

Acta Pedagogica Naturalis

Former Annual of Konstantin Preslavsky University

Journal homepage: <http://acta-pedagogica.shu.bg>

Received: 02.09.2022

Accepted: 20.12.2022

Implementation of environmental education and education for sustainable development in the teaching of organic chemistry in the 9th grade

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***Abstract:** An important factor for forming a positive attitude towards the environment and building ecological awareness and ecological culture is the process of learning, during which students acquire knowledge necessary for understanding the processes taking place in the system "man - society - nature" and an active civic stance is being fostered based on a sense of empathy and personal responsibility. The ecological and health training of students is becoming one of the main dimensions of modern educational practice and one of the ways to form important key competences. Proof of this is the fact that the skills for supporting sustainable development and a healthy lifestyle and sports activities are included in the Preschool and School Education Act. The achievement of these skills is carried out with the help of environmental education and education for sustainable development. In the present work, an opportunity to implement ecological education and education for sustainable development in organic chemistry education in the 9th grade is presented.*

***Keywords:** environmental education, education for sustainable development, training in organic chemistry*

Introduction

The environment is studied by many sciences, each of which examines a particular set of interrelationships. Different aspects of the ecological situation are studied in various school subjects, and the system of ecological knowledge is built on this basis.

The 1977 Declaration of the UNESCO Intergovernmental Conference on the Environment are suggested the following possible solutions for integrating environmental knowledge into school education:

- inclusion of environmental highlights of the environmental problem in each studied subject;
- work in interdisciplinary teams;
- addressing specific issues that students and teachers can observe [3].

These nearly 45-year-old recommendations have not lost their relevance even today. In addition, effective approaches are still needed that are interdisciplinary, creative, motivating and require active participation of students in discussing environmental issues.

The occurrence and solution of environmental problems are closely related to chemistry, with its theoretical and practical significance. Unfortunately, in textbooks, ecological information is more often found in supplements, which does not motivate students to learn it. What has been said so far determines the purpose of the present research, namely to develop and apply in the process of learning organic chemistry (section "Hydrocarbons") specific constructions with an ecological orientation, which will help for the implementation of the ideas of environmental education and education for sustainable development.

Theoretical setting

The term environmental education was first used in 1948 at a meeting of the International Union for Conservation of Nature (IUCN) in Paris by Thomas Pritchard, Deputy Director of Conservation in Wales. In the pedagogical literature, the term was used more widely in the late 1960s and early 1970s in connection with the growing interest in environmental problems [5].

In her monographic work „Conceptual foundations of environmental education“ Z. Kostova defines environmental education as „a process that aims to create a world population, aware and concerned about the environment as a whole and its related problems, and which has the knowledge, skills, attitudes, motivation and commitment to work individually and collectively to solve current problems and to prevent new problems from arising. It is problem-oriented, interdisciplinary, social and value-oriented, engaged with human experiences, activity-based, focused on today and tomorrow. Environmental education involves learners in planning, enables decision-making and bearing the consequences; examines the environmental aspects of development plans and projects; helps students discover the symptoms and causes of environmental degradation; develops critical thinking; takes place in a diverse learning environment with hands-on activities“ [4].

Environmental education is aimed at forming an ecological culture, ecological awareness and ecological behavior in their interrelationship and unity with a view to preserving the ecological balance. It is education for building ecological competences, which are the foundation of ecologically sustainable development. It emphasizes the ecological laws, the basis of ecological balance and healthy lifestyles, and the responsibility of man and society for their observance. [6]The content of environmental education in the current stage of development relates to such issues as health, healthy lifestyle, human rights, justice, safety, social, religious and political tolerance. In our country, in an educational aspect, **the main goal** of environmental education is the building of environmental culture, environmental awareness and environmental.

Ecological culture includes a set of meaningful ecological knowledge, in which, on the one hand, the interrelationships between all forms of life and the living environment are revealed, and on the other, the role and place of man as a biosocial being in nature. Ecological culture implies a system of knowledge, skills, habits and attitudes to create material and spiritual goods, in accordance with ecological regularities, to carry out public activities for the protection and reproduction of the natural environment. Ecological culture exists as an aspect of various forms of public consciousness and is the basis of ecological consciousness [2].

