THE APPLICATION OF INTERACTIVE LEARNING TASKS MADE BY USING DIGITAL HYBRID ILLUSTRATIONS IN THE TOPIC "HYDROCARBONS" IN EIGHTH-GRADE ORGANIC CHEMISTRY CLASSES

Agneš R. Sedlar
University of Novi Sad, Republic of Serbia
Agricultural School Dormitory – Futog, Republic of Serbia
E-mail: agnes.sedlar@gmail.com

Tamara N. Rončević , Saša A. Horvat
University of Novi Sad, Republic of Serbia
E-mail: tamara.hrin@dh.uns.ac.rs, sasa.horvat@dh.uns.ac.rs

Abstract

The content of organic chemistry is closely related to our everyday life, to nature, and to the human body. Illustrations play a big role in the acquisition of the course material, especially if those help to make the interpretation of the textual content easier. Hybrid illustrations are made up of combinations of realistic images (photographs, drawings) with abstract conventional elements (symbols, models, chemical equations). This type of illustration fuses difficult-to-interpret symbols often found in chemistry with everyday images that bring students closer to the content. The following study examines the use of digitally edited hybrid illustrations in interactive learning tasks that were used in the review and practice lessons on the Hydrocarbons topic in eighth-grade organic chemistry classes. The research took place in an experimental group of students from primary school in Novi Sad (Republic of Serbia), during which the students solved the given tasks on their cell phones via the Moodle platform. In the control group, teaching and learning took place in the traditional, or conventional way applying a lecture and a discussion method. After processing the Hydrocarbons topic, the experimental and control groups underwent the same testing process, the results of which prove the advantages of using the tasks created with the help of digital hybrid illustrations in the abstract parts of the curriculum.
Keywords: *digital learning, organic chemistry, hydrocarbons, hybrid illustrations*

Introduction

A visual learning strategy has three basic components: the teacher, the student, and the learning process. The teacher's role involves monitoring the learning process by considering the best way to develop higher-order thinking skills. Many studies show that students learn most effectively when they receive information in a visual format

https://doi.org/10.33225/BalticSTE/2023.210

as visual representations enhance students' learning (Ainsworth, 2006; Evagorou et al., 2015; Raiyn, 2016). Teachers can facilitate the communication of information in a visual format by showing, for example, pictures, diagrams, flow charts, and interactive simulations (Raiyn, 2016).

Representing abstract invisible objects, concepts, and processes helps to process data through visual perception, thus facilitating their understanding and learning (Mayer et al., 1995). In science education, pictures can be used not only as illustrations, as supplementary elements to the verbal elements of the text, but also as a central part of the content, to express the main ideas to be communicated (Ametller & Pintó, 2002). An example of the application of the illustrative-graphic method in the teaching of natural sciences is hybrid illustrations, which are defined in the work of Dimopoulos et al. (2003). The characteristic of hybrid illustrations is that these illustrations combine abstract hard-to-understand content (such as chemical formulas, structures, and alphanumeric characters) with realistic everyday elements known from everyday life, which people observe and understand through visual perception (Dimopoulos et al., 2003).

There has already been an example of examining the use of the illustrative-graphic method, including hybrid illustrations with eighth-grade students, during which biologically important organic compounds ("Amino acids and proteins") were presented. In the data analysis, it was revealed that in the case of certain tasks, it is useful to use hybrid illustrations created from the synthesis of conventional and realistic elements in the teaching of chemistry, in order to increase the performance of primary school students (Rončević et al., 2019a). In the present study, one step forward was taken, as up-to-date unexamined forms of hybrid illustrations, i.e., interactive digital hybrid illustrations were included as new teaching and learning tools. Also, organic chemistry as a different chemistry discipline was chosen on which interactive hybrid illustrations were used.

Research Problem

Today, it is widely accepted that textual content alone is not enough to help students recognize relationships, group objects, perceive big ideas, and solve problems. Facts must be conceptually framed in order to be understood and remembered. Teachers can facilitate conceptualization by making concepts and generalizations (rather than facts) the focus of activities, providing students with a variety of experiences, helping them learn how to observe and represent what they see and hear, and showing them many examples of what they are teaching (Birbili, 2007). Chemistry is considered a particularly abstract subject and students face many problems when learning its contents. The chemistry teacher must have appropriate teaching tools to process the content of the given material, apply methods that support higher-order thinking skills and help students master the content more easily.

