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Development of the Structure of Matter Diagnostic Test and Determination of Misconceptions*

Maddenin Yapısı Teşhis Testinin Geliştirilmesi ve Kavram Yanılgılarının Belirlenmesi

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Abstract: This study aims to develop a valid and reliable two-tier open-ended diagnostic test that can be administered to 5th and 6th-grade students, in line with the 2018 and 2024 Science Curriculum learning outcomes related to the Structure of Matter, and to identify students' misconceptions. This study, which followed Treagust's (1988) test development steps, was structured based on an exploratory sequential design. The test includes questions on the "particulate structure of matter", "density", "matter and heat", and "fuels and human-environment interaction". The data were obtained from 350 secondary school students. The face and content validity of the test were established, and as a result of the reliability analysis, the average difficulty value was calculated to be .42, and the average discrimination value was calculated to be .44. The KR-20 reliability coefficient was calculated to be .75, the Cronbach Alpha coefficient was .81, and the Pearson Correlation coefficient was .91. As a result of the study, a valid and reliable two-tier "Structure of Matter Diagnostic Test" containing 18 items aimed at determining misconceptions was introduced to the literature. In addition, as a result of the content analysis, four misconceptions not encountered in the literature were identified, and a total of 39 misconceptions were identified.

Keywords: Two-tier diagnostic test, misconception, science education, structure of matter, concept test development, scale development

Öz: Bu çalışmanın amacı, Maddenin Yapısına ilişkin 2018 ve 2024 Fen Bilimleri Öğretim Programı öğrenme çıktıları ile uyumlu, 5. ve 6. sınıf düzeyindeki öğrencilere uygulanabilecek geçerli ve güvenilir iki aşamalı açık uçlu bir teşhis testi geliştirmek ve öğrencilerin kavram yanılgılarını belirlemektir. Treagust'un (1988) test geliştirme aşamalarının izlendiği bu çalışma, keşfedici sıralı desene dayalı olarak yapılandırılmıştır. Testte, "maddenin tanecikli yapısı", "yoğunluk", "madde ve ısı" ve "yakıtlar ve insan-çevre etkileşimi"ne yönelik sorulara yer verilmiştir. Veriler, 350 ortaokul öğrencisinden elde edilmiştir. Testin görünüş ve kapsam geçerliği sağlanmış ve güvenirlik analizi sonucunda ortalama güçlük değeri .42, ortalama ayırt edicilik değeri .44 olarak hesaplanmıştır. KR-20 güvenirlik katsayısı .75, Cronbach Alfa katsayısı .81 ve Pearson Korelasyon katsayısı .91 olarak hesaplanmıştır. Çalışma sonucunda kavram yanılgılarını belirlemeye yönelik 18 madde içeren geçerli ve güvenilir iki aşamalı "Maddenin Yapısı Teşhis Testi" literatüre kazandırılmıştır. Ayrıca içerik analizi sonucunda, ulusal ve uluslararası literatürde rastlanmayan dört kavram yanılgısı tespit edilmiş ve toplamda 39 kavram yanılgısına ulaşılmıştır.

Anahtar Kelimeler: İki aşamalı teşhis testi, kavram yanılgısı, fen eğitimi, maddenin yapısı, kavram testi geliştirme, ölçek geliştirme

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Introduction

The basis of science education lies in the teaching of various concepts that enable individuals to make sense of events occurring in their environment. For meaningful learning to occur, students must construct conceptual relationships between their existing concepts and new concepts (Acar Şeşen, 2019). Research on students' conceptual knowledge shows that their thoughts in many areas differ from scientific views (Duit, 1991). These alternative concepts -commonly referred to as misconceptions- are frequently brought into the science classroom (Driver & Oldham, 1986). Misconceptions are defined as understandings that explain the student's experiences and observations, are consistent with their worldview, and seem quite logical to them but develop differently from scientific acceptance (Sanger & Greenbowe, 1997). A range of factors contribute to the development of these misconceptions: daily life experiences, misinformation obtained from teachers, lack of knowledge, incorrect usage in daily language, language of instruction, shifts in the meanings of terminology, and the content presented in textbooks (Acar Şeşen, 2019; Schmidt, 2000). If misconceptions are not questioned and corrected, they can integrate into the cognitive structure of students and prevent subsequent learning (Griffiths & Preston, 1992; Treagust, 2006). Consequently, identifying misconceptions is crucial for designing effective instructional processes and addressing students' challenges in comprehending scientific concepts (Kirbulut & Geban, 2014; Mardiyyaningsih, Erlina, Ulfah, & Wafiq, 2023).

Various measurement tools have been developed to determine students' misconceptions. These tools include drawings (Smith & Metz, 1996), concept maps (Novak & Gowin, 1984), concept cartoons (Keogh & Naylor, 1993), interviews (Osborne & Gilbert, 1980), word association (Gussarsky & Gorodetsky, 1990), and diagnostic tests (Treagust, 1988). While individual interviews were generally preferred to determine misconceptions in the past (Treagust, 1988), one-tier multiple-choice tests, which save time and allow for objective assessment, are widely used today. Although these tests have high content validity and reliability (Karataş et al., 2003), it is stated that they tend to investigate students' misconceptions and conceptual understanding at a superficial level (Law, 2008). In addition, in such tests, there is a possibility that students who don't know the subject will give correct answers (Karataş et al., 2003). To prevent this situation and to conduct a more in-depth analysis,

* This study was produced from the doctoral thesis prepared by the first author under the supervision of the second author.

measurement tools have been developed that question the reasons for the answers given by students (Treagust, 1991). For this purpose, the two-tier diagnostic tests developed by Treagust (1988) require the answer given in the first tier to be explained with its justification in the second tier. In this way, the reasons underlying the students' misconceptions can be determined. The questions in this test go deep enough to reveal the conceptual thought system in the student's mind. For this reason, these questions can also be called "probing questions"(Kabapınar, 2003). There are three types of these tests (see Table 1).

Table 1. Types of two-tier tests (karataş et al., 2003)

Types of Two-Tier Tests	First Tier	Two Tier
Two-tier multiple-choice test	Multiple choice	Multiple choice (+open-ended)
Two-tier requiring classification	True-False	Multiple choice (+open-ended)
Open-ended two-tier test	Multiple choice	Open-ended

There are multiple-choice sections in the second tier of the two-tier tests that require multiple-choice and classification. In these tests, there may be a possibility that students may choose the correct answer option even though they don't know the reason for the answer they have marked. This situation may limit the power of the test to determine the underlying causes of misconceptions and to measure conceptual understanding. In contrast, there is no such possibility in two-tier open-ended tests. In addition, two-tier open-ended tests provide the opportunity to evaluate students' reasoning skills more comprehensively (Voska & Heikkinen, 2000) and to determine whether there are misconceptions that are different from previously determined misconceptions (Mann & Treagust, 1998). The development process of such diagnostic tests typically involves the following steps:

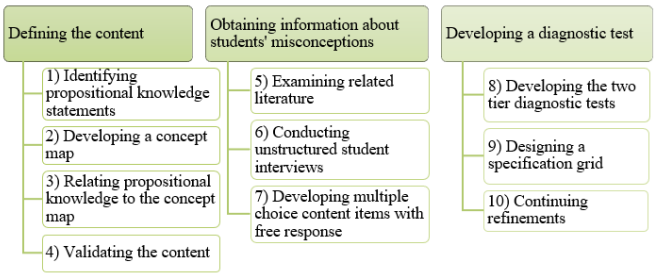

Figure 1. Treagust's (1988) two-tier diagnostic test development steps

The process begins with defining the boundaries of the concept, followed by formulating propositional statements, creating a concept map, and refining the content through expert feedback. After these stages, students' misconceptions are determined through literature review and interviews, and the first multiple-choice part is created in line with the data obtained. The second section of the test is constructed based on students' explanations for their choices in the first part, along with insights gathered from interviews and a review of the literature. Another important stage of the test development process is the preparation of a specification grid. Then, the test is applied to different student groups, validity and reliability studies are conducted, and the test is continuously improved.

Many researchers in science education have contributed to the development of two-tier diagnostic tests (Chandrasegaran, Treagust, & Mocerino, 2007; Gürsel & Akçay, 2022; Lin, 2016). The Structure of Matter is one of the fundamental topics of science education and is considered a difficult subject to understand because it contains abstract concepts (Sirhan, 2007). The literature frequently highlights that students, from primary school through university, struggle to comprehend concepts related to this subject and have misconceptions (Acar Sesen & Tarhan, 2010; Boylan, 2008; Griffiths & Preston, 1992; Johnson, 1998; Özmen, Ayas, & Coştu, 2002; Tüysüz, 2009). In addition, it is known that misconceptions seen at the secondary school level continue to exist among university teacher candidates (Altay & Balım, 2021; Aydeniz, Bilican, & Kirbulut, 2017; Hejnova, 2022; Kiray et.al., 2015; Rule, 2005). This situation reveals the need for early diagnosis of misconceptions; otherwise, students' future learning processes may be negatively affected.

The 2024 Science Curriculum foresees that the basic knowledge that students bring from their previous learning processes should be revealed through preliminary assessment at the beginning of the teaching-learning process to diagnose misconceptions early and establish correct conceptual learning. Thanks to this approach, it is aimed to establish strong connections between students' current knowledge and their new learning (MoNE, 2024).

