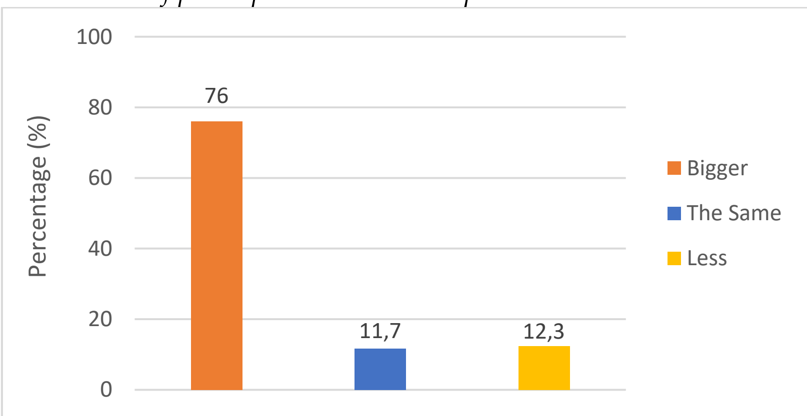


Figure 4
*Distribution of participants' answers to question 2*




Question 3 presented a scenario in which two balls were balanced on the ends of a scale, as illustrated in Figure 5. Respondents were asked to determine whether the ball on the left had a higher, lower, or equal density compared to the ball on the right.

The statistical analysis of the responses, depicted in Figure 6, indicates that a substantial majority of respondents, 262 out of 300 (87.3%), correctly answered that the ball on the left has a lower density. This correct response suggests an understanding that density, rather than just mass, plays a crucial role in determining the balance on the scale. However, 38 respondents (12.6%) provided incorrect answers. Of these, 13 respondents believed that the ball on the left had a higher density, while 25 respondents thought that the densities were equal.

The predominant correct response demonstrates a widespread understanding of the concept that, for the two balls to balance, the ball with the lower density must occupy a greater volume to offset its lower mass per unit volume. This concept aligns with fundamental principles of physics, specifically the relationship between mass, volume, and density. Conversely, the incorrect responses reveal common misconceptions. The belief that the left ball has a higher or equal density may stem from a misunderstanding of how density influences balance. These respondents might be conflating the concepts of mass and density, failing to recognize that an object with lower density must compensate with a larger volume to achieve balance.

This analysis underscores the need for clearer educational emphasis on the distinction between mass and density, and how these properties interact in physical systems. While a significant majority of respondents demonstrated correct understanding, the incorrect answers highlight areas where conceptual clarity could be improved.

Figure 5
*Scale for question 3*

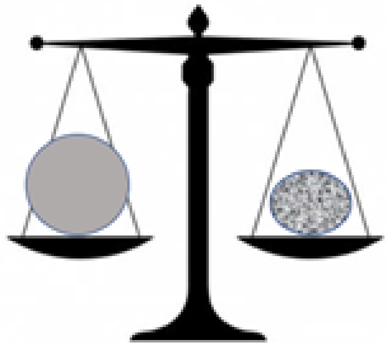
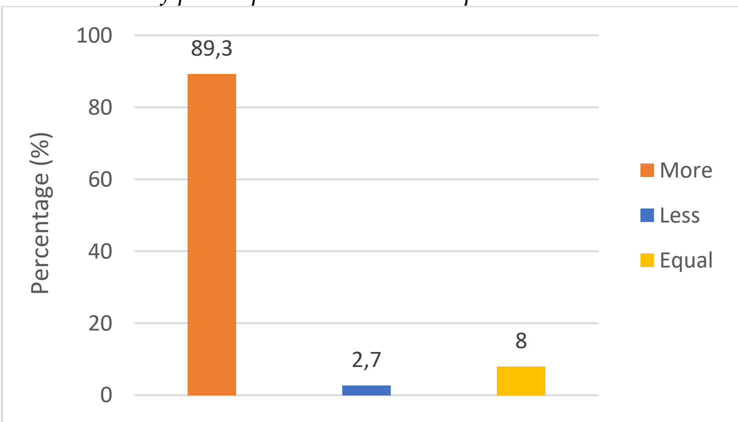


Figure 6
*Distribution of participants' answers to question 3*




In Question 4, participants were asked to consider a scenario where two balls of identical size were balanced at the ends of a scale, as depicted in Figure 7. The question posed was whether the ball on the left had more, less, or equal density compared to the ball on the right.

