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

Extended summary

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. The aim of this research was to conduct a diagnostic assessment of pupils' understanding of the content about aliphatic hydrocarbons at the given educational level, by using a three-tier diagnostic test. This type of tests had been previously used only among university students and high-school pupils. For the first time in the world, the test was used at the elementary school level in this research.

The three-tier tests were developed to overcome the significant shortcomings of the tests used for diagnostic check-up of students' understanding. An important limitation of multiple-choice tests refers to the relatively high probability of producing the correct answers to multiple-choice questions through guesswork. This limitation was partly overcome by developing two-tier diagnostic tests in which each task consists of two multiple-choice questions where the answer to the second question, i.e., the second tier, explains the answer to the first tier. Though two-tier tests significantly diminish the possibility for guesswork, they are still unable to distinguish whether the wrong answers were caused by the lack of knowledge or misconceptions.

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Three-tier tests were designed for this purpose and they contain two tiers of tasks of the same structure as the tasks in two-tier tasks, whereas in the third tier, by choosing Yes or No answers, the pupils state whether they are sure about their answers to the questions in the first two tiers. Consequently, a satisfactory understanding of the subject matter is indicated by correct answers to the questions from the first two tiers with a Yes answer to the question from the third tier. The incorrect combinations of answers to the questions from the first two tiers with a No answer indicate a lack of knowledge, while incorrect combinations of answers to the questions from the first two tiers with the answer Yes to the question from the third tier point to misconceptions. Finally, all misconceptions identified in more than 10% of pupils are marked as essential misconceptions, which are considered significant for the entire population of pupils of the given educational level.

Preparing a three-tier test to check the understanding of the content on aliphatic hydrocarbons, the distractors for the questions in the first tier were formulated through interviews with elementary school chemistry teachers, who identified the most common difficulties of the eighth-grade pupils related to this subject matter. A preliminary version of the test was created in which the first tier of each task was a multiple-choice question, while the second tier was an open-ended question. This version of the test was completed by 32 eighth-grade pupils, whose most frequent incorrect answers to the mentioned open-ended questions were used to formulate the distractors of the second tier of tasks in the pre-pilot version of the test, which was also in the form of multiple-choice questions. The pre-pilot test was validated by two experts from the field of organic chemistry, after which the third tier was added to each task, and then pilot testing was organized with a new sample consisting of 41 pupils. All pupils completed the pilot test within one school lesson without any problems, without reporting any ambiguities regarding the content of any tasks, but with the indication that all pictures of the structural formulas of the compounds within the test should be enlarged. After completing the proposed corrections, the final version of the test was obtained which consisted of ten three-tier tasks.

The final version of the test was completed by 114 pupils of the eighth grade of elementary school. Between 51.75% and 63.16% of the pupils showed a satisfactory understanding of the seven tasks. The highest percentage of the pupils with a satisfactory understanding was found on the task related to the nomenclature of the alkanes. Over 55% of the pupils with the satisfactory understanding were also identified on tasks related to the nomenclature of alkenes and alkynes, as well as pentane isomerism, while between 51.75% and 55% of the pupils showed a satisfactory understanding on tasks related to the aggregate state of linear alkanes, isomerism 1- hexene, and oxidation of aliphatic hydrocarbons. The task related to the oxidation of aliphatic hydrocarbons was the only task related to the chemical reactions of these compounds in which more than 50% of pupils showed a satisfactory understanding. Less than 40% of pupils showed a satisfactory understanding of all three remaining tasks of this type, which were related to the monochlorination of ethane, synthesis of polyethylene, and complete hydrogenation of ethyne. Using the three-tier test, six essential misconceptions related to aliphatic hydrocarbons were detected. Thus, it was established that more than 10% of pupils believe that linear alkanes at room temperature can only be in liquid and solid aggregate state, that monochlorination of ethane produces two molecules of chloromethane, and that 2-hexene is not an

isomer of 1-hexene. More than 10% of the pupils also expressed the belief that polyethylene is synthesized from a large number of ethene monomer units, that ethene is formed by complete hydrogenation of ethene, and that, unlike alkenes and alkynes, alkanes are not flammable. In this way, a detailed insight into the understanding of aliphatic hydrocarbons among the eighth-grade elementary school pupils was obtained.

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

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