The formation of ecological culture is determined by the extent to which knowledge and skills have become internal convictions, motives for environmental protection activities and a responsible attitude towards nature. It includes meaningful ecological knowledge, in which, on the one hand, the interrelationships between all forms of life and the living environment are revealed, and on the other, the role and place of man as a biosocial being in nature. Ecological culture implies a system of knowledge, skills, habits and attitudes to create material and spiritual goods, in accordance with ecological regularities, to carry out public activities for the protection and reproduction of the natural environment. Ecological culture exists as an aspect of various forms of public consciousness and is the basis of ecological consciousness [2]. The formation of ecological culture is determined by the extent to which knowledge and skills have become internal convictions, motives for environmental protection activities and a responsible attitude towards nature.

Ecological consciousness can be considered in a broad sense as a form of reflection of the objective relationships between society and nature, and in a narrow sense as a reflection of the spontaneously arising ecological situation. It includes the following components: purposeful activity aimed at optimizing interaction with nature; environmental knowledge; environmental self-awareness; a system of intellectual, moral, economic, aesthetic and value attitudes towards nature and the environment, manifested in practical activity [4].

S.V. Biran defines ecological literacy as „... the ability of a person to absorb and use natural scientific knowledge and knowledge of the regularities of the human-society-nature interaction in order to recognize and pose questions related to the acquisition of new knowledge necessary to explain phenomena and formulate conclusions based on scientific evidence in the field of environmental protection and restoration; to determine the specific consequences of the impact of human activity and technology on the material, intellectual and cultural sphere of society, making a conscious choice that ensures effective environmental protection. The possession of ecological literacy by a person is manifested in his emotional-value attitude towards the environment, understanding and compliance with the rules of ecological behaviour, manifestation of an active civic position when considering problems related to the environment“ [1].

The development of scientific knowledge shows that ecological thinking, ecological consciousness and culture are not born randomly and spontaneously. They are the result of purposeful insight into the mechanisms of functioning of the biosphere, understanding of natural regularities, rethinking of natural possibilities and human needs. The path to building an ecologically sustainable economy passes through individual and collective human consciousness. This presupposes building a way of thinking that is able to assess man's place in the world, meet the challenges of the time and integrate knowledge into life behaviour [2].

Education for sustainable development plays an important role in achieving this task. Education for sustainable development involves complex and diverse issues, which is why there are different definitions of it. According to Barker (2000) „it is education that enables people to develop the knowledge, values and skills needed to participate in decision-making about how we act, individually and collectively, locally and globally, so that the quality of life increases without destroying the future of the planet“. There are other definitions in the existing literature, but in all of them the relationship „knowledge – lifestyle“ occupies a certain place.

The main objective of the education for sustainable development is: ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all. The education for sustainable development requires a reorientation from focusing entirely on the knowledge for solving problems and finding possible solutions. Therefore, education should retain its traditional focus on individual subjects, but at the same time open the doors to multi- and interdisciplinary study of real-life situations.

The effective education for sustainable development is designed to form practical knowledge, ecological beliefs and a new attitude of the individual towards the natural environment. And since the system of competences needed by young people includes, in addition to linguistic, informational, sociocultural and educational and health-ecological aspects, it is imperative to integrate them ecologically with health, civic and economic education. All of this must be linked to the formation of behaviour patterns that support the ecological balance and quality of the environment. It can be summarized that the formation of ecological consciousness is individual in each person, but its manifestations in the behaviour of the person can lead to the coordination of activities for sustainable development in society [7].

Discussion and results

The Chemistry and Environmental Protection curriculum for grade 9 specifies the requirements regarding the knowledge, skills and competences that students must acquire as a result of the study. It regulates the goals of training and education, as well as the expected results of the training. In its part related to the organic chemistry curriculum, the curriculum includes requirements for the acquisition of basic knowledge and the formation of skills related to the classification, structure and properties of organic substances, planning and conducting experiments and research. Emphasis is placed on the significance of the studied substances for everyday life and practice, as well as their impact on the environment and human health.