Improving the process of learning and understanding is especially important in the eighth-grade chemistry curriculum in primary schools because it covers the concepts of organic chemistry. Organic chemistry generally includes carbon-based compounds, and students are faced with the chemical composition of organic compounds, their properties and the reactions they undergo (Salame et al., 2019). Recognizing formulas, functional groups, compounds found in nature, or logical connections between reactions

https://doi.org/10.33225/BalticSTE/2023.210

and properties of organic compounds exposes students to many abstract concepts and phenomena that increase the abstract nature of the course content. In this study, it was examined the possibilities of applying the illustrative-graphic method, more precisely digital hybrid illustrations in the form of interactive learning tasks that might improve the teaching and learning of organic chemistry contents at the primary school level.

Research Focus

Visual learning is the acquisition of information through a visual format. Students understand classroom information better when they see it. Visual information is presented in a variety of formats such as pictures, process diagrams, videos, simulations, graphs, cartoons, coloring books, slide shows/Powerpoint presentations, posters, movies, games, and flashcards (Rodger et al., 2009). A teacher can use the formats mentioned above to present a large amount of information in an easy-to-understand manner and help the students to discover relationships between concepts. According to various studies, students remember information better when it is presented both visually and verbally (Bobek & Tversky, 2016; Raiyn, 2016). These strategies help students of all ages better manage learning goals and achieve academic success (Raiyn, 2016).

Research Aim and Research Questions

The aim of the present study was to analyze the advantages of using digital hybrid illustrations in the form of interactive learning tasks that serve as an example in the lessons of repeating the teaching content of chemistry in the eighth grade of primary school. The study focuses on the lessons of the units "Review of saturated hydrocarbons and general properties of hydrocarbons" and "Systematization of materials from hydrocarbons" of the curriculum. Both teaching units are covered within the teaching module "Hydrocarbons" (Teaching and learning program for the eighth grade of basic education and upbringing, 2019). As one group of students was subjected to the illustrative-graphic method and digital hybrid illustrations, the goal of this study was to analyze the differences in the students' performances of two groups, one experimental (E group) and one control (C group) observing the Hydrocarbons teaching topic in eighth-grade organic chemistry classes.

In accordance with the goal, the study is conducted through the following research questions:

1. Are there statistically significant differences in students' overall performances on knowledge tests between the experimental and control groups?
2. Are there statistically significant differences in students' performances in test tasks with illustrations between the experimental and control groups?
3. Are there statistically significant differences in students' performances in test tasks without illustrations between the experimental and control groups?

Research Methodology

General Background

The research began with initial testing in January 2023, which evaluated the students' prior knowledge of inorganic chemistry. Based on the statistical analysis of the initial test results, the students were divided into experimental (E) and control (C) groups. After the initial testing, detailed ongoing discussions were held with the teacher in the E group, during which a coordinated joint plan was prepared to start the research.

It is important to mention that the Serbian basic curriculum provides two introductory lessons to organic chemistry, as students encounter this branch of chemistry for the first time. After that, there are twelve lessons for the processing of the new teaching content and revision of the relevant parts of the Hydrocarbons topic. Out of these twelve lessons, the experimental part of this study used up two revision lessons. These lessons took place after the processing of the new teaching contents. Based on consultation with the teacher in the experimental classes, the first revision lesson was held after the processing key concepts in organic chemistry: distinction of hydrocarbons based on their structural features, their occurrence in everyday life, their physical properties, and the presentation of the nomenclature of saturated hydrocarbons.

Sample

A total of 191 students from eighth-grade classes (14-15 years old students) were included in this study. The students attended two schools in Novi Sad, Republic of Serbia. It must be highlighted that in the Republic of Serbia, formal education covers preschool, primary school, secondary school, and higher education. The eighth-grade students are included in the second learning cycle of primary school. The research was done in the Serbian language, with the permission of the principals of the schools and the students included in the research.

Before the experimental teaching and according to the initial chemistry knowledge test results, the students were divided into two groups: experimental and control. After the statistical analysis of the results of the initial chemistry knowledge test, 4 eighth-grade classes from the primary school "Petefi Šandor" were included in the E group, while 4 eighth-grade classes from the primary school "Nikola Tesla" were included in the C group.