The statistical analysis of the responses, illustrated in Figure 8, reveals that a significant majority of respondents, 268 out of 300 (89.3%), correctly identified that the ball on the left has a lower density. This correct response indicates an understanding of the principle that for two objects of the same size, the one with the lower density must have less mass to maintain balance on the scale. However, 32 respondents (10.7%) provided incorrect answers. This group comprised respondents who either believed that the ball on the left had more density or the same density. The accurate determination that the left ball is less dense hinges on the understanding that density is a measure of mass per unit volume. Given that both balls are of the same size (volume), the ball with less density must have a lower mass, which is why the scale remains balanced.

The predominant correct response suggests that the majority of participants possess a sound comprehension of density and its relationship to mass and volume in the context of balancing scales. This understanding is critical in recognizing that the ball with less density will be lighter, hence balancing the scale against a ball of the same size but higher density on the opposite side. Conversely, the incorrect responses highlight a misconception among some respondents regarding the relationship between density and balance. These respondents may be misinterpreting how equal volumes can contain different masses based on density, or they might be confusing density with other physical properties.

The findings emphasize how density determines the mass of objects with the same volume. While the majority demonstrated a correct understanding, the incorrect answers indicate a need for further educational focus to address and rectify these misconceptions.

Figure 7
*Scale for question 4*

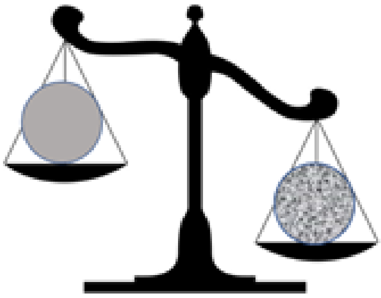
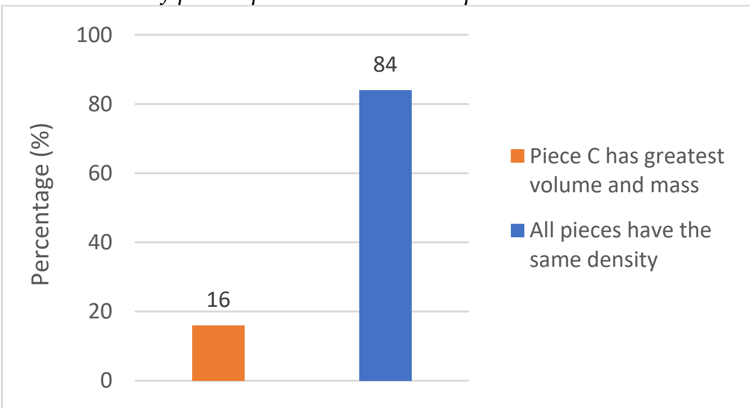


Figure 8
*Distribution of participants' answers to question 4*




Question 5, participants were presented with a scenario in which a straight, uniform table was cut into three pieces of different sizes. The sum of the lengths of the two shorter pieces was equal to the length of the longer piece. Each piece maintained the same width and thickness. Participants were asked to determine which piece had the most significant volume, mass, and density, as shown in Figure 9.

The analysis of responses revealed that all participants correctly identified that piece C, the longest piece, would have the most significant volume and mass. This is consistent with the understanding that volume and mass are directly proportional to the length of the pieces, given that width and thickness remain constant. However, responses to the question regarding density showed a notable divergence. Only 48 out of 300 participants (16%) incorrectly answered that piece C would have the greatest density, while the majority, 252 out of 300 participants (84%), correctly answered that all pieces would have the same density, as depicted in Figure 10.

The accurate majority response indicates an understanding that density is an intrinsic property of the material, defined as mass per unit volume, and remains constant regardless of the size or shape of the pieces. This conceptual understanding is fundamental in physics, where density is a characteristic property of materials that does not change with the division of a uniform object. The minority who believed that piece C would have a greater density may be conflating density with mass or volume, erroneously assuming that the larger mass and volume of piece C would translate to a higher density. This misconception highlights a common error in understanding the distinction between extensive properties (such as mass and volume, which depend on the size of the object) and intensive properties (such as density, which do not depend on the size of the object).