The dynamic structure of the Science Curriculum and its constant updating (MoNE, 2024) increase the need for regular research due to the changing student profiles and teaching-learning activities. A review of the existing research reveals that there is a scarcity of studies focused on the development of two-tier diagnostic tests related to the structure of matter at the secondary education level (Avcı, Şeşen, & Kırbaşlar, 2018; Civangönül & Çıbık, 2023; Kenan & Özmen, 2014; Özalp & Kahveci, 2011). In addition, it is noteworthy that the number of open-ended two-tier diagnostic test development studies is insufficient (Civangönül & Çıbık, 2023; Sarı & Çakır, 2024). In this context, the fact that no diagnostic test that directly meets the learning outcomes on the structure of the matter determined in the study has been found in the literature increases the importance of this study. Therefore, this study aims to develop a valid and reliable two-tier open-ended diagnostic test that can be administered to 5th and 6th-grade students, in line with the 2018 and 2024 Science Curriculum learning outcomes related to the Structure of Matter, and to identify students' misconceptions (MoNE, 2018, 2024). It is anticipated that the developed test will contribute to the literature based on current data and will guide researchers who want to develop open-ended, two-tier diagnostic tests. The study is based on two main questions:

1. Is the Structure of Matter Diagnostic Test (SMDT) a valid and reliable instrument?
2. What are the misconceptions of secondary school students about the "Structure of Matter"?

Method

In this study, Treagust's two-tier diagnostic test development procedures were employed. Given that these procedures incorporate both qualitative and quantitative elements, an exploratory sequential design, one of the mixed methods typologies, was preferred (see Figure 2). The design, which is frequently used in tool development studies, begins with the qualitative stage, and the qualitative data obtained contributes to the structuring of the quantitative stage (Creswell & Plano Clark, 2018).

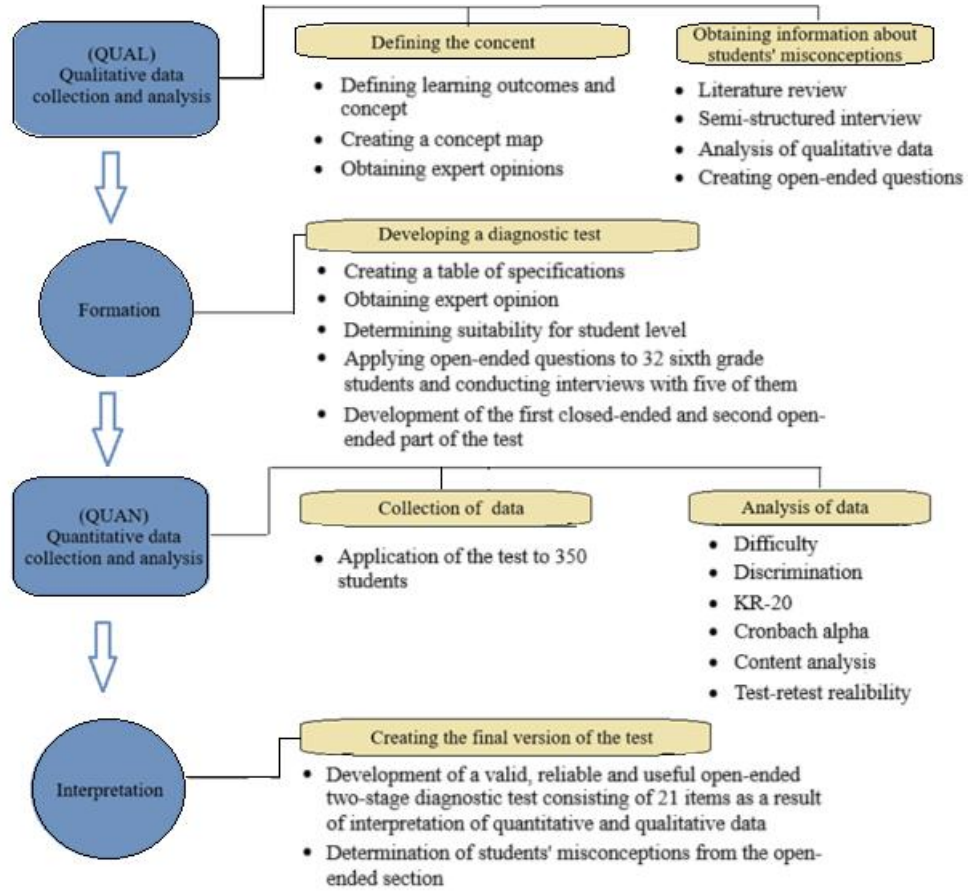

Figure 2. Exploratory sequential design

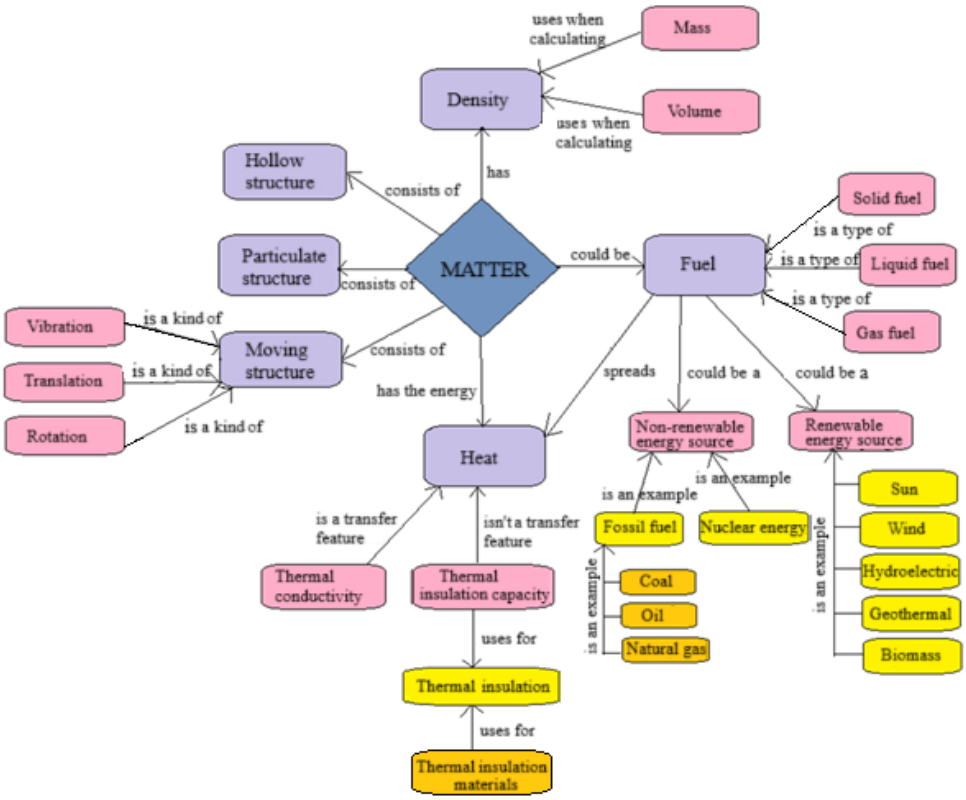

Figure 3. Concept map covering the content

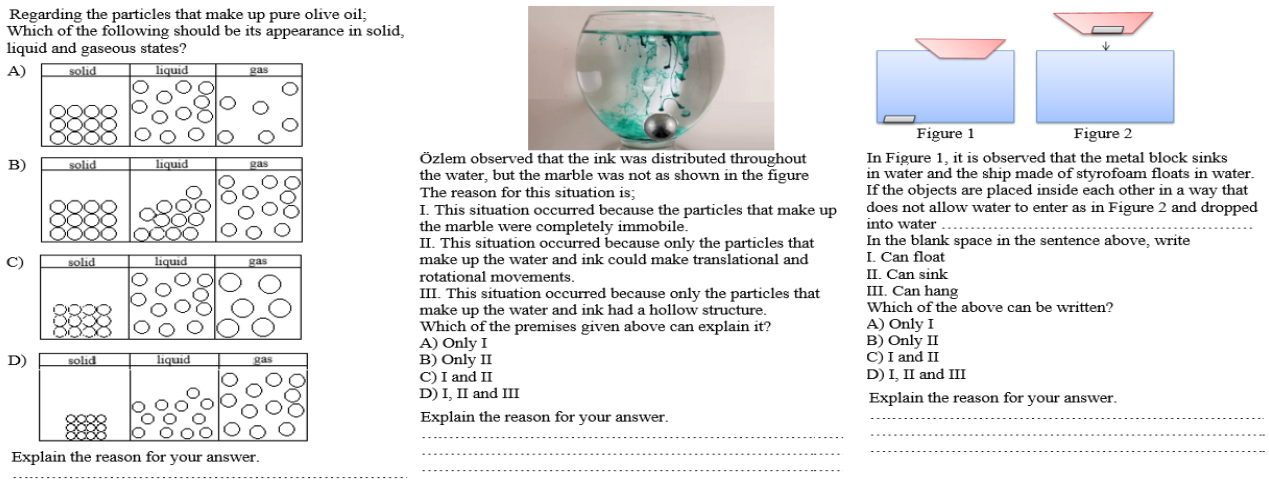

Figure 4. Questions extracted from the test

Defining the content: The subjects of "particulate structure of matter", "density", "matter and heat", and "fuels and human-environment interaction" under the title of structure of matter were determined as the content of the test. In this context, basic concepts of the relevant subjects were determined, and a concept map was created. Then, the opinions of an expert faculty member and three science teachers were consulted; the map was finalized in line with the feedback obtained (see Figure 3).

