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Оригинални научни рад

Diagnostic assessment of elementary school pupils' understanding of aliphatic hydrocarbons by using a three-tier test[2]

Abstract: *Diagnostic assessment of understanding of content that is currently being elaborated provides teachers with an important insight into the way in which the learning process unfolds among their pupils. In chemistry teaching, this type of assessment is particularly important in situations when complex teaching content, such as organic chemistry content related to aliphatic hydrocarbons in the eighth grade of elementary school, is introduced to the pupils for the first time. To assess the understanding of this content at the given educational level, the present study used a three-tier diagnostic test. A satisfactory understanding on such tests is indicated by correct answers to the first two tiers and the answer Yes to the third tier, while incorrect answer combinations on the first two tiers and the answer Yes to the third tier imply the presence of misconceptions. The three-tier test composed of ten items was completed by 114 pupils. On seven items the satisfactory understanding was shown in 51.75% to 63.16% of the pupils, while on three items, related to the chemical reactions of aliphatic hydrocarbons, the satisfactory understanding was found in less than 40% of the pupils. Six genuine misconceptions, held by at least 10% of the pupils, were also detected. Thus, a detailed insight into the eighth-grade elementary school pupils' understanding of aliphatic hydrocarbons was obtained.*

Keywords: *diagnostic assessment, three-tier tests, aliphatic hydrocarbons, elementary school pupils*

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Introduction

Diagnostic assessment of pupils' understanding which is conducted during the teaching process provides teachers with an important insight into their pupils' learning (Bennet, 2011; Boston, 2019; Graf, 2008). Through this type of assessment, pupils' conceptual challenges with the content that is currently being elaborated are promptly identified, based on which teachers can alter their instruction and, thus, ensure the timely overcoming of the above-mentioned difficulties (Bennet, 2011; Boston, 2019). Within this process, detection and rectification of pupils' misconceptions (MCs) are of particular significance since, if not rapidly corrected, such scientifically incorrect conceptions can be transferred to all related teaching content, including that elaborated within other school subjects (Yong & Kee, 2017), as well as higher educational levels (Smith & Villarreal, 2015).

Regarding chemistry, accurate and timely diagnostic assessment of pupils' understanding is of special importance in situations when complex teaching content, such as organic chemistry content about aliphatic hydrocarbons in the eighth grade of elementary school, is introduced to the pupils for the first time. Throughout the seventh and the first half of the eighth grade of elementary school pupils only dealt with general and inorganic chemistry content, following which, prior to the elaboration of the three classes of aliphatic hydrocarbons (alkanes, alkenes, and alkynes), only one teaching unit from the field of organic chemistry, which referred to the general properties of organic compounds, was elaborated. In this way, the pupils had the opportunity to acquire certain knowledge that is helpful for understanding the content about aliphatic hydrocarbons, such as the knowledge about elements hydrogen and carbon and their properties, polarity of chemical bonds and solubility of chemical compounds in polar and nonpolar solvents, as well as the knowledge regarding the basic structural characteristics of organic compounds. However, the fact remains that the content related to structure, nomenclature, isomerism, and physical and chemical properties of the three classes of aliphatic hydrocarbons considerably differs from all types of chemistry content that the pupils previously encountered. Given that the basic principles of nomenclature and isomerism, as well as the factors that affect physical and chemical properties of aliphatic hydrocarbons also apply to all the other classes of organic compounds which are yet to be elaborated (Vollhardt & Schore, 2010), diagnostic assessment of pupils' understanding of this content has great significance.