Figure 9
*Scale for question 5*

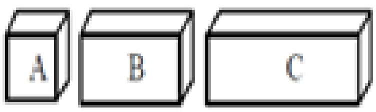
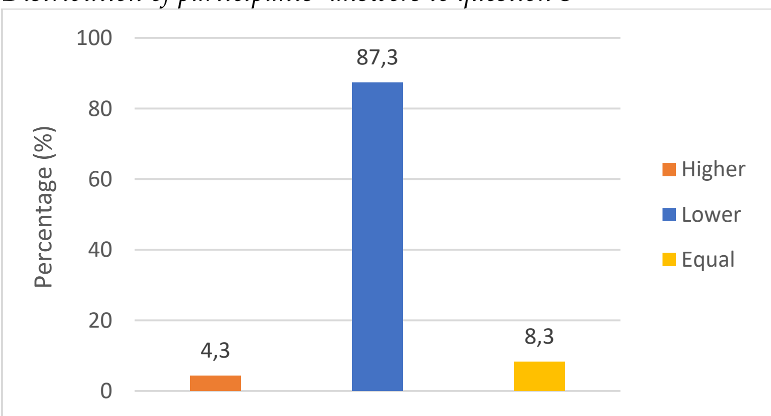



Figure 10
*Distribution of participants' answers to question 5*



These findings highlight the importance of reinforcing the concept that while mass and volume are dependent on the dimensions of the pieces, density remains unchanged in uniform materials. The majority's correct understanding indicates a solid grasp of this principle, yet the misconceptions held by a minority of respondents suggest a need for further educational emphasis on the intrinsic nature of density.

### 5.1. Calculation of the Total Performance (Score)

The percentage of scientifically correct answers for each question and the overall performance were calculated for the data collected (Table 3). As shown in Table 3, the overall performance for the Cognitive Subject of Chemistry is (75.59 ± 16.53).

Table 3
*Respondents' total performance (total)*

| | *Cognitive Subject of Chemistry* |
|---|---|
| Questions | Percentage of scientifically correct answers (%) (Total (n) = 300) |
| Q (1) | 41.00 |
| Q (2) | 76.00 |
| Q (3) | 87.33 |
| Q (4) | 89.33 |
| Q (5) | 83.67 |

It was then investigated whether there is an effect of the gender of the participants on the overall performance as calculated for the subject of chemistry. There was no statistically significant difference in the two genders' overall performance in the subject of chemistry.

Table 4
*Respondents' overall performance (total) by gender*

| | *The gender of the respondents* | | *p*-value |
|---|---|---|---|
| | Boys (N=162) | Girls (N=138) | |
| Score Chemistry | 3.71± 0.83 | 3.86 ± 0.82 | 0.11 |
| Score Chemistry (100%) | 74.16 ± 16.53 | 77.25 ± 16.42 | 0.11 |

As shown in Table 5, no statistically significant correlation existed between students' interest in chemistry subjects and Overall Performance (Score).

Table 5
*Respondent's interest in chemistry subject and Overall Performance (Score)*

| | *Interest of respondents* |
|---|---|
| Score Chemistry | Chi-Square = 3.960<br>df = 4<br>p = 0.385 |

## 6. Discussion

Literature reviews by both Greek and international scholars in the field of science teaching have been conducted to document and categorize alternative ideas and perceptions held by students and teachers across various science concepts. These concepts include areas such as energy, gravity, and force, with a focus on identifying the disparities between these alternative understandings and established scientific principles (Daud et al., 2015; Kotsis & Panagou, 2022;).

The current study investigates the alternative perceptions of density in the sciences among honours students transitioning from Lyceum to medical school, with a specific emphasis on chemistry. The research group consisted of honours students distinguished by their exemplary performance in the National Entrance Examinations, signaling proficiency in science and chemistry. Nonetheless, the study's findings underscore the notion that superior performance in these examinations does not invariably correspond to a nuanced comprehension of the subject matter. Examination of the gathered data reveals that a substantial proportion of honours students uphold alternative perspectives regarding fundamental chemistry concepts. This is consistent with international research in science, which also focuses on high-achieving students and the exploration and categorization of alternative perceptions across diverse scientific concepts (Kahana & Tal, 2014; Panagou et al., 2024a; Raub et al., 2017).

During our investigation into alternative conceptions surrounding the concept of density, we observed that thirty percent of the students failed to acknowledge that two distinct liquids of equal volume could possess differing densities (as indicated by their responses to Question 1), despite being instructed on the inherent characteristic of density in all liquids (Tyrrell & Harris, 2017). Moreover, a considerable number of students incorrectly asserted that the balance would tilt towards the heavier object, contrary to the established understanding that balances are employed to measure an object's mass rather than its weight.