Obtaining information about students' misconceptions: To explore misconceptions regarding the specified topics and concepts, a literature review was undertaken. The misconceptions collected are listed in Appendix 1. Moreover, semi-structured interviews were conducted with a group of six sixth-grade students. Content analysis of the interview data revealed several misconceptions, such as the belief that "the way a substance is thrown into water determines whether it floats or sinks", "plastic conducts heat very well and therefore melts immediately", and "metals can be used as thermal insulation materials". At the end of these processes, 22 open-ended questions were prepared.

Developing a diagnostic test: A table of specifications, comprising the subject, learning outcomes, key concepts, and item information, was prepared and then reviewed by two academic experts and two science teachers specializing in the field. Based on expert feedback, necessary revisions were implemented, resulting in a reduction of the number of questions to 21. Interviews were conducted with six students to determine the suitability of the questions to the student level; data was collected on which questions the students had difficulty understanding and how they perceived the questions. The prepared open-ended questions were then applied to 32 sixth-grade students. Following the implementation, individual interviews were held with five students. Based on their responses and the identified misconceptions, the first tier of the test -the multiple-choice component- was developed. Later, the "Explain the reason for your answer"section, which asked for the reason for the answer given in the first tier, was added by making use of the studies in the literature (Civangönül & Çıbık, 2023; Karataş et.al., 2003; Sarı & Çakır, 2024), and the second open-ended tier of the test was developed. As a result of the analyses, three questions shown in Figure 4 were removed from the 21-item test. Misconceptions were determined from the open-ended section of the test, which finally consisted of 18 items (see Appendix 2), and a test-retest application was performed as the final process.

The Structure of Matter Diagnostic Test; Questions 1, 2, 5, 6, 7, and 8 were developed by using the literature (Başer & Çataloğlu, 2005; Gedik, 2019; Griffiths & Preston, 1992; Saydam, 2013; Soylu, Karamustafaoğlu, & Karamustafaoğlu, 2020; Soyyiğit, 2019), questions 10, 13, and 14 were developed from interviews, and questions 3, 4, 9, 11, 12, 15, 16, 17, and 18 were developed by the researchers. This study is based on a component of the thesis study approved by the Social and Human Sciences Research Ethics Board. Therefore, the entire process in the study was carried out within the scope of ethical approval. This test includes questions specifically related to the topics included in the 2018 Science Curriculum 6th grade and the revised 2024 Science Curriculum, 5th and 6th grades. The specification table containing information about the final version of the two-tier 18-question SMDT is shown in Table 2.

Participants

This study included a total of 325 students from low socioeconomic levels attending a public secondary school in Istanbul, located in western Türkiye. Additionally, 25 seventh-grade students participated in the application of the test-retest method. DeVellis (2014) suggests that, in the process of scale development, the sample size should be at least five times greater than the number of items included in the scale. In addition, the number of participants has a great effect on the final results in factor analysis. The adequacy of the number of participants is evaluated as very weak for 50, weak for 100, moderate for 200, good for 300, very good for 500, and excellent for 1000 or more (Comrey & Lee, 1992). From this perspective, the number of participants in the study can be evaluated as good. More detailed information about the participants is presented in Table 3.

As shown in Table 3, the participants in this study consisted of 5th, 6th, and 7th-grade students. The main reason for including students from different grade levels in the study is that the diagnostic test was developed for the "structure of matter" topics in the 2018 and 2024 Science curricula for 5th and 6th grade. At the same time, considering that misconceptions can arise not only at the grade level where the topic is first learned but also after different learning experiences and can persist after instruction, 7th-grade students who had previously encountered the topic were also included in the participant group.

Table 2. Table of specifications for the SMDT

Subject	2018 Learning Outcomes Codes	2024 Learning Outcomes Codes	Key Concepts	Number of items	Item number
Particulate Structure of Matter	F.6.4.1.1.	FB.5.5.1.1.	Particular structure, Hollow structure, Moving structure, Vibration, Translation, Rotation	3	1,2,3
	F.6.4.1.2.			3	1,2,3
Density	F.6.4.2.1.	FB.6.5.3.1.	Mass, Volume, Density	4	4,5,6,8
	F.6.4.2.2.	FB.6.5.3.2.		2	5,6
	F.6.4.2.3.			1	7
	F.6.4.2.4.	FB.6.5.3.3.		2	8,9
Matter and Heat	F.6.4.3.1.	FB.5.5.4.1.	Heat, Thermal conductivity, Thermal insulation capacity, Thermal insulation Thermal insulation materials	3	10,11,13
	F.6.4.3.2.			1	12
	F.6.4.3.3.	FB.5.5.4.2.		1	13
	F.6.4.3.4.	FB.5.5.4.1.		1	14
Fuels/ Human-Environment Interaction*	F.6.4.4.1.	FB.6.7.2.1.	Solid fuels, Liquid fuels, Gas fuels, Renewable energy sources, Non-renewable energy sources, Fossil fuels	3	15,16,17
	F.6.4.4.2.			2	16,17
	F.6.4.4.3.			1	18

*The learning outcomes included under the heading of fuels in the 2018 Science Curriculum are included under the heading of Human and Environmental Interaction in the 2024 Science Curriculum.

Table 3. Participant information

Gender	Class level		
	5th grade	6th grade	7th grade
Number of female students	27	44	99
Number of male students	23	49	83
Total	50	93	182

Data Analysis

An item analysis was performed to evaluate the reliability of the multiple-choice first tier of the SMDT applied to 325 students, and the KR-20 reliability coefficient was used. In the item analysis, the multiple-choice section was given 1 or 0 points (Civangönül & Çıbık, 2023; Sarı & Çakır, 2024). The raw data from the multiple-choice section were entered into Microsoft Excel, and item difficulty (Pj) and discrimination (Rjx) indices—both average values and values for each item—were calculated using the TAP software. The KR-20 reliability coefficient was obtained with SPSS software. Subsequently, a total of 105 students representing the highest, middle, and lowest scoring groups on the multiple-choice section were selected. Their responses to both the first multiple-choice and second open-ended tiers of the SMDT were jointly evaluated, and the Cronbach alpha reliability was calculated (Kurtoğlu-Güldalı & Karslı-Baydere, 2023; Orduhan & Çakır, 2023; Sarı & Çakır, 2024). In the evaluation process, the graded evaluation rubric adapted from Karataş et al. (2003) was used. In the multiple-choice tier, answers were coded as 1 or 0 points. In the open-ended section, correct justification (C.J.) was coded as 2 points, partially correct justification (P.C.J.) as 1 point, and misconception (M), superficial knowledge (S.K.), and blank answers were coded as 0 points. Thus, the range of points that can be obtained from each item varies between 0 and 3. Examples of coding student answers are shown in Table 4 based on a randomly selected question.

Coding consistency was determined to be 95% based on the formula 'Reliability = Consensus / (Consensus + Disagreement)' proposed by Miles and Huberman (1994). Since the obtained value exceeded the commonly accepted threshold of.70, the results were considered to indicate an acceptable level of reliability (Büyüköztürk et al., 2018).

Content analysis was conducted to evaluate the open-ended section, through which students' misconceptions were identified. Additionally, to establish the reliability of the diagnostic test, a test-retest procedure was administered to 25 seventh-grade students at intervals of 3 to 4 weeks, and the Pearson correlation coefficient was calculated.

Findings

Findings for the Research Question "Is the SMDT a Valid and Reliable Instrument to Measure Secondary Students' Conceptual Understanding?"

The face and scope validity were established by preparing the specification table mentioned in the method section for SMDT, obtaining expert opinions, and determining the suitability for the student level. To find the reliability of the developed test, item analysis, KR-20, and Cronbach Alpha reliability coefficients, and Pearson correlation coefficient were calculated within the scope of the test-retest method (Karakoç & Dönmez, 2014).

Findings obtained from the item analysis of the two-tier SMDT

The data obtained from the item analysis of the two-tier SMDT showed that items 1, 2, and 8 had difficulty indices below 0.30 and discrimination indices below 0.20 (see Table 5). Since this showed that the items were difficult and their discrimination was low, these items were removed from the test (Avcı, 2020; Sontay & Karamustafaoğlu, 2020; Tekin, 2010). The average discrimination index of the items in the two-tier SMDT was found to be.44. It is preferred for the average difficulty to be between.40 and .60 (Büyüköztürk et.al., 2018). The average item difficulty index of the SMDT was found to be.42. According to Büyüköztürk et al. (2018), an item discrimination index above.40 is considered very good, between.30 and.39 is considered good, between.20 and.29 is considered moderate, and below.20 is regarded as poor. In light of these criteria, the SMDT was determined to be appropriate in terms of both average item difficulty and average item discrimination.