Diagnostic assessment is commonly conducted by using multiple-choice tests (Graf, 2008). Although they are highly economical when it comes to time, an important limitation of such tests refers to the relatively high probability of producing the correct answers to multiple-choice questions through guesswork (Milenković et al., 2016). Additionally, it remains unclear whether the pupils' wrong responses on these tests originate from misconceptions (MCs), or a lack of knowledge (Sreenivasulu & Subramaniam, 2014). To overcomeg some of these limitations, two-tier tests were introduced. The two-tier test items consist of the answer tier (AT) and reason tier (RT) in the form of multiple-choice questions, and the response to the RT justifies the selection of answer to the AT (Treagust, 1986). Since two-tier item is answered correctly only when the responses to both the AT and RT are correct, the probability of guessing the correct answer on these items is considerably reduced (Milenković et al., 2016). However, two-tier tests are still unable to distinguish between wrong answers caused by the lack of knowledge and the presence of MCs (Sreenivasulu & Subramaniam, 2014). This limitation can be overcome through the assessment of pupils' confidence in their responses, due to which three-tier tests were developed (Caleon & Subramaniam, 2010a). The AT and RT of items in these tests are identical in composition to the two-tier items, while within the third tier, by selecting the response Yes or No, pupils state whether or not they are confident in their answers to the first two tiers. Subsequently, the understanding of each pupil on a three-tier item is assessed in the following manner (Arslan et al., 2012; Milenković et al., 2016). Firstly, the satisfactory understanding is indicated by the correct responses to the AT and RT, along with the response Yes to the third tier. If, however, an incorrect answer-reason combination is accompanied by the response Yes to the third tier, this indicates the presence of an MC. Furthermore, all answer-reason combinations in which a pupil is not confident are indicative of a lack of knowledge. In the end, all MCs held by at least 10% of the pupils are labeled as genuine MCs (Caleon and Subramaniam, 2010b; Tan et al., 2002), as such MCs are considered to be of significance for the entire population of pupils of the given educational level.

Until now, three-tier chemistry tests have been used at university (Milenković et al., 2016) and high-school levels (Cetin-Dindar & Geban, 2011; Jusniar et al., 2020; Sen & Yilmaz, 2017), but they have never been applied among elementary school pupils. Furthermore, in most of the above-mentioned studies, such tests were implemented in regard to general chemistry content (Cetin-Dindar & Geban, 2011; Jusniar et al., 2020; Sen & Yilmaz, 2017), while only one study, related to carbohydrates, assessed the understanding of the organic chemistry content (Milenković et al., 2016).

When it comes to the aliphatic hydrocarbons, up to date, only one prior study (Karini et al., 2022) has explored elementary school students' conceptual difficulties with this content, thus detecting MCs related to the structure, nomenclature, and isomerism of alkenes and alkynes, the boiling points of all three types of aliphatic hydrocarbons, and dehydrogenation reactions of alkanes and alkenes. Although its focus was not on the identification of conceptual difficulties, the study of Putica and Ralević (2022) provided further confirmation that chemical reactions of alkanes represent a highly challenging content area for elementary school students. Ultimately, it is important to note that MCs related to the structure, nomenclature, isomerism, and chemical reactions of alkenes have also been detected among university students (Sendur, 2012) which shows that, if not promptly corrected, such conceptual difficulties can persist even after several years of education in the field of organic chemistry.

Research Methodology

Research aims and research tasks

This study aimed to assess eighth-grade elementary school pupils' understanding of aliphatic hydrocarbons and detect their genuine MCs about this content by means of a three-tier diagnostic test. According to these aims, the following research tasks were defined:

1. Development of a three-tier diagnostic test for the assessment of elementary school pupils' understanding of aliphatic hydrocarbons;
2. Application of the three-tier test among eighth-grade elementary school pupils who recently completed the elaboration of the above-mentioned content;
3. Analysis of the collected data, based on which the percentage of pupils with satisfactory understanding, lack of knowledge, and MCs is determined;
4. Identification of all genuine MCs held by eighth-grade elementary school pupils regarding aliphatic hydrocarbons.

Preparation of the three-tier test

In the first step of preparation of the three-tier test, through interviews with three elementary school chemistry teachers, the most frequent difficulties of the eighth-grade pupils with understanding of aliphatic hydrocarbons were identified, based on which the distracters for the AT of items in the preliminary version of the test were composed. In this version of the test, which consisted of ten items, only the AT had the form of a multiple-choice question, while the RT represented an open-ended question. Following the administration of the preliminary version of the test to 32 eighth-grade pupils, the most frequent incorrect answers to the RT of each test item were used to compose the distracters for the RT of items in the pre-pilot test, within which this tier also represented a multiple-choice question. The pre-pilot test was subjected to validation by one university organic chemistry professor and one elementary school chemistry teacher who confirmed that the test was scientifically correct and, based on its composition and phrasing, appropriate for the assessment of eighth-grade pupils' understanding of aliphatic hydrocarbons. After this, the third tier was added to each test item, following which pilot testing with a new sample of 41 pupils was conducted. All pupils were able to complete the pilot test within one chemistry lesson period of 45 minutes, and none of them reported uncertainties regarding the phrasing of any of the test's items. However, the pupils advised that the structural formulas of compounds within the items referring to the structure and nomenclature of the three classes of aliphatic hydrocarbons should be enlarged. Once these corrections were completed, the final version of the test, comprised of ten three-tier items, was obtained.