During the analysis of the students' performances on the initial chemistry knowledge test, the Shapiro-Wilk test was used on collected data and showed that the distribution of data in the E group departed significantly from normality ($W = 0.971$, $df = 91$, $p = .042$, $p < .05$), while in the C group, it showed a normal distribution ($W = 0.976$, $df = 91$, $p = .088$, $p > .05$). Based on this outcome, a non-parametric Mann-Whitney U test was used to compare the medians, which showed no statistically significant difference between the E group ($M = 10.16$, $SD = 2.79$) and C group ($M = 10.65$, $SD = 3.54$), as for $U = 4276.50$ p-value was greater than .05 ($p = .471$). During the statistical processing of the initial test results, special attention was also paid to the distribution of boys and girls, as well as to the number of students in the classes. Therefore, the E group consisted of 91 students and the C group consisted of 100 students.

Procedures

The activities in the experimental classes were carried out through the Moodle platform, which is available on the subdomain https://kurs.organskahemija.com/login/index.php (the main domain is on the website www.organskahemija.com). In compiling the task types on the Moodle platform, it was necessary to use the H5P plugin, which offers many interactive options for the editor. The home page of the interactive course includes a short guide to using the site and a general introduction to the history of organic chemistry. The contents of the site and the tasks are entirely in Serbian. During the first trial lesson, the students were able to familiarize themselves with the platform, for which they registered with their own account, thus making it available for them to access the site continuously from anywhere and anytime. The site also supports logging in as a guest if students encounter problems during login. The students followed the learning tasks on their cell phones, which the teacher leading the experimental class also projected on the whiteboard, so they worked on them together.

The first experimental lesson included five learning tasks to review the general properties of hydrocarbons with a special focus on saturated hydrocarbons. The first learning task (see Figure 1) is a find-the-hotspot task on the composition of hydrocarbons, in which the students had to select the parts of the illustration that represent carbon and hydrogen atoms. The hybrid illustration contains the atomic models of carbon, hydrogen, sulfur, oxygen, and nitrogen (based on the colors of atomic model kits used in organic chemistry), supplemented with a photograph of their elemental state. For carbon, an image of a briquette for a grill is used and in the case of hydrogen, the image used depicts the large amount of hydrogen found in outer space. For nitrogen, a photograph of the atmosphere is used. In the case of sulfur, a photograph taken near a volcano indicates its occurrence in an elemental state in the environment, while an oxygen tank indicates the popular use of elemental oxygen.

Figure 1
Find-the-Hotspot Task on the Composition of Hydrocarbons

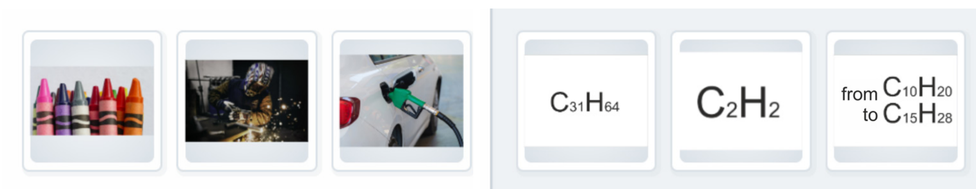
The second learning task deals with the division of hydrocarbons, in which the students had to place the specified groups on the concept map on the indicated green board. The symbol next to some parts of the division is helpful, for example, the representation of single, double, and triple bonds, the closed carbon chain, or Kekule's concept of benzene. The third, fourth and fifth learning tasks could be seen within the platform (www.organskahemija.com).

After the first experimental lesson, the teacher of the experimental classes continued the teaching and learning process with an evaluation, the processing of alkenes, alkynes, and the most important steps in their nomenclature, as well as the chemical properties of hydrocarbons, and finally the processing of crude oil, natural gas and polymers. After the processing of the new teaching contents, it was time for a revision lesson, which was implemented in the form of systematization (comprehensive review) by the teacher leading the E group through the Moodle platform (www.organskahemija.com).

The first learning task of the second experimental lesson is used to determine the state of hydrocarbons based on their use. The students matched images depicting the number of carbon atoms in a given hydrocarbon (molecular formulas) and their state of matter during industrial use - forming a hybrid illustration (Figure 2). For example, gas ethyne (C_2H_2) is suitable for welding, liquid hydrocarbon mixture (diesel) as fuel, and solid paraffin for making wax-containing objects.