Table 4. Examples of coding student responses

Question	Part I	Part II				Point
	T/F	C.J.	P.C.J.	M	S.K.	
 Teacher Celal brings a device to the classroom and provides heat to a glass container filled with ice to enable his students to observe the phase change. Then, he asks them to make a comparison about the speed of movement of the particles of water in solid, liquid, and gas states depending on the phase change. Which of the following comparisons is correct? A) Solid=Liquid=Gas B) Solid<Liquid<Gas C) Liquid<Solid<Gas D) Gas<Liquid<Solid E) Solid<Gas<Liquid Write the reason for your answer.	Answer B			Because solids are hard, their particles are slow.		1
	Answer B				Because the order of state change is explained.	1
	Answer B		Because solid particles are slow.			2
	Answer B	Because as heat is given to the particles, their movement speed increases.				3

Table 5. Item analysis results

Item	Pj*	Rjx**	Item	Pj	Rjx
1	.23	.04	12	.33	.50
2	.15	.15	13	.60	.40
3	.40	.40	14	.37	.31
4	.60	.40	15	.32	.45
5	.50	.40	16	.35	.37
6	.40	.46	17	.53	.53
7	.59	.38	18	.40	.60
8	.20	.20	19	.33	.49
9	.33	.44	20	.31	.43
10	.42	.52	21	.36	.37
11	.36	.44	Mean	.42	.44

*Pj: Item difficulty index, **Rjx: Item discrimination index

Findings regarding the reliability of the two-tier SMDT

To find the reliability of the two-tier SMDT consisting of 18 items, the KR-20 coefficient, Cronbach's alpha, and Pearson's correlation coefficient were calculated. The KR-20 reliability coefficient for the first tier of the two-tier SMDT (n=325) was calculated as.75. When both tiers were evaluated together, the Cronbach's alpha coefficient (n=105) was found to be.81. Additionally, the Pearson correlation coefficient (n=25, p=.00) was calculated as.91. These values, all exceeding the commonly accepted threshold of.70, indicate that the two-tier SMDT demonstrates a high level of reliability and stability (Büyüköztürk, 2019; Şeker & Gençdoğan, 2020; Tavşancıl, 2014).

Findings Regarding the Question "What Are the Misconceptions that Secondary School Students Have about the Structure of Matter?"

To identify secondary school students' misconceptions about the structure of matter, the responses of 105 students to the second, open-ended section of the 18-item SMDT were analyzed using content analysis. This analysis revealed a total of 39 distinct misconceptions (see Table 6).

These misconceptions relate to particulate structure, hollow structure, moving structure, mass, volume, density, thermal insulation materials, thermal conductivity, and energy sources.

Conclusion And Discussion

This study aimed to develop a useful, valid, and reliable open-ended two-tier SMDT and to determine students' misconceptions. Two-tier diagnostic tests, which were recommended for use in the recently revised Science Curriculum (MoNE, 2024), can be used to determine misconceptions in science education (Karataş et al., 2003; Ningroom, Yamtinah, & Riyadi, 2025; Talens, Chiu, & Sevilla, 2024). Through a two-tier assessment, students justify their answers, and more sensitive measurements can be made. In addition, these tests allow teachers to discover the reasoning behind students' misconceptions (Tsai & Chou, 2022). In this way, two-tier diagnostic tests help teachers teach topics and concepts better.

In this study, the test development steps proposed by Treagust (1988) were followed. To ensure face and content validity, a test specification table was prepared, expert opinions were obtained, and the appropriateness of the items for the student level was evaluated (Avcı et al., 2018; Gürsel & Akçay, 2022; Şahin & Çepni, 2011). For reliability analysis, the test was initially administered to a sample of 325 secondary school students, and item analysis was conducted. As a result, three items with difficulty indices below.30 and discrimination

indices below.20 were excluded from the test (Büyüköztürk et al., 2018). Since there were other items in the test related to the outcome addressed by these items, the removal of these items didn't affect the content validity of the test (Orduhan & Çakır, 2023). In its final version, the test comprised 18 items, with average item difficulty and discrimination indices calculated as.42 and.44, respectively. These values show that SMDT is suitable in terms of average item difficulty and average discrimination (Büyüköztürk et al., 2018). Following the item analysis, the reliability of the first tier was examined, resulting in a KR-20 coefficient of.75. Then, the reliability of the first and second tiers of the test when evaluated together was investigated, and the Cronbach alpha coefficient was calculated as.81. In addition, a test-retest procedure was conducted with 25 seventh-grade students, resulting in a Pearson correlation coefficient of.91. All of these reliability values exceed the accepted threshold of.70, demonstrating that the two-tier SMDT is both reliable and stable (Büyüköztürk, 2019; Şeker & Gençdoğan, 2020; Tavşancıl, 2014). As a result, a useful, valid, and reliable diagnostic test consisting of 18 items that can contribute to the literature by allowing the collection of up-to-date data was developed. This situation is consistent with the results of two-tier open-ended diagnostic test development studies in the literature addressing different topics and learning outcomes, such as “pure matters and mixtures” (Civangönül & Çıbık, 2023) and “pressure” (Sarı & Çakır, 2024).

Table 6. Misconceptions obtained

Subject	Concept	Misconceptions	f	%
Particulate Structure of Matter	Particulate structure	When a matter changes state, there is a change in the number of particles.	32	30.48
		When a matter changes state, particles freeze, melt, or evaporate.	24	22.86
		When a matter changes state, changes are observed in the size of the particles.	24	22.86
		When the particles receive heat, they can combine or break apart.	21	20.00
	Hollow structure	Gas particles are light, liquid particles are medium light, and solid particles are heavy.	16	15.24
		There is no space between the particles forming the solid.	14	13.33
		The hollow structure is an air/air bubble.	12	11.43
	Moving structure	**When the space between the particles increases, the particles accelerate.***	23	21.90
		The particles that form the solid are motionless.	21	20.00
		The speeds of the particles that form a solid, liquid, and gas are equal.	18	17.14
		When a matter is heated, the vibration in its particles decreases.	11	10.48
		Since solids are hard, their particles are slower than liquids.*	9	8.57
Density	Mass	When matters freeze, their mass increases.	21	20.00
		As a matter gets smaller, its mass increases.	18	17.14
		When a matter is changed by applying force to its shape, its mass also changes.	16	15.24
	Volume	**When a matter is given different shapes, its volume doesn’t change.***	15	14.28
	Density	Heavy matters sink; light matters float.	37	35.24
		The floating-sinking-suspending states of matters are only related to mass.	32	30.48
		Matters with large mass and volume are the densest.	26	24.76
		The floating-sinking-suspending states of matters are only related to volume.	26	24.76
		Hard matters sink, soft matters float.	22	20.95
		The positions of immiscible liquids with different densities are related to their masses.	21	20.00
		The one with the higher density of two immiscible liquids remains on top.	19	18.09
		For a matter to float in water, its density must be greater than the density of water.	18	17.14
		The positions of immiscible liquids with different densities are related to their volumes.	18	17.14
		The way a matter is thrown (vertical/horizontal) affects whether it floats or sinks.	14	13.33
		The smaller the volume of a matter, the heavier it becomes.	13	12.38
		All pure solids sink in their own liquids.	10	9.52
Matter and Heat	Thermal insulation	Thermally insulated houses are always warm.	21	20.00
		Thermal insulation doesn’t contribute to the family economy because it causes more money to be spent.	18	17.14
		Matters such as cotton, felt, and styrofoam don’t transmit cold.	18	17.14
	Thermal insulation materials	Thermal insulation materials (cotton, felt) heat the environment they are in.	21	20.00
		Aluminum and steel are insulating matters.	17	16.19
		Plastic reflects heat. *	13	12.38
		Plastics don’t heat.	12	11.43
	Thermal conductivity	Metals absorb heat/cold.	30	28.57
		Metals are always hot/cold.	24	22.86
Fuels/ Human-Environment Interaction	Energy sources	Non-renewable energy sources don’t harm human health or inanimate matter.	21	20.00
		Natural gas is a renewable energy source and doesn’t harm human health.	24	22.86

*Represents misconceptions not encountered in national and international literature.

In addition, the study examined students' misconceptions through the analysis of responses in the open-ended section. Content analysis revealed a total of 39 misconceptions related to the structure of matter. This situation shows that the developed test is effective in determining students' misconceptions (Tüysüz, 2009). The reason for reaching a large number of misconceptions may be that students are asked to explain why they chose that option after each multiple-choice test item (Töman, Karataş, & Çimer, 2013). In addition, this may be attributed to the fact that the answer choices were developed based on both students' written responses to the open-ended questions and misconceptions previously reported in the literature (Alwan, 2011; Griffiths & Preston, 1992; Kenan, Özmen, & Güney, 2007; Kılıç, 2017; Kiray & Simsek, 2021; Lee, 2014; Schnittka, 2009; Tamkavas, Kıray, Koçak, & Koçak, 2016). 4 of the misconceptions identified were not found in the national and international literature. The identification of new misconceptions may be attributed to the opportunity provided by the second tier of the diagnostic test, which allowed students to articulate their thoughts in greater detail.