Research sample

The research sample consisted of 114 eighth-grade pupils from three elementary schools in Belgrade. Administration of the three-tier test was approved by the principal of each school and all pupils completed the test voluntarily.

Data analysis

As in the prior research on three-tier tests (Arslan et al., 2012; Milenković et al., 2016), pupils' correct responses to the AT and RT of each test item received a score of 1, while the incorrect responses scored 0. Furthermore, both tiers (BTs) score for a given item was 1 if both the AT and RT were answered correctly, or 0 in all other circumstances.

The reliability of the test regarding the pupils' scores on the AT, RT, and BTs was assessed by calculating Cronbach's alpha values.

After this, following the assessment of understanding of each pupil according to the approach described in the Introduction section, the percentage of pupils with satisfactory understanding, lack of knowledge, and MCs on each test item was determined. Finally, all MCs held by at least 10% of the pupils were labeled as genuine MCs.

Results and Discussion

Table 1 presents the Cronbach's alpha values for the pupils' scores on the AT, RT, and BTs of the three-tier test. As can be seen, all values were higher than the lowest acceptable value of 0.70, which confirms the satisfactory reliability of the test. It can also be observed that the value for BTs was higher than the values for the AT and RT on their own, which shows that considering the pupils' responses to the AT in light of the reasons for their selection results in the increase of the reliability of the test.

Table 1. Cronbach's Alpha Values for the Pupils' Scores on the AT, RT and BTs of the Three-Tier Test.

Reliability measure	AT	RT	BTs
Cronbach's alpha	0.81	0.78	0.85

The percentage of the pupils with satisfactory understanding, lack of knowledge, and MCs on each of the ten test items is presented in Table 2.

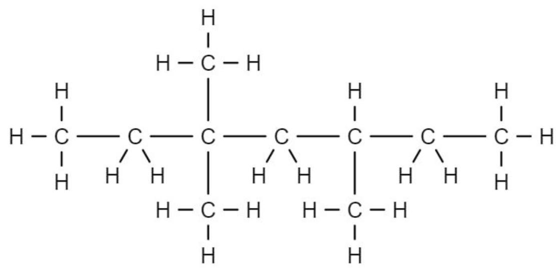
Table 2. The Percentage of the Pupils with Satisfactory Understanding, Lack of Knowledge, and MCs on Each of the Items in the Three-Tier Test.

Item	Percentage of pupils with satisfactory understanding	Percentage of pupils with a lack of knowledge	Percentage of pupils with MCs
1	63.16	36.84	-
2	59.65	40.35	-
3	51.75	22.81	25.44
4	30.70	45.61	23.69
5	57.02	42.98	-
6	52.63	15.79	31.58
7	34.21	30.70	35.09
8	56.14	43.86	-
9	35.96	28.14	35.90
10	54.38	8.78	36.84

The results presented in Table 2 indicate that between 51.75 and 63.16% of the pupils exhibited satisfactory understanding on seven out of ten test items, while on three items satisfactory understanding was shown by less than 40% of the pupils. The highest percentage of pupils with satisfactory understanding was found on item 1, which dealt with the nomenclature of alkanes. This result is in accordance with the previous findings that elementary school students, generally, have no major difficulties with understanding the nomenclature of alkanes (Putica & Ralević, 2022). More than 55% of the pupils also showed the satisfactory understanding of the nomenclature of the other two classes of aliphatic hydrocarbons, as well as the structural isomerism of n-pentane. Conversely, all items on which the percentage of pupils with satisfactory understanding was below 40% were related to the chemical reactions of aliphatic hydrocarbons, which confirms the previous findings that pupils, generally, find reactions of organic compounds to be the most difficult part of organic chemistry content (Bhattacharyya & Bodner, 2005).

As already noted, item 1 in the test referred to the nomenclature of alkanes. The pupils were shown a structural formula of an alkane (Figure 1) and asked to determine which of the following four compounds, 2-ethyl-2,4-dimethylhexane, 2-ethyl-4,4-dimethylhexane, 3,3,5-trimethylheptane or 3,5,5-trimethylheptane is presented by it.