Figure 2

Matching Images: The Number of Carbon Atoms in Hydrocarbons and Their State of Matter



The second learning task focuses on the three most important chemical reactions of hydrocarbons, where the students had to choose the name of the given reaction from those listed. Each task was solved based on a description with an assigned hybrid illustration. The substitution was introduced first, for which eighth-grade chemistry textbooks mainly use the process of methane halogenation as an example. The assignment shows an older type of refrigerator and the formula of dichlorodifluoromethane (CFC, Freon) next to it, for which the students listed refrigerators, air conditioners and other equipment as their primary use. The second part of the assignment contains a description of polymerization, and the assigned hybrid illustration shows several PET bottles and the monomer of the polyethylene molecule. The students mentioned many areas of use for polymers, such as the production of plastic foil and nylon. The last part of the task concerned the oxidation of hydrocarbons. The hybrid illustration shows the chimney of a crude oil refinery while the flammable gas is burned at the top. The description next to the flame in the picture also confirms that during the reaction the resulting products are carbon (IV) oxide and water. The other two learning tasks have also been introduced in the form of interactive hybrid illustrations.

https://doi.org/10.33225/BalticSTE/2023.210

With regard to the interactive content of both experimental lessons, it is worth highlighting that the platform allows access from an unlimited number of devices at the same time, so each of the students could work without interruption on their own device at school, or even at home from their computer. Each of the tasks can be repeated, and viewed again, and the solution key is also available for them, which helps the students in studying and reviewing at home.

Instrument

After the teaching and learning process within the topic of Hydrocarbons, both the E and C groups underwent uniform testing. A total of 89 (46 girls and 43 boys) eighth-grade students in the E group and 98 (42 girls and 56 boys) eighth-grade students in the C group were tested.

Students took a test consisting of 15 tasks of which 11 tasks were multiple-choice, 3 tasks were fill-in-the-blank, and one task was a matching question. The test included a total of 9 illustrations, 3 of which were realistic photographs that load to the solution, and 6 of which were conventional content to supplement the task (chemical reaction equation, molecular model, and structural formula). Examples of tasks number 4 and 13 are presented in Figure 3.

The students filled out the test in color printout in paper form and had a maximum of 45 minutes to solve it. The maximum possible performance score on the test was 28 points.

Figure 3
(A) Task without Illustration

4. Complete the sentences with the missing words.
According to the way of binding carbon atoms in strings, hydrocarbons are divided into ______________ and ______________. 2,4-dimethylhexane is an example of the ______________ hydrocarbon in whose molecule carbon atoms are connected by ___________________ bonds and form an _____________ chain.

(B) Task with Illustration

13. Fractional distillation of crude oil yields various products that have everyday and industrial uses as sources of energy. Circle the letter in front of the product obtained by fractional distillation of crude oil, which boils at 170ºC and is mostly used as fuel for passenger aiplanes.

А. diesel fuel;
Б. gasoline;
В. kerosene;
Г. bitumen.

Data Analysis

The statistical analysis of the results obtained during the testing of the groups revealed that the E group had a normal distribution ($W = 0.979$, $df = 89$, $p = .167$, $p > .05$), while the C group had a not normal distribution of collected data ($W = 0.951$, $df = 89$, $p = .002$, $p < .05$). The Mann-Whitney U test as a non-parametric test was applied in order to verify if there was a statistically significant difference in performance between the E and C groups.

Research Results

The basic statistical parameters obtained for E and C groups students' performance on knowledge tests are summarized in Table 1. These parameters include mean scores (*M*), standard deviation (*SD*), minimum and maximum, and range. The mean scores indicated that the E group ($M = 13.34$) achieved slightly higher scores in comparison to the C group ($M = 10.85$), observing students' performance on each task on the knowledge test. The maximum possible score on the knowledge test was 28 points. None of the students in the E and C groups achieved the highest score. It is interesting to mention that the highest score achieved on the knowledge test on Hydrocarbons was 27 in the E group, while it was 23 points in the C group. On the other hand, the lowest score was 2 points in the E group and 1 point in the C group.

Table 1
The Basic Statistical Parameters Obtained from Students' Performance on Knowledge Test

Statistical parameter	Group	
	Experimental	Control
M	13.34	10.85
Minimum	2.00	1.00
Maximum	27.00	23.00
Range	25.00	22.00

To determine whether there was a statistically significant difference in the students' performance between the E and C groups, a non-parametric Mann-Whitney U test was applied. A statistically significant difference was found in favor of the E group, since the *p*-value was less than .05 ($p = .035$), for the $U = 3583.50$.