When the misconceptions obtained regarding the "particulate structure of matter" are evaluated holistically, it is seen that students hold misconceptions concerning the submicroscopic properties of matter and tend to interpret submicroscopic concepts using macroscopic-level reasoning. The literature frequently emphasizes that students encounter difficulties when dealing with concepts presented across different representational levels (Chittleborough & Treagust, 2008; Wu, Krajcik, & Soloway, 2001). For example, Özmen (2011) reported that students in grades 4 through 6 demonstrated a low level of understanding regarding the submicroscopic properties of matter. Nakhleh and Samarapungavan (1999) found that students had an idea of macroscopic structure rather than submicroscopic structure. Chandrasegaran, Treagust, and Mocerino (2007) found that students had difficulties with macroscopic and submicroscopic representations.

Misconceptions determined regarding the "particulate structure of matter" are as follows: "When matter changes state, there is a change in the number of particles", "When a matter changes state, particles freeze, melt, or evaporate", "When a matter changes state, changes are observed in the size of particles", "When particles receive heat, they can combine or break apart", "Gas particles are light, liquid particles are medium light, and solid particles are heavy", "There is no space between the particles forming the solid", "The hollow structure is air/air bubble", "The particles that form the solid are motionless", "The speeds of the particles that form a solid, liquid, and gas are equal" and "When a matter is heated, the vibration in its particles decreases" This situation doesn't come as a surprise to students who are just starting to move into the abstract operations period. An analysis of the literature revealed the presence of similar misconceptions (Demircioğlu, Vural & Demircioğlu, 2013; Griffiths & Preston, 1992; Kapıcı & Akçay, 2016; Kuşakçı-Ekim, 2007; Ormancı & Balım, 2014; Özmen, 2011). Kuşakçı-Ekim (2007) reported that some students held the misconception that "The particles in a solid state remain entirely stationary", Demircioğlu, Vural and Demircioğlu (2013) found the misconception that "The number of particles of the same amount of matters in different states is different", and Griffiths and Preston (1992) found the misconception that "Heat causes the particles (molecules) to expand during melting and the particles to separate or break apart" and "The mass of water particles varies with state, being greatest in the solid phase and least in the gaseous phase".

In this study, two misconceptions that are not encountered in national and international literature regarding the "particulate structure of matter" were identified. The first of these is, "When the space between particles increases, the particles accelerate." In fact, when the mobility of particles increases, the space between them increases. This misconception indicates that students struggle to establish cause-and-effect relationships and fail to comprehend how heat influences particle behavior. Although this identified misconception superficially resembles those reported by Çavdar, Okumuş, and Doymuş (2016) as "Solids are immobile because there is little intermolecular space," by Özalp and Kahveci (2015) as "When iron is in the solid phase its atoms do not move because there is not any space between atoms of solids." and by Tsitsipis, Stamovlasis, and Papageorgiou (2012) as "There is no intrinsic motion of molecules especially in the solid state where no motion of the substance is visible." it reveals a different cognitive structure. While previous studies addressed particle motion and the hollow structure through a dualistic view of presence or absence, the misconception identified in this study involves a more dynamic cause-and-effect model that attempts to explain the speed of motion. Therefore, this misconception expands upon the "hollow and immobility" relationship frequently reported in the literature, pointing to a more complex mental model established between hollow and speed. A possible explanation for this misconception may be that teachers have taught the change of the porous and mobile structure during the phase change of particles as separate pieces of information, independent of each other. In addition, since the visuals in the textbooks are stationary, the cause-and-effect relationship between the mobile and porous structure may not have been established. Another possible situation is that the visuals in the textbooks may reflect the text incompletely or incorrectly. In these cases, students may be asked to explain the visuals and have an in-class discussion about the visuals (Kapıcı & Savaşcı-Açıkalın, 2015).

Another misconception that was not encountered in the national and international literature regarding the "particulate structure of matter" in this study is "Since solids are hard, their particles are slower than liquids." In fact, the reason why the particles that make up a solid are slower than the particles that make up a liquid is that they have less heat. As matters receive heat, the mobility of the particles increases. With this misconception, it can be said that students cannot comprehend the particulate structure of matter and heat interaction (Kaplan & Boyacıoğlu, 2013) and try to explain a submicroscopic property of matter by looking at its macroscopic property (Chandrasegaran et al., 2007). Previous studies aimed at identifying misconceptions have reported, independently of each other, the misconceptions that "solid particles are hard" (Ayyıldız & Tarhan, 2013; Tatar, 2011) and "solid particles are immobile" (Adadan, Irving, & Trundle, 2009; Çavdar et al., 2016). The misconception obtained in this study shows that students directly transfer the hardness of solids at the macroscopic level to the microscopic level and consider it as a factor affecting the mobility of the particles. Therefore, this misconception reveals that the misconceptions regarding the hardness and mobility of solid particles exhibit a more intertwined and causal structure than those discussed in the literature.

When the misconceptions obtained regarding "density" are evaluated holistically, it has been observed that students often conflate the concept of density with mass or volume, assuming that density can be determined based solely on one of these properties. This situation is frequently encountered in the literature (Dawkins et.al., 2008; Harrell & Subramaniam, 2014; Tasdere & Ercan, 2011; Yin, Tomita, & Shavelson, 2008). Harrell and Subramaniam (2014) highlighted that many students focus on only one aspect of density and experience difficulties in applying relational reasoning, which requires the integrated consideration of both variables. They attributed this issue largely to a rote-learning approach to conceptual understanding.

Misconceptions determined regarding the Density are as follows: "When matters freeze, their mass increases", "As a matter gets smaller, its mass increases", "When a matter is changed by applying force to its shape, its mass also changes", "Heavy matters sink; light matters float", "The floating-sinking-suspending states of matters are only related to mass", "Matters with large mass and volume are the densest", "The floating-sinking-suspending states of matters are only related to volume", "Hard matters sink, soft matters float", "The positions of immiscible liquids with different densities are related to their masses", "The one with the higher density of two immiscible liquids remains on top", "For a matter to float in water, its density must be greater than the density of water", "The positions of liquids with different densities that don't mix with each other are related to their volumes", "The way a matter is thrown (vertical/horizontal) affects whether it floats or sinks", "The smaller the volume of a matter, the heavier it becomes" and "All pure solids sink in their own liquids". Density is often regarded as a complex concept, as it represents a ratio between mass and volume rather than a directly measurable quantity (Dawkins, Dickerson, McKinney, & Butler, 2008). Students' inadequate conceptual knowledge about the concepts of mass and volume, their inability to grasp the particulate structure of matter, and their weak learning about ratio and proportion in mathematics may have caused these misconceptions. An analysis of the literature revealed the presence of similar misconceptions (Griffiths & Preston, 1992; Harrell & Subramaniam, 2014; Kılıç, 2017; Kiray et al., 2015; Kiray & Simsek, 2021; Ültay & Akpinar, 2008; Yin, Tomita, & Shavelson, 2008). Ültay and Akpinar (2008) reached the misconception that "The density of objects with large volumes is also high", Kiray and Simsek (2021) reached the misconception that "Phase change doesn't affect the density of matters", Tasdere and Ercan (2011) reached the misconceptions that "The density of an object floating in a liquid is equal to the density of the liquid", Kılıç (2017) reached the misconception that "For an object to float in water; its total density must be greater than the density of water", and Harrell and Subramaniam (2014) reached the misconception that "Density is the same as mass and weight"

In this study, a misconception that isn't encountered in the national and international literature on density was reached. This misconception is as follows: "When a matter is given different shapes (such as a boat and a ball), its volume doesn't change". In fact, when a matter is given different shapes, its volume can change. With this misconception, it can be said that students cannot grasp the concept of volume. The reason for this situation may be that students cannot visualize volume change, lack of knowledge, or have memorized the concept definition (Guerra-Reyes, Guerra-Dávila, Naranjo-Toro, Basantes-Andrade, & Guevara-Betancourt, 2024; Wiyantara, Widodo, & Prima, 2021). Another reason might be the confusion between the properties of mass and volume, which are discussed in relation to density. Students may have incorrectly applied the concept of volume to their previous lesson's understanding of "mass is conserved". This situation shows that even accurate information can pave the way for new misconceptions if the contextual boundaries of concepts are not sufficiently emphasized. Therefore, the misconception revealed in this study may stem not only from a misunderstanding of the concept of volume, but also from students' tendency to overgeneralize relationships between different physical quantities. Previous studies have shown that students develop misconceptions through overgeneralizations (Karaağaç & Köse, 2015). This result from the study highlights the importance of addressing the relationships between mass, volume, and density in a clear and comparative manner when teaching the concept of density. The volume-related misconception identified in this study differs significantly from commonly reported misconceptions in the literature. Previous studies have addressed misunderstandings regarding volume, particularly in the context of phase transitions. For example, Stojanovska, Soptrajanov, and Petrusevski (2012) reported the misconception that "In a process of ice melting, the volume of the system (mixture of ice and liquid water) increases" and Özalp and Kahveci (2015) reported the misconception that "Since iron heats during it melts, its atoms also heat, so atoms melt and their volume increases" in their studies. The misconception identified in this study deals with the relationship between shape change and volume. From this perspective, the identified misconception enriches the literature on misconceptions about volume with a new example.

When the misconceptions obtained regarding "matter and heat" in the study are evaluated holistically, it is observed that students can't understand the events of heat conduction and thermal insulation. When the literature is examined, Uzoğlu and Yıldız (2011) also determined that students' level of understanding of the concepts of heat, heat conduction, and thermal insulation is weak. For heat conduction and thermal insulation events to be understandable, it is necessary to have a complete and accurate understanding of the particulate structure of matter (Sopandi et.al., 2018). Because heat conduction is the transfer of energy of particles by colliding with each other.