Figure 1. The Structural Formula of Alkane that had to be Identified in Item 1.



63.16% of the pupils showed satisfactory understanding on this item by selecting 3,3,5-trimethylheptane as their answer to the AT and explaining that the carbon chain of alkane in Figure 1 contains seven carbon atoms, with two methyl groups attached to the carbon atom number 3 and one methyl group attached to the carbon atom number 5. On the other hand, 36.84% of the pupils exhibited a lack of knowledge regarding the nomenclature of the given alkane. At the same time, as in only other previous research that explored elementary school students' conceptual difficulties with aliphatic hydrocarbons (Karini et al., 2022), genuine MCs related to the nomenclature of alkanes have not been detected.

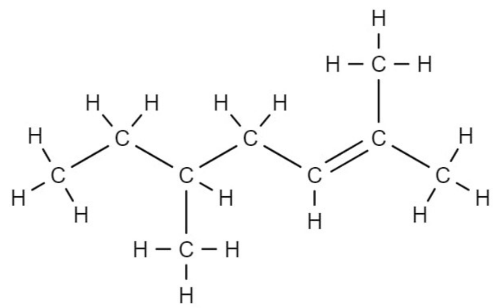
Item 2 was related to the structural isomerism of alkanes, as the pupils were asked which of the following four compounds, 2-methylbutane, 3-methylbutane, 2-methylpentane or 1-pentene, is a structural isomer of n-pentane. 59.65% of the pupils showed satisfactory understanding on this item by selecting 2-methylbutane as their response to the AT. The pupils explained that this compound is the structural isomer of n-pentane because the two compounds have the same molecular formula but different arrangements of atoms in their molecules and in the molecule of an alkane with a total of five carbon atoms, whose carbon chain consists of four carbon atoms, methyl group can only be attached to the carbon atom number 2. At the same, 40.35% of the pupils exhibited a lack of knowledge on this item. Genuine MCs on Item 2 have not been identified, which aligns with the results of previous research (Karini et al., 2022) that also did not detect MCs related to the structural isomerism of alkanes among elementary school students.

Item 3 referred to the aggregate states of the straight-chain alkanes at room temperature, as the pupils were asked whether, under such conditions, these compounds exist in all three aggregate states, in a liquid and solid state, only in a gaseous state, or only in a solid state. 51.75% of the pupils showed satisfactory understanding on this item by stating that, at room temperature, straight-chain alkanes can be found in all three aggregate states and explaining that straight-chain alkanes consisting of 1- 4 carbon atoms are found in a gaseous state, those comprised of 5-17 carbon atoms exist in a liquid state, while straight-chain alkanes with more than 17 carbon atoms are found in a solid aggregate state under such conditions. On the other hand, 22.81% of the pupils showed a lack of knowledge on this item, while 25.44% of them were found to hold a genuine MC that straight-chain alkanes can only exist in a liquid and solid state at room temperature. This MC stemmed from the erroneous belief that straight-chain alkanes with 1-17 carbon atoms exist in a liquid state, while those with more than 17 carbon atoms exist in a solid state under such conditions.

Item 4 was related to the products of monochlorination of ethane. Only 30.70% of the pupils showed satisfactory understanding on this item by selecting chloroethane and hydrochloric acid as their response to the AT and explaining that within the above-mentioned reaction one atom of hydrogen attached to one of the two carbon atoms of ethane is substituted with one atom of chlorine to form chloroethane, following which hydrochloric acid is formed as the second reaction product. 45.61% of the pupils exhibited a lack of knowledge on this item, while 23.69% of them were found to harbor MCs. One genuine MC, held by 21.92% of the pupils was detected, as the pupils in question stated that the products of the above-mentioned reaction are the two molecules of chloromethane. This MC was based on the erroneous belief that within the given reaction single covalent bond between the two carbon atoms of ethane gets broken, following which one atom of chlorine is attached to each of these carbon atoms, thus forming two molecules of chloromethane as reaction products.

Item 5 assessed the understanding of the nomenclature of alkenes. The pupils were shown the structural formula of an alkene (Figure 2), and asked to determine which of the following four compounds, 3,6-dimethyl-5-heptene, 2,5-dimethyl-2-heptene, 5-ethyl-2-methyl-2-hexene, or 2-ethyl-5-methyl-4-hexene is depicted by it.