The examination of the knowledge test results was followed according to the test task types: those with and without illustrations integrated into it. Looking at students' performance on the test tasks with illustrations, the non-parametric Mann-Whitney U test showed that there was no statistically significant difference in the performance of the E group ($M = 6.79$, $SD = 2.85$) and C group ($M = 6.36$, $SD = 3.58$), as the *p*-value was greater than .05 ($p = .845$) for the $U = 4289.00$. This might be explained by the fact that the test tasks were provided with illustrations that the students of both groups could have encountered in everyday life, in previous school lessons, or even in their textbooks.

https://doi.org/10.33225/BalticSTE/2023.210

Also, the illustrations were realistic and of a conventional type and not a hybrid type with which E group students were faced during experimental classes.

The data gathered from the knowledge test result on the tasks without illustrations was also statistically analyzed. Non-parametric Mann-Whitney U test showed that there was a statistically significant difference in the performance of the E group ($M = 6.54$, $SD = 3.28$) and C group ($M = 4.49$, $SD = 2.75$), as obtained p-value was significantly lower than .05 for the $U = 2984.50$.

Discussion

In this study, the overall results showed a statistically significant difference in the performance of the knowledge test between the two groups. However, the similarity in the E and C groups students' performance on the knowledge test on Hydrocarbons was observed (E group students' average performance was about 46%, and the C group average performance was about 39%). In the previous study by Rončević et al. (2019a), no statistically significant difference in the average students' performance was found between the groups, where the experimental group was using hybrid illustrations as teaching and learning visual tools, and the control group was subjected to traditional chemistry teaching methods (i.e., lecture, laboratory chemistry demonstrations and discussion).

It is important to mention that the knowledge test on Hydrocarbons teaching topic included numerous tasks with illustrations. About 53.5% (15 points) of the maximum possible score on the knowledge test came from tasks with illustrations, while the rest, 46.5% (13 points) were tasks with only text content without illustrations. Therefore, the test results were also examined according to those aspects.

During the analysis of the test results from the perspective of the tasks complemented with illustrations, there was no statistical difference between the groups. The textbook that follows the curriculum related to the Hydrocarbons teaching topic in primary school contains a significant number of conventional illustrations, which were presented in both the E and C groups. The part of the teaching topic dealing with nomenclature and writing formulas of organic compounds was taught to both groups of students by relying on the traditional method and was introduced exclusively with abstract conventional illustrations. During the revision classes in the E group students, the nomenclature, formulas of organic compounds and organic reactions were additionally exemplified with hybrid illustrations, supplemented with realistic images to highlight individual groups of atoms, reagents, or products. In the previous study by Rončević et al. (2019b), it was found that secondary school students possessed difficulties in reading illustrations included in the test of knowledge about dispersed systems. When students' answers about realistic illustrations were analysed, these difficulties came to the forefront. It was concluded that students relied on what they literally saw in realistic illustrations, i.e. photography, and they did not make proper connections with the chemical content of interest (Rončević et al., 2019b). A similar approach to students' interpretation of science textbook illustrations was presented in the study by Ametller and Pinto (2002).

However, it is worth highlighting some differences between the E and C groups observing test tasks with illustrations. In the first task on the test, the goal was to circle a false statement about the structural formula of but-1-ene, i.e. the answer was "the

https://doi.org/10.33225/BalticSTE/2023.210

compound is the fourth member of the homologous series of alkenes". The E group students solved the task with a percentage of 47.19%, while the C group students only achieved a result of 18.75%. In this case, the C group students may have a misconception, as they mistakenly regard 1–butene as the fourth member of the homologous series of alkenes and rule out the correct answer. The almost 30% difference in the results on this test task between the E and C groups indicates that during the lesson "Systematization of contents of hydrocarbons" the E group students effectively mastered the structural features of Hydrocarbons through an interactive game related to nomenclature with hybrid illustrations, sharply separating the homologous series of the alkanes, alkenes, and alkynes.

Another difference in the performance of the E and C groups was found in task 13 of the knowledge test. The task asks for the name of the crude oil fraction used in passenger aircraft, which has a boiling point of 170^{o}C. The task is presented with a picture of an aeroplane. The E group solved the task correctly with 82% success. On the other hand, 66% of the C group students circled the correct option "kerosene". During the "Systematization of contents from hydrocarbons" the E group students placed the fractions produced during the refining of crude oil on a summary hybrid illustration, matched with the appropriate boiling point, used in everyday life, and name of the fraction. This interactive hybrid illustration provided the students with a complete picture of the most important products of crude oil refining, the effectiveness of which is indicated during the testing. Both previous studies showed that including hybrid illustrations as teaching, learning or evaluation tools can provide valuable information about students' misunderstandings and misconceptions (Rončević et al., 2019a, 2019b).