The misconceptions determined regarding "matter and heat" are as follows: "Thermally insulated houses are always warm", "Thermal insulation doesn't contribute to the family economy because it causes more money to be spent", "Matters such as cotton, felt, and styrofoam don't transmit cold", "Thermal insulation materials (cotton, felt) heat the environment they are in", "Aluminum and steel are insulating matters", "Plastics don't heat", "Metals absorb heat/cold" and "Metals are always hot/cold". The reason for these misconceptions may be the meanings that students attribute to their daily experiences (Luera, Otto, & Zitzewit, 2005). For example, the student's feeling of warmth after wearing a sweater made of wool yarn may have led him to think that this insulation material has a heating feature. The fact that families living in a region with a low annual average temperature want to have thermal insulation done only to maintain the heat in their homes during the winter months may have created the misconception in students that houses with thermal insulation are always warm. Similarly, a family who wants to have thermal insulation done in their home may have expressed the necessary expenses and not mentioned the long-term gain. An analysis of the literature revealed the presence of similar

misconceptions (Akpınar & Çite, 2015; Alwan, 2011; Çelik, 2024; Başer & Çataloğlu, 2005; Duman & Avcı, 2016). Alwan (2011) reached the misconceptions "Metal can attract, retain, concentrate or absorb heat and cold" and "Materials such as wool have the ability to heat things". Çelik (2024) reached the misconception "Wool clothes warm people". The misconception of Akpınar and Çite (2015) and Başer and Çataloğlu (2005), and "Aluminum foil provides more thermal insulation than wool" was reached.

In this study, a misconception that is not encountered in the national and international literature on matter and heat was reached. This misconception is "Plastic reflects heat". In fact, shiny and light-colored surfaces reflect heat. The reason why students have this misconception may be the temperature measurement they make with their hands by touching plastic in daily life. The students may have thought that they felt cool because plastic reflects heat, not because it is a thermal insulator. The development of misconceptions from everyday experiences is a common occurrence in the literature (Schmidt, 2000; Treagust, 1988). In previous studies, students have attributed properties such as "absorption", "confinement", or "retention" to heat (Lewis & Linn, 2003; Schnittka, 2009; Tamkavas et al., 2016). The misconception identified in this study, unlike those in the literature, is that heat is "reflected". This misconception suggests that students are transferring previously learned physical processes, such as the reflection of light, to the concept of heat and confusing concepts related to different types of energy. Therefore, this finding indicates that it is not merely an inference based on experience, but also the product of a more complex mental model resulting from interdisciplinary conceptual transfer.

When the misconceptions obtained regarding "fuels and human-environment interaction" in the study are evaluated holistically, it is seen that the students can't make sense of the concepts of renewable and non-renewable energy, confuse them with each other, and have a lack of knowledge about their effects on humans and the environment. Benzer et al. (2014), as noted in the literature, reported that students demonstrated limited understanding of energy sources. Boylan (2008) also found that students had misconceptions about renewable and non-renewable energy sources and that their understanding was low. It is also noteworthy that students had fewer misconceptions than those on other topics covered in the study. The reason for this may be that the concepts in this topic (e.g., oil, natural gas, fossil fuel, solar energy, etc.) are concrete concepts used in daily life and heard in the media.

The misconceptions determined regarding "fuels and human-environment interaction" are as follows: "Non-renewable energy sources don't harm human health or inanimate matter" and "Natural gas is a renewable energy source and doesn't harm human health". The misconception that natural gas is a renewable energy source and is harmless may have arisen from the word "Natural". Students may have interpreted the word "Natural" as meaning that natural gas must be renewable (Boylan, 2008). The misconception that non-renewable energy sources don't harm human health and inanimate matter may have arisen from a lack of knowledge. An analysis of the literature revealed the presence of similar misconceptions (Boylan, 2008; Cırıt, 2017; Tortop, 2012; Yaman, 2018). Boylan (2008), Cırıt (2017), and Tortop (2012) reported the misconception that "Natural gas is a renewable energy source", and Yaman (2018) reported the misconception that "Fossil fuels do not cause the greenhouse effect" in their studies.

Recommendations

- Two separate data sets can be obtained by considering only the first multiple-choice tier of the developed SMDT, namely, academic achievement, and conceptual understanding by considering both tiers.
- SMDT can be used to determine misconceptions by using it before teaching and to adapt teaching strategies accordingly.
- SMDT can be used to provide diagnostic assessment by using it before teaching, and it can also be used for formative assessments by applying it at the beginning, middle, and end of the teaching process to measure conceptual change.
- The test can be applied on digital platforms such as Google Forms, and thus, student responses can be accessed quickly.
- Considering the 39 misconceptions identified, it's recommended to reconsider the ways of teaching concepts and to adopt student-centered education methods.
- It's recommended that studies be conducted with a larger number of participants to increase the generalizability of the test.
- Furthermore, applying the test to students from different grade levels may allow researchers to perform cross-comparisons.

Author Contributions

The authors contributed equally to the preparation of this manuscript. Both authors have read and approved the final version of the manuscript. This study was produced from the first author's doctoral thesis, conducted under the supervision of the second author.

Ethical Declaration

This study was conducted with the approval decision taken at the meeting of Istanbul University-Cerrahpasa Social and Human Sciences Research Ethics Committee (No. 2023/316) dated 12.09.2023 (Number: E-74555795).

Conflict of Interest

The authors declare that there is no conflict of interest with any institution or person within the scope of the study.

Declaration of Generative AI Use

The authors declare that they did not use any artificial intelligence tools in this study.

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Appendix 1. Misconceptions collected from the literature regarding the structure of matter

Subject	Concepts	Misconceptions	Source
Particulate Structure of Matter	• Particulate structure • Hollow structure • Moving structure • Vibration • Translation • Rotation	• The particles that make up matter can be seen under a microscope. • Particles (atoms) are alive because they move. • The smallest particles that make up solid matter are also solid. • When a matter changes state, changes are observed in the size and shape of the particles. • The shape of the container affects the shape of the molecules (particles). • Pressure can change the size and number of particles. • The number of particles increases as a result of heating the matters, and decreases as a result of cooling. • Since the particles of solid matters are in contact with each other, there is no space between them. • The particles of solid matters are not regular. • The particles of solid matters can change places. • The particles of liquid and gaseous matters only make rotational movements, not vibrations. • There is matter between the particles. • The space between the particles is the least in gases. • The distance between liquid particles is moderate compared to the distance between solid and gas particles. • Gases can't be compressed; liquids can be compressed. • A glass of milk has a certain volume but no shape. • When air is heated, the speed of the particles decreases. • Gas particles settle to the bottom in a closed container. • Water particles in a phase (solid, liquid, or gas) can have different sizes.	• Adadan et. al. (2009) • Doran & Pella (1970) • Gökulu (2013) • Griffiths & Preston (1992) • Kenan, Özmen & Güney (2007) • Kılıç (2017) • Meşeci, Tekin & Karamustafaoğlu (2013)
Density	• Mass • Volume • Density	• Heavy matters are dense. • Matters with the same weight have the same density. • Heavy matters sink, and light matters float. • It can be understood that the matter will float or sink just by looking at its shape. • Density isn't a distinguishing feature for pure matters. • The density of floating matters is equal to the liquid. • The densities of sinking matters in liquid are equal. • The density of matters with large masses is also large. • As density increases, mass increases. • Of two liquids that cannot be mixed, the one with the higher density remains on top. • The density of matters with large volumes is large • Since floating and sinking are related to the density of the matter, it's independent of the density of the liquid. • The density of all liquids that freeze increases because their volume will decrease. • Phase change doesn't affect the density of matters. • Density remains constant because mass doesn't change during phase change. • Density remains constant because volume doesn't change during phase change. • For a matter to float in water, its density must be greater than the density of water. • Holes sink. • A hollow matters will float because it will be filled with air. • Hollow things float; things with air inside float. • Vertical things sink; horizontal things float. • Hard things sink, soft things float. • When two floating matters are combined into a block, the block sinks due to the increase in its volume. • When two floating matters of the same density are combined into a block, the block remains suspended in the liquid due to the increase in its density.	• Griffiths & Preston (1992) • Kılıç (2017) • Kiray & Simsek (2021) • Kiray et.al. (2015) • Tasdere & Ercan (2011) • Yin, Tomita & Shavelson (2008)
Matter and Heat	• Heat • Thermal conductivity • Thermal insulation capacity • Thermal insulation	• Cold is a moving matter. • Metal matters are colder than plastic ones. • Metal attracts cold. • The directionality of heat transfer is not understood because heat is not a form of energy. • Metal doesn't conduct heat well; it takes it all.	• Alwan (2011) • Aydoğan, Güneş & Gülçiçek (2003) • Lee (2014)