Figure 2. The Structural Formula of Alkene that had to be Identified in Item 5.



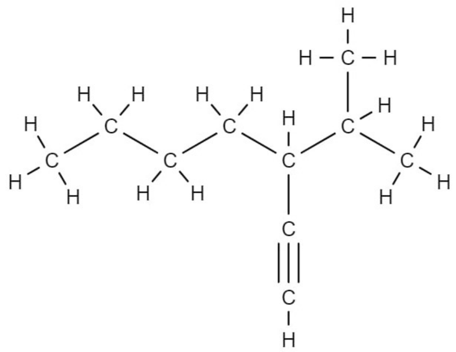
57.02% of the pupils showed satisfactory understanding by selecting 2,5-dimethyl-2-heptene as their answer to the AT and explaining that the carbon chain of the compound in question contains seven carbon atoms, with methyl groups attached to the carbon atoms number 2 and 5, and a double bond between carbon atoms number 2 and 3. At the same time, almost 43% of the pupils showed a lack of knowledge regarding the nomenclature of this alkene. The absence of genuine MCs on Item 5 opposes the findings of previous research (Karini et al., 2022) that detected elementary school students' MCs about the nomenclature of alkenes related to the incorrect numbering of carbon atoms in the carbon chains of these compounds and the erroneous belief that aliphatic hydrocarbons whose molecules contain double bonds represent alkynes.

Item 6 referred to the isomerism of 1-hexene, as the pupils were asked which of the following four compounds, 2-hexene, 4-methyl-1-pentene, 2,2-dimethyl-1-butene, and 3,3-dimethyl-1-butene is not an isomer of 1-hexene. 52.63% of the pupils showed satisfactory understanding on this item by stating that 2,2-dimethyl-1-butene is not an isomer of 1-hexene and explaining that such a compound cannot exist because its carbon atom number 2 would form five instead of the maximum four covalent bonds through which an atom of carbon can be linked with its surrounding atoms. At the same time, 15.79% of the pupils exhibited a lack of knowledge on this item, while 31.58% of them were found to hold genuine MC that 2-hexene is not an isomer of 1-hexene because the two compounds differ in the position of a double bond in their molecules. Interestingly, identical MC according to which alkenes with the same number of carbon atoms but different position of double bond along their carbon chains are not isomers, has also been detected among university students (Sendur, 2012).

Item 7 assessed the understanding of the synthesis of polyethylene, as the pupils were asked whether this polymer is synthesized through the linking of a large number of monomer units of ethyne, ethene, ethane, or methane to each other. Only 34.21% of the pupils showed satisfactory understanding of polyethylene synthesis by stating that this polymer is produced through the linking of a large number of monomer units of ethene to each other and explaining that these reactions unfold in such a way that, upon their completion, the polymer's carbon chain does not contain double bonds. 30.70% of the pupils exhibited a lack of knowledge on this item, while 35.09% of them were found to hold MCs. One genuine MC harbored by 32.46% of the pupils was detected, as the pupils in question stated that polyethylene is produced through the linking of a large number of monomer units of ethyne to each other, explaining that these reactions unfold in such a way that, upon their completion, the two carbon atoms from all monomer units that form the polymer's carbon chain remain attached to each other through a double bond. While MCs related to the polymerization of ethene had previously not been identified among the elementary school students, prior research (Sendur, 2012) established that university students often hold the erroneous belief that ethene is the only alkene that can undergo polymerization reactions.

Item 8 referred to the nomenclature of alkynes. The pupils were shown the structural formula of an alkyne (Figure 3) and asked to determine which of the following four compounds, 3-butyl-2-methyl-4-pentyne, 3-butyl-4-methyl-1-pentyne, 3-(1-methylethyl)-1-heptyne, or 5-(1-methylethyl)-6-heptyne is depicted by it.

Figure 3. The Structural Formula of Alkyne that had to be Identified in Item 8.



56.14% of the pupils showed satisfactory understanding on this item by selecting 3-(1-methylethyl)-1-heptyne as their answer to the AT and explaining that the carbon chain of alkyne presented in Figure 3 contains seven carbon atoms, with 1-methylethyl (isopropyl) group attached to the carbon atom number 3 and a triple bond between carbon atoms number 1 and 2. At the same time, 43.86% of the pupils showed a lack of knowledge on this item.