The students predominantly approached the questions utilizing the mathematical definition of density, as opposed to employing a particle model based on atomic-molecular mass (Dreizler & Gross, 2012). An alternative conceptualization, noted in the literature and echoed in our study, albeit by a minority of students, posits density as an extensional quantity, wherein its value is contingent upon the quantity of material present (Labanowski & Andzelm, 2012)). Specifically, in response to Question 5, 16% of the respondents (48 out of 300) expressed the belief that the largest object would exhibit the highest density.

After analyzing the accuracy of responses, it is clear that even high-achieving students admitted to prestigious university departments such as medical schools may have misconceptions about the concept of density. This finding is consistent with multiple studies that have examined students' alternative ideas at different educational levels (Kotsis & Panagou, 2023; Panagou et al., 2022), as well as surveys targeting educators (Kotsis & Panagou 2022).

## 7. Conclusions

In conclusion, the responses of the top students of our educational system show the two familiar characteristics that are also distinguished in the perceptions of students at all levels of education on science concepts. On the one hand, they are based on their mental schemas that are intuitive or empirical and, on the other hand, on scientific knowledge gained from teaching that has confused these experiences (Kotsis & Panagou, 2022; Panagou et al., 2022). However, since we are referring to students who have passed through all levels of education, the predominant characteristic is the latter, i.e., their perceptions have been shaped during their years of education with knowledge from the scientific model.

The current approach to teaching science involves considering students' alternative ideas (Barthlow & Watson, 2014). As a result, teachers should consider these alternative ideas when transforming their instructional methods before developing a lesson plan (Abell, 2013). They should also choose appropriate teaching tools to modify and develop these ideas towards scientifically correct ones. When planning instruction, teachers should consider the specific characteristics of their students and the class composition in addition to their alternative ideas (Van Driel, 2021).

Language peculiarities, the educational background of the family, and social issues may influence the students' perceptions. Pre-existing/alternative ideas play a vital role in further learning processes because how pupils observe and interpret various events and phenomena, communicate, or receive new information is related to these ideas (Larkin, 2012). The existence of students' alternative ideas, which cannot be answered whether the teacher, the method, or the textbook is responsible, reflects their knowledge, and it is concluded that the necessary conceptual change has not occurred.

According to recent results, the main feature of the Chemistry curricula published in 2014 and 2015 is the need for more references to exploratory teaching approaches (laboratory or nonlaboratory) and how they enhance the learning of Chemistry (Salta, 2017). In addition, the Middle School Teacher's Guide provides considerable help to teachers regarding students' ideas about crucial chemistry concepts and suggestions for handling them. At the same time, the same is not valid for high school teachers. Also, many expected learning outcomes are observed in the high school curriculum concerning the time available for teaching the course (Salta, 2017). Therefore, there is an urgent need to redefine the science curricula to develop exploratory learning-teaching environments in which formal and non-formal education activities are combined to be meaningful and beneficial for students (Panagou et al., 2022).

A change in teaching strategy is needed to enable a more practical approach and full clarification of science concepts by students. Science lessons and teaching activities should flow from a framework of a qualitative approach to the different concepts so that students adopt them through their active engagement (Jimoyiannis & Komis, 2003). Laboratory activities, which are an integral part of the teaching of science courses and, therefore, of chemistry courses, provide meaningful learning experiences and form the basis for the development of skills such as listening, observation, and investigation, but also communication, organisational, creative and manipulative skills (Hofstein et al., 2013). They also contribute to cultivating skills such as formulating scientifically sound questions and scientific reasoning.

## 8. Research Limitations and Further Research

The primary constraint identified in this study pertains to the methodology adopted for data collection, which exclusively focuses on the acquisition of quantitative data. To attain a more comprehensive insight into the conceptions of students' comprehension and interpretation of the concept of density, it is suggested to supplement the existing approach with interviews. This will also provide qualitative data for more comprehensive and efficient research.

Additionally, a significant concern arising during the research process revolves around the constrained scope of the sample, which solely comprises students from one university in Greece. Consequently, the findings lack generalizability to encompass all higher education institutions within the country. To enhance the study's validity for prospective research, it is recommended to broaden the sample selection criteria to encompass a diverse array of institutions.

Furthermore, an additional didactic approach could be implemented concerning the concept of density to determine whether there is a noticeable conceptual change in the alternative perceptions maintained by students.

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