	• Thermal insulation materials	• When we touch wood or metal at room temperature, we feel the metal is cold because our hand is warm. • Metals provide better thermal insulation. • Plastic doesn't conduct heat; it is a good method to keep matters cold. • For heat conduction to occur, there must be a conductive medium or a matter. • Heat flows more easily in large matters • Glass is a thermal insulator. It prevents heat exchange. • Matters store heat. • Heat spreads by melting solids. • Matters have the same heat absorption resistance. • A cold matter doesn't contain heat. • The temperature of a matter depends on its size. • Heat and cold flow like liquids. • Temperature is a property of a particular material or object. • Matters such as wool can warm the environment. • Some matters are difficult to heat: they are more resistant to heat. • A heat-insulated container designed to keep water hot will not work to keep ice cream cold.	• Schnittka (2009) • Tamkavas, Kıray, Koçak & Koçak (2016)
Fuels/ Human-Environment Interaction	• Solid fuels • Liquid fuels • Gas fuels • Renewable energy sources • Non-renewable energy sources • Fossil fuels	• Natural gas is a renewable energy source. • Nuclear energy is a renewable energy source. • Batteries and light bulbs are renewable energy sources. • Electricity is an energy source. • Renewable energy sources have no harmful effects. • Fertilizer is an energy source. • Air, water, sun, exercise, ambient temperature, and sleep are energy sources. • There are natural and artificial energy sources. • Fossil fuels can be formed in a short time. • Natural gas is the same as gasoline. • Coal is formed from rocks. • Wood is a non-renewable energy source. • Fossil fuels don't cause the greenhouse effect.	• Benzer, Bayrak, Eren & Gürdal (2014) • Boylan (2008) • Boz & Gorgulu Arı (2020) • Çoker, Çatlıoğlu & Birgin (2010) • Rule (2005) • Saraç & Bedir (2014) • Töman & Çimer (2013) • Yaman (2018)

Appendix 2 (A)

1. Teacher Celal brings a device to the classroom and provides heat to a glass container filled with ice to enable his students to observe the phase change. Then, he asks them to make a comparison about the speed of movement of the particles of water in solid, liquid, and gas states, depending on the phase change. Which of the following comparisons is correct?
A) Solid = Liquid = Gas
B) Solid < Liquid < Gas
C) Liquid < Solid < Gas
D) Gas < Liquid < Solid
E) Solid < Gas < Liquid
Write the reason for your answer.

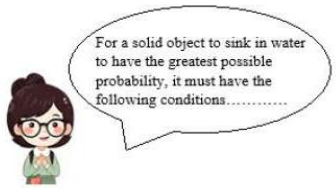
.....

2. When pure water in liquid state at 24°C is cooled to 0°C and freezes, which of the following will occur in the movement of its particles?
A) No change occurs.
B) Acceleration occurs.
C) Deceleration occurs.
Write the reason for your answer.

.....

3. When a piece of iron is melted by applying heat, the space between the particles that make up the iron becomes .....
Which of the following can be written in the blank in the sentence above?
A) Increases
B) Decreases
C) Remains unchanged
Write the reason for your answer.

.....



4. Which of the following should complete the teacher's sentence?
A) It should have a small mass and a large volume.
B) It should have a large mass and a small volume.
C) It should have a small mass and a small volume.
D) It should have a large mass and a large volume.
Write the reason for your answer.

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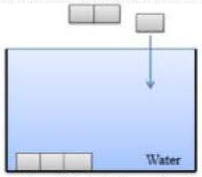

5. In the image above, a pure iron block is thrown horizontally into water and it is observed to sink. What do you think will happen if a part of the block is thrown into the water horizontally, as shown in the image?
A) It sinks
B) It floats
C) It remains suspended
Write the reason for your answer.

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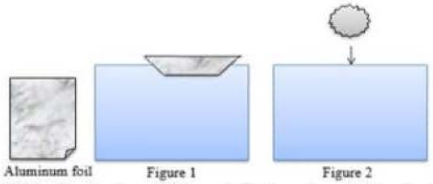

6. When the aluminum foil shown in the image is made into a boat and placed in the water, the situation shown in Figure 1 is observed. When the same aluminum foil is crushed into a ball and placed in the water as shown in Figure 2,

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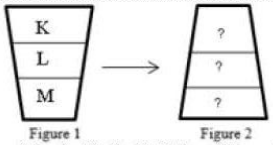
Which of the following can be written in the blank in the sentence above?
I. It can float
II. It can sink
III. It can remain suspended
A) Only I
B) Only II
C) I and II
D) I, II and III
Write your reason for answer.

.....



7. As shown in Figure 1, immiscible liquids K, L, and M are placed in a bottle. Their positions inside the bottle are observed as shown in the figure. Then, as seen in Figure 2, the bottle is inverted with its mouth closed. In Figure 2, which liquids are in the bottle from top to bottom in order?
A) M, L, K
B) K, L, M
C) L, K, M
D) L, M, L
Write the reason for your answer.

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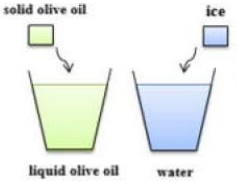

8. What happens if ice and solid olive oil, which have the same volume, are placed in their own liquids as shown in the figure?
A) Solid olive oil and ice sink in their own liquids.
B) Solid olive oil and ice float in their own liquids.
C) Solid olive oil floats in its own liquid, while ice sinks in its own liquid.
D) Solid olive oil sinks in its own liquid, while ice floats in its own liquid.
Write the reason for your answer.

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9. Today, it is known that water begins to freeze from the top due to the difference in density. If ice were denser than water;
I. All the water in lakes, seas, and oceans could freeze.
II. The ice layer would remain on top.
III. The lives of aquatic creatures could be endangered.
Which of these premises could occur?
A) Only I
B) Only II
C) I and III
D) II and III
E) I, II, and III
Write the reason for your answer.

.....

10. On a hot summer day, when two trays of the same size and temperature, one made of steel and the other of plastic, are left under the sun;
A) The steel tray heats up faster than the plastic tray.
B) The plastic tray heats up faster than the steel tray.
Write the reason for your answer.

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11. There are two different drain pipes on the roof, made of copper and aluminum, of the same thickness. Which of the following is true regarding the freezing of the pipes?

A) The copper pipe will freeze first.
B) The aluminum pipe will freeze first.
C) Both pipes will freeze at the same time.
Write the reason for your answer.

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Parts of the House	Materials
-Interior and exterior walls -Interior and exterior flooring	-Styrofoam -Stone wool -Glass wool -Wood

12. Which of the above given thermal insulation materials would you use in which part of the house?

A) Interior and exterior walls - Wood
Interior and exterior flooring - Styrofoam
B) Interior and exterior walls - Styrofoam
Interior and exterior flooring - Wood
C) Interior and exterior walls - Styrofoam
Interior and exterior flooring - Stone wool
D) Interior and exterior walls - Glass wool
Interior and exterior flooring - Styrofoam
Write the reason for your answer.

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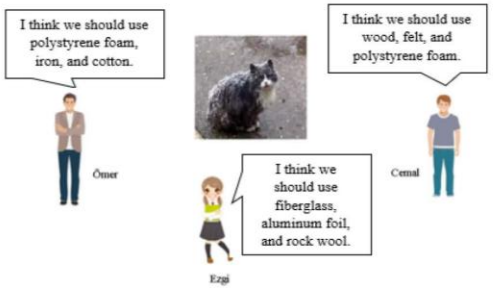

13. Ömer, Ezgi, and Cemal have decided to build a "cat house" to protect their cats from the cold during the winter months. However, they haven't been able to decide which materials to use for insulation. Which of their suggestions do you think provides the best insulation?

A) Ömer
B) Ezgi
C) Cemal
Write the reason for your answer.

.....

14. Serra told Sibel that she wanted to live in a well-insulated house and that this choice would contribute to the family budget. Sibel disagreed with this idea and said that it wouldn't be effective in contributing to the family budget. Which one do you agree with?

A) Serra
B) Sibel
Write the reason for your answer.

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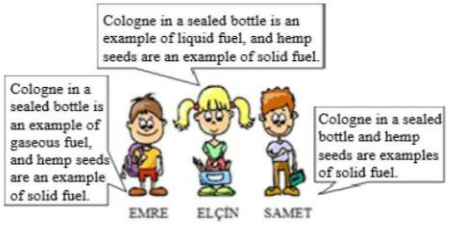

15. Which of the students who made the above comments has the correct comment?
A) Emre
B) Elçin
C) Samet
D) None of them
Write the reason for your answer.

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I. Cologne
II. Coal
III. Biomass
IV. Natural Gas
16. Which of the combustible materials given above do you think we should use for heating purposes in the future?
A) Only III
B) I and III
C) I and IV
D) II and IV
E) III and IV
Write the reason for your answer.

.....

17. (1) All fuels used for heating are non-renewable energy sources. (2) Coal, oil, and natural gas can be given as examples of non-renewable energy sources. (3) All of these sources cause the release of toxic gases into nature. (4) While the release of these gases harms human health, it has no harm to inanimate objects.
Which of the numbered sentences in the paragraph above contains incorrect information?
A) Only 3
B) 1 and 3
C) 1 and 4
D) 2 and 4
E) 3 and 4
Write the reason for your answer.

.....

I. The stove's air inlets should be completely closed.
II. The area where the stove is located should be continuously ventilated.
III. Too much fuel should be added to a dying fire to reignite it.
18. Which of the above should be done to prevent stove poisoning?
A) Only I
B) Only II
C) I and II
D) I, II, and III
Write the reason for your answer.