The highest difference in the performance between the E and C groups appeared in test tasks without illustrations. In this test tasks category, E group students outperformed C group students. Among the tasks without illustrations, task 4 showed significant differences between groups E and C. The assignment was a fill-in-the-blank question. The text was about the division of hydrocarbons and the structure of the alkane. Out of the maximum 5 points, the students of group E scored an average of 2.3, while the students of group C scored only 0.9. This can be explained by the fact that the students of group E solved an interactive task during the revision classes in which they had to match the detailed division of hydrocarbons with diagrams of structural features, thus helping them master this abstract concept. Certainly, hybrid illustrations with efficient methodological design could help students to develop conceptual understanding and clarify some important chemical concepts (Rončević et al., 2019a).

Conclusions and Implications

The eighth-grade organic chemistry curriculum serves as the basis for later, more detailed knowledge of this branch of chemistry. Hence, it is important to record the basic concepts and structural features of organic compounds for the students. They get to know how these compounds play an active role in their everyday life, how important they are for industry, and how can be found in the energy sources. By using digital, interactive hybrid illustrations, the teaching process itself can make learning chemistry playful and motivating, as evidenced by the openness experienced by the students in the experimental classes towards this application of the illustrative-graphical teaching method and the use of mobile phones for educational purposes.

https://doi.org/10.33225/BalticSTE/2023.210

In the case of tasks without illustrations, the interactive tasks used during revision classes played a very important role. Through these interactive tasks, the students of group E could not only learn about the properties of hydrocarbons in text form but could also practice them with the help of hybrid illustrations. As a result, they gave correct answers to the questions asked in the test even if they did not contain illustrations. The differences between the results of the groups E and C are shown in the tasks with illustrations on everyday use of hydrocarbons and the representation of their formulas. These tasks brought the students closer to the concept we expected them to know, which was one of the main goals during the revision classes in the E group.

It is important to conclude that the overall test results showed a statistically significant difference in the performance of the E group and C group students, in slight favor of the E group. The E group worked with the illustrative-graphic method (i.e., interactive form of hybrid illustrations) within only 2 school lessons before the performance test on Hydrocarbons. According to our opinion, a more significant difference in the groups' performance requires the continuation of the experimental teaching and learning in the E group of students.

Also, there were differences between the groups' performances in the individual test tasks. In these cases, it would be worthwhile to analyze the sources of possible misconceptions generated by the students. Analyzing the details of the tasks representing the divergence between the E and C groups, it is necessary to continue the research on other topics of organic chemistry with increased attention, focusing on their role in everyday life, their impact on health and their functional groups.

The processing of the topic "Oxygen-containing organic compounds" is currently ongoing in the concerned primary school in Novi Sad, so the lessons for the review classes for this part of the curriculum are also continuously prepared on the Moodle platform. After the end of the topic, another testing will be conducted, in which the performance of E and C groups students will be compared again.

The research on which this paper is based was carried out through the Moodle system, a free educational platform available worldwide and offering a wide range of possibilities. It also provides space for development and expansion based on the suggestions of the users. The application of Moodle platform in this research was limited to the repetition lessons, but it can also provide an opportunity for the interactive processing of new educational materials and even for evaluation. From the point of view of digital education, it is easy to use and can be an excellent teaching aid for all teachers, for which the courses created during our research serve as an example. Also, in the available literature in science education domain, there are a few empirical studies about the usage of hybrid illustrations in the science classroom, and therefore there is a necessity for the new, ongoing studies.

Acknowledgements

The authors gratefully acknowledge the financial support of the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Grant No. 451-03-47/2023-01/200125). The author gratefully acknowledges the financial support of the Sapientia Hungarie Foundation and the State Secretariat for National Policy of Hungary.

Declaration of Interest

The authors declare no competing interest.

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Received: *April 05, 2023* Accepted: *May 15, 2023*

Cite as: Sedlar, A. R., Rončević, T. N., & Horvat, S. A. (2023). The application of interactive learning tasks made by using digital hybrid illustrations in the topic "Hydrocarbons" in eighth-grade organic chemistry classes. In V. Lamanauskas (Ed.), *Science and technology education: New developments and Innovations. Proceedings of the 5th International Baltic Symposium on Science and Technology Education (BalticSTE2023)* (pp. 210-222). Scientia Socialis Press. https://doi.org/10.33225/BalticSTE/2023.210