Within item 9, the pupils were asked whether the complete catalytic hydrogenation of ethyne yields ethene, two molecules of methane, ethane, or 1,3-butadiene as its product. Regarding this item, 35.96% of the pupils showed satisfactory understanding by selecting ethane as the product of interest and explaining that complete catalytic hydrogenation of ethyne presupposes the addition of two molecules of hydrogen to the triple bond of ethyne. 28.14% of the pupils showed a lack of knowledge on this item, while 35.90% of them were found to hold a genuine MC that the product of the complete catalytic hydrogenation of ethyne is ethene, which was based on the erroneous belief that the given reaction presupposes the addition of one molecule of hydrogen to the triple bond of ethyne. In view of the given MC and the previous findings that elementary school students often hold an erroneous belief that the elimination of one molecule of hydrogen from a double bond of alkenes leads to the formation of alkanes (Karini et al., 2022), it can be concluded that students at this educational level experience considerable difficulties with understanding hydrogenation and dehydrogenation reactions of aliphatic hydrocarbons.

Item 10, related to the products of combustion of n-hexane, 1-hexene, and 1-hexyne, was the only item that referred to chemical reactions of aliphatic hydrocarbons on which satisfactory understanding was exhibited by more than 50% of the pupils. This result is in alignment with the previous finding that elementary school students usually have no major difficulties with understanding of the combustion of organic compounds (Putica & Ralević, 2022). Thus, 54.38% of the pupils showed satisfactory understanding by stating that the products of combustion of each of the above-mentioned compounds are carbon (IV) oxide and water, as these two compounds represent the products of combustion of all aliphatic hydrocarbons. Around 9% of the pupils exhibited a lack of knowledge on this item, while 36.84% of them harbored the genuine MC that n-hexane is not combustible, while the products of combustion of 1-hexene and 1-hexyne are carbon (IV) oxide and water, which was explained by the notion that, unlike alkenes and alkynes, alkanes represent non-combustible compounds.

All genuine MCs detected in this study are presented in Table 3.

Table 3. An Overview of all Detected Genuine MCs.

Genuine MC	Percentage of the pupils holding the genuine MC
At room temperature, straight-chain alkanes can only be found in liquid and solid aggregate states.	25.44
The products of monochlorination of ethane are the two molecules of chloromethane.	21.92
2-hexene is not a structural isomer of 1-hexene.	31.58

Polyethylene is formed through the linking of a large number of monomer units of ethyne to each other.	32.46
The product of the complete catalytic hydrogenation of ethyne is ethene.	35.90
Unlike alkenes and alkynes, alkanes are non-combustible.	36.84

Conclusion

In this study, a three-tier diagnostic test was used to assess the eighth-grade elementary school pupils' understanding of aliphatic hydrocarbons. The results indicate that between 51.75 and 63.16% of the pupils exhibited satisfactory understanding on seven out of ten test items. The highest percentage of pupils with satisfactory understanding was found on the four items referring to the nomenclature of alkanes, alkenes, alkynes, and the structural isomerism of alkanes. As the basic principles of the nomenclature of aliphatic hydrocarbons and structural isomerism of alkanes also apply to all other classes of organic compounds which are yet to be elaborated, it is important that the pupils did not experience great challenges while dealing with this content. On the other hand, around 32% of the pupils were found to hold the genuine MC that 2-hexene is not a structural isomer of 1-hexene. Structural isomerism related to the position of a double bond is specific to alkenes and, based on this finding, teachers are advised to put special emphasis on it during the initial elaboration of this class of aliphatic hydrocarbons. Furthermore, better visualization of structural isomers of alkenes that differ in the position of a double bond could be achieved through the use of multimedia tools.

While around 52% of the pupils had satisfactory understanding of aggregate states of straight-chain alkanes at room temperature, around 25% of them held the genuine MC that straight-chain alkanes can only be found in a liquid and solid state under such conditions. Invoking cognitive conflict and, thus, directly facing the pupils with errors in their understanding represents an important approach for rectification of MCs (Brandriet & Bretz, 2014). Regarding the above-mentioned MC, cognitive conflict could be induced by asking the pupils to browse the internet and ascertain the chemical composition of gas that is used for central heating, or gas that is used in gas cookers at their homes to prepare meals. Thus, through examples from everyday life, pupils would be faced with the fact that alkanes with up to four carbon atoms exist in a gaseous state at room temperature.