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Appendix 2 (B)

1. Celal öğretmen sınıfa getirdiği düzenek ile içerisi buz dolu cam kaba ısı vererek öğrencilerinin hal değişimini gözlemlemesini sağlıyor. Ardından hal değişimine bağlı olarak suyun katı, sıvı ve gaz hallerdeki taneciklerinin hareket hızları hakkında bir kıyaslama yapmalarını istiyor. Aşağıda verilen kıyaslamalardan hangisi doğrudur?

A) Katı=Sıvı=Gaz
B) Katı<Sıvı<Gaz
C) Sıvı<Katı<Gaz
D) Gaz<Sıvı<Katı
E) Katı<Gaz<Sıvı
Cevabınızın nedenini yazınız.

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2. 24°C'deki sıvı haldeki saf su, 0°C'ye kadar soğutulup donduğu zaman taneciklerinin hareketinde aşağıdakilerden hangisi olur?

A) Hiçbir değişiklik olmaz.
B) Hızlanma olur.
C) Yavaşlama olur.
Cevabınızın nedenini yazınız.

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3. Bir demir parçasına ısı verilerek eritildiğinde demiri oluşturan tanecikler arasındaki boşluk .....
Yukarıdaki cümlede bulunan boşluğa aşağıdakilerden hangisi yazılabilir?
A) Artar
B) Azalır
C) Değişmez
Cevabınızın nedenini yazınız.

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4. Öğretmen cümlesini aşağıdakilerden hangisi ile tamamlamalıdır?
A) Kütlesi az, hacmi büyük olmalıdır.
B) Kütlesi çok, hacmi küçük olmalıdır.
C) Kütlesi az, hacmi küçük olmalıdır.
D) Kütlesi çok, hacmi büyük olmalıdır.
Cevabınızın nedenini yazınız.

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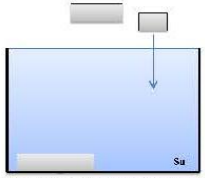

5. Yukarıdaki görselde verilen saf demir blok yatay şekilde suya atılıyor ve battığı gözlemleniyor. Sizce bloğun görseldeki gibi bir parçası suya yine yatay olacak şekilde atıldığında ne olur?
A) Batar
B) Yüzer
C) Askıda kalır
Cevabınızın nedenini yazınız.

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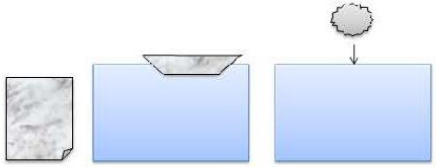

6. Şekildeki alüminyum folyo kayık haline getirilerek suya bırakıldığında Şekil 1'deki durum gözlemleniyor. Aynı alüminyum folyo içi tamamen dolu olacak şekilde ezilerek top haline getirilip Şekil 2'deki gibi suya bırakıldığında .....
Yukarıdaki cümlede bulunan boşluğa
I. Yüzebilir
II. Batabilir
III. Askıda kalabilir
Yukarıda verilenlerden hangileri yazılabilir?
A) Yalnız I
B) Yalnız II
C) I ve II
D) I, II ve III
Cevabınızın nedenini yazınız.

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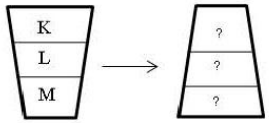

7. Şekil 1'de gösterildiği üzere bir şişeye birbirine karışmayan K, L ve M sıvıları konuluyor. Şişe içerisindeki konumlar şekildeki gibi gözleniyor. Daha sonra Şekil 2'de görüldüğü üzere şişe ağzı kapalı bir şekilde ters çevriliyor. Şekil 2'de şişenin yukarıdan aşağıya doğru sırasıyla hangi yer alır?
A) M, L, K
B) K, L, M
C) L, K, M
D) L, M, L
Cevabınızın nedenini yazınız.

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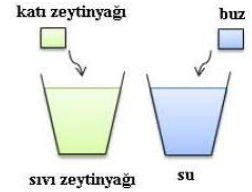

8. Aynı hacme sahip katı haldeki buz ve zeytinyağı, şekildeki gibi kendi sıvılarına bırakılırsa ne olur?
A) Katı haldeki zeytinyağı ve buz kendi sıvılarında batar.
B) Katı haldeki zeytinyağı ve buz kendi sıvılarında yüzer.
C) Katı haldeki zeytinyağı kendi sıvısında yüzerken, buz kendi sıvısında batar.
D) Katı haldeki zeytinyağı kendi sıvısında batarken, buz kendi sıvısında yüzer.
Cevabınızın nedenini yazınız.

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9. Günümüzde suyun yoğunluk farkı nedeniyle üstten donmaya başladığı bilinmektedir. Buz, sudan daha yoğun olsaydı;
I. Göl, deniz ve okyanuslardaki suyun tamamı donabilirdi.
II. Buz tabakası üstte kalırdı.
III. Suda yaşayan canlıların yaşamı tehlikeye girebilirdi.
Öncüllerinden hangileri gerçekleşebilirdi?

A) Yalnız I
B) Yalnız II
C) I ve III
D) II ve III
E) I, II ve III
Cevabınızın nedenini yazınız.

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10. Sıcak bir yaz günü aynı boyut ve sıcaklıklardaki çelik ve plastikten yapılmış iki tepsi Güneş'in altında kaldığında;
A) Çelik tepsi plastik tepsiden daha hızlı ısınır.
B) Plastik tepsi çelik tepsiden daha hızlı ısınır.
Cevabınızın nedenini yazınız.

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11. Çatıda yer alan aynı kalınlıktaki bakır ve alüminyumdan yapılmış iki farklı tahliye borusu bulunmaktadır. Boruların buz tutması ile ilgili olarak aşağıdakilerden hangisi doğrudur?

A) Bakır boru daha önce buz tutar.
B) Alüminyum boru daha önce buz tutar.
C) İki boru aynı anda buz tutar.
Cevabınızın nedenini yazınız.

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Evin bölümleri	Malzemeler
-İç ve dış cepheler -İç ve dış döşemeler	-Strafor köpük -Taş yünü -Cam yünü -Ahşap

12. Yukarıda verilen ısı yalıtım malzemelerinden hangilerini evin hangi bölümünde kullanırsınız?
A) İç ve dış cepheler-Ahşap
İç ve dış döşemeler-Strafor köpük
B) İç ve dış cepheler-Strafor köpük
İç ve dış döşemeler-Ahşap
C) İç ve dış cepheler-Strafor köpük
İç ve dış döşemeler-Taş yünü
D) İç ve dış cepheler-Cam yünü
İç ve dış döşemeler-Strafor köpük
Cevabınızın nedenini yazınız.

.....

13. Ömer, Ezgi ve Cemal kedileri kış aylarında soğuktan korumak için bir "kedi evi" yapma kararı almıştır. Fakat ısı yalıtımı için hangi malzemeleri kullanacaklarına karar verememişlerdir. Sizce hangisinin önerisiyle en iyi ısı yalıtımı sağlanır?
A) Ömer
B) Ezgi
C) Cemal
Cevabınızın nedenini yazınız.

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14. Serra, Sibel'e ısı yalıtımlı bir evde oturmak istediğini ve bu seçiminin aile ekonomisine katkı sağlayacağını ifade etmiştir. Sibel ise bu fikre katılmadığını ve aile ekonomisine katkı sağlama konusunda bu durumun etkili olmadığını söylemiştir. Siz hangisine katılıyorsunuz?
A) Serra
B) Sibel
Cevabınızın nedenini yazınız.

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15. Yukarıdaki yorumları yapan öğrencilerden hangisinin yorumu doğrudur?

A) Emre
B) Elçin
C) Samet
D)Hiçbiri
Cevabınızın nedenini yazınız.

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I.Kolonya
II. Kömür
III. Biyokütle
IV. Doğalgaz

16. Yukarıda verilen yanıcı maddelerden sizce hangisini/hangilerini gelecekte ısınma amaçlı kullanmamız gerekir?
A) Yalnız III
B) I ve III
C) I ve IV
D) II ve IV
E) III ve IV
Cevabınızın nedenini yazınız.

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17. (1) Isınma amaçlı kullanılan yakıtların tümü yenilenemez enerji kaynaklarıdır. (2) Kömür, petrol ve doğal gaz yenilenemez enerji kaynaklarına örnek olarak verilebilir. (3) Bu kaynakların tümü doğaya zehirli gazların salınmasına sebep olur. (4) Bu gazların salınımı insan sağlığına zarar verirken, canlı maddelere hiçbir zararı yoktur.

Yukarıdaki paragrafta numaralanmış cümlelerin hangisi/hangileri yanlış bilgi içermektedir?

A) Yalnız 3
B) 1 ve 3
C) 1 ve 4
D) 2 ve 4
E) 3 ve 4
Cevabınızın nedenini yazınız.

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I.Sobanın hava girişleri tamamen kapatılmalı.
II.Sobanın bulunduğu alan devamlı havalandırılmalıdır.
III.Sönmekte olan sobaya tutuşması için çok fazla yakıt konulmalıdır.

18. Soba zehirlenmesinin yaşanmaması için yukarıda verilenlerden hangileri yapılmalıdır?
A) Yalnız I
B) Yalnız II
C) I ve II
D I, II ve III
Cevabınızın nedenini yazınız.

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