All items on which the percentage of pupils with satisfactory understanding was below 40% referred to the chemical reactions of aliphatic hydrocarbons. Furthermore, genuine MCs related to the halogenation of alkanes, hydrogenation of alkynes, and synthesis of polyethylene were also detected. Thus, around 22% of the pupils expressed the belief that the products of monochlorination of ethane are the two molecules of chloromethane. If this MC is not promptly corrected, pupils holding it will experience considerable difficulties with understanding of synthesis and chemical properties of haloalkanes, which represent the next class of organic compounds that will be elaborated after hydrocarbons. As the molecules of ethane and chlorine are relatively small, adequate visualization of the above-mentioned reaction could be achieved through the use of their tridimensional models, made by the teacher and/or the pupils themselves. Such models could also be used to promote understanding of the complete catalytic hydrogenation of ethyne and rectify the genuine MC, held by almost 36% of the pupils, that the product of this reaction is ethene. Conversely, proper visualization of ethene polymerization, along with the tridimensional structure of polyethylene, can only be achieved through the use of multimedia tools.

The only item related to the chemical reactions of aliphatic hydrocarbons on which more than

50% of the pupils exhibited satisfactory understanding referred to the combustion of these compounds. On the one hand, this is a relatively simple reaction which, regardless of the aliphatic hydrocarbon that takes part in it, always produces carbon (IV) oxide and water as final products. However, nearly 37% of the pupils expressed the genuine MC that, unlike alkenes and alkynes, alkanes are not combustible. This MC could stem from the fact that, when comparing the reactivity of the three classes of aliphatic hydrocarbons, teachers often emphasize that alkanes are less reactive than alkenes and alkynes. To correct the given MC, teachers could once again invoke the cognitive conflict through examples of gas used for central heating, or gas used in gas cookers. By browsing the internet to ascertain which chemical reactions produce heat that is used to keep their homes warm in the winter and cook their meals, pupils would be faced with the fact that alkanes also represent combustible compounds.

The present study provides an important initial overview of the elementary school pupils' understanding of aliphatic hydrocarbons and their greatest conceptual challenges with this content. Additionally, the study provides the first evidence that three-tier tests can be successively applied for diagnostic assessment of understanding of elementary school organic chemistry content. Thus, future studies should consider the application of such tests for the assessment of understanding of all other classes of organic compounds encompassed by the elementary school chemistry curriculum. Future studies could also attempt to ascertain the exact reasons for the occurrence of genuine MCs detected in this study and determine which strategies are the most effective for their rectification. As the principles of isomerism as well as the factors that determine physical and chemical properties of aliphatic hydrocarbons also apply to all the other classes of organic compounds, overcoming of the detected MCs is expected to contribute to an overall improvement of understanding the organic chemistry content which is elaborated at the elementary school level.

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ДИЈАГНОСТИЧКА ПРОВЕРА РАЗУМЕВАЊА АЛИФАТИЧНИХ УГЉОВОДОНИКА КОД УЧЕНИКА ОСНОВНИХ ШКОЛА ПРИМЕНОМ ТРОСЛОЈНОГ ТЕСТА

Дијагностичка провера разумевања градива које се тренутно обрађује наставницима пружа значајан увид у начин на који се процес учења одвија код њихових ученика. У настави хемије овај тип провере је посебно значајан у ситуацијама када се са комплексним градивом, попут оног везаног за алифатичне угљоводонике у осмом разреду основне школе, ученици сусрећу први пут. Последично, циљ овог истраживања била је дијагностичка провера разумевања градива о алифатичним угљоводоницима код ученика поменутог образовног нивоа употребом трослојног теста. Тестови овог типа претходно су коришћени искључиво у раду са студентима и ученицима средњих школа, док је у овом истраживању, први пут у свету, такав тест примењен и на нивоу основне школе.

Трослојни тестови развијени су ради превазилажења значајних ограничења тестова који су се до сада користили за дијагностичку проверу ученичког разумевања. Тако, велики недостатак тестова састављених из питања вишеструког избора представља релативно висока могућност за погађање тачних одговора. Ово ограничење је делимично превазиђено развојем двослојних дијагностичких тестова, у којима се сваки од задатака састоји из два питања вишеструког избора, при чему се одговором на друго питање, тј. питање из другог слоја, образлаже одговор на питање из првог слоја. Иако се овако значајно смањује могућност за погађање тачних одговора, применом двослојних тестова се и даље не може утврдити да ли су нетачни одговори ученика последица незнања или мисконцепција. Да би се то установило, дизајнирани су трослојни тестови, у којима прва два слоја задатака имају исту структуру као и задаци у двослојним тестовима, док у оквиру трећег слоја, одабиром одговора Да или Не, ученици наводе да ли су сигурни у своје одговоре на питања из прва два слоја. Последично, задовољавајуће разумевање градива индиковано је тачним одговорима на питања из прва два слоја уз одговор Да на питање из трећег слоја, нетачне комбинације одговора на питања из прва два слоја уз одговор Не указују на недостатак знања, док нетачне комбинације одговора на питања из прва два слоја уз одговор Да на питање из трећег слоја указују на мисконцепције. Финално, све мисконцепције које су идентификоване код више од 10% ученика означавају се као суштинске мисконцепције, које се сматрају значајним за целокупну популацију ученика датог образовног нивоа.

Припремајући трослојни тест за проверу разумевања градива о алифатичним угљоводоницима, дистрактори за питања из првог слоја формулисани су кроз интервјуе са наставницима хемије у основној школи, којима су идентификоване најчешће потешкоће ученика осмог разреда везане за ово градиво. Тако је сачињена прелиминарна верзија теста у којој је први слој сваког задатка чинило питање вишеструког избора, док је други слој представљало питање отвореног типа. Ову верзију теста попунила су 32 ученика осмог разреда, чији су најчешћи нетачни одговори на поменута питања отвореног типа искоришћени *за формулисање дистрактора другог слоја задатака у препилот верзији теста, који је тако такође добио форму питања вишеструког избора. Препилот-тест валидирала су два експерта из области органске хемије, након чега је сваком задатку додат и трећи слој, а затим организовано пилот-тестирање са новим узорком који је чинио 41 ученик. Сви ученици су без проблема попунили пилот-тест у оквиру једног школског часа, без пријаве нејасноћа у вези са садржајем било ког задатака, али уз указавање да је све слике структурних формула једињења у оквиру теста потребно увећати. По завршетку предложених корекција добијена је финална верзија теста, која се састојала из десет трослојних задатака.*

Финалну верзију теста попунило је 114 ученика осмог разреда основне школе. На седам задатака задовољавајуће разумевање је показало између 51,75% и 63,16% ученика. Највећи проценат ученика са задовољавајућим разумевањем установљен је на задатку који се односио на номенклатуру алкана. Преко 55% ученика са задовољавајућим разумевањем било је и на задацима везаним за номенклатуру алкена и алкина, као и изомерију пентана, док је између 51,75% и 55% ученика показало задовољавајуће разумевање на задацима везаним за агрегатно стање линеарних алкана, изомерију 1-хексена и оксидацију алифатичних угљоводоника. Задатак у вези са оксидацијом алифатичних угљоводоника био је једини задатак у вези са хемијским реакцијама ових једињења на коме је задовољавајуће разумевање показало више од 50% ученика. На сва три преостала задатка овог типа, која су се односила на монохлоровање етана, синтезу полиетилена и потпуну хидрогенацију етина, задовољавајуће разумевање показало је мање од 40% ученика. Употребом трослојног теста детектовано је и шест суштинских мисконцепција везаних за алифатичне угљоводонике. Тако је установљено да више од 10% ученика верује да линеарни алкани на собној температури могу бити само у течном и чврстом агрегатном стању, да монохлоровањем етана настају два молекула хлорметана, те да 2-хексен није изомер 1-хексена. Више од 10% ученика такође је изразило уверење да се полиетилен синтетише из великог броја мономерних јединица етина, да потпуном хидрогенацијом етина настаје етен те да, за разлику од алкена и алкина, алкани нису запаљиви. Овако је стечен детаљан увид у разумевање алифатичних угљоводоника код ученика осмог разреда основне школе.

***Кључне речи**: дијагностичка провера, трослојни тестови, алифатични угљоводоници, ученици основних школа*