The curriculum provides for the study of topics that will give students the necessary knowledge and skills to describe phenomena, processes and substances, to characterize their physiological action and application in practice. Ecological knowledge and problems of environmental protection are presented in the various textbooks of the publishing collectives or in specific lesson units or as an additional information. Unfortunately, regardless of the fact that for each topic in the curriculum, as an expected result, the student is expected to explain the harmful impact of the respective representative on the environment and health, the ecological information in the textbooks is most often present in the supplements. This is one of the reasons why students, however aware they may be, do not appreciate its importance.

The findings identify the need to specifically direct learners' attention to environmental and human health issues, both through the available learning content and through additional emphasis brought in as information, class work tasks, independent work tasks and review tasks and assessment of acquired knowledge and skills.

Table 1 presents some of the concepts and knowledge of an ecological nature, on which we have worked further and more deeply during the course of the experiment.

For the successful execution of the curriculum in the implementation of environmental education and education for sustainable development, it is necessary to apply and combine traditional and modern forms, methods and approaches in organizing the educational process, with active inclusion of elements of the research and problem-based approach and use of the possibilities of information and communication technologies.

It is appropriate for students to put themselves in an environmental problem situation, proposing ways to solve it, to face environmental problem issues from everyday life, to search for materials themselves and to propose ways to overcome environmental problems. In this process, they should be the active, creative side, and the teacher should only guide and coordinate the activities. Possible activities in this direction are participation in projects, development of essays, eco-tables, rebuses, crosswords to be presented to other students in order to build and form an ecological culture among them. Another possibility is the inclusion of students in organized environmental events at school, regional and national level.

The pedagogical experiment was carried out with the students of the 9th grade of the First Language High School, Varna, who are trained according to the textbook for compulsory preparation of the „Prosveta“ publishing house. In addition to it, we also use an aid from the publishing house „Bulvest 2000“ and the publishing house „Anubis“ in German, because we study the academic content in German.

Table 1. A system of ecological concepts and knowledge on the topics of the „Hydrocarbons“ section

Subjects of the learning content	Concepts with ecological content	Environmental knowledge about:
1. Hydrocarbons Alkanes Alkenes Alkynes Arenas	pollutant insecticides pesticides greenhouse effect ozone layer smog halogen derivatives freons	<p>1.1. Methane as a greenhouse gas, because it retains 17 times more heat than carbon dioxide. The increase in its amount in the atmosphere is related to the global increase in population, and also to some resulting human activities such as raising cattle.</p> <p>1.2. The dual role of methane in the biosphere, its use in biotechnology and organic synthesis.</p> <p>1.3. Biological and physiological functions of hydrocarbons (Eg. ethene is a plant hormone associated with fruit ripening or leaf fall)</p> <p>1.4. Environmental problems caused by the use of alkanes as fuel - greenhouse effect. Another problem - when propane-butane is used as a heating agent, the oxygen in the room is depleted and it should be frequently ventilated to ensure the access of oxygen from fresh air.</p> <p>1.5. Polyethylene and polypropylene as permanent pollutants of the natural environment.</p> <p>1.6. The release of toxic substances during heating of empty Teflon (polytetrafluoroethylene) containers.</p> <p>1.7. Hydrocarbons as components in the formation of photochemical smog.</p> <p>1.8. Halogen derivatives with a poisonous effect (Vinyl chloride is used as a monomer in the production of polyvinyl chloride (PVC). In 1974, its toxic effect on the human body was proven).</p> <p>1.9. Freons and their influence on the ozone layer, which retains part of the solar radiation and prevents the impact of high-energy rays on the earth's surface, which are very dangerous for living organisms. (In 1987, the Montreal Protocol was signed, which limits the production and use of substances that, passing into the atmosphere, destroy the ozone layer. According to the protocol, the list of controlled substances includes freon 12, freon 22 (CHClF₂) and freon 11, as from 1.01.2010 freon 12-CCl₂F₂ and freon 22, with which the air conditioners used to work, are prohibited for use).</p> <p>1.10. The general toxic and mutagenic action of arenes and their influence on human heredity. Persistent organic pollutants (POPs) have toxic properties. They persist for a long time in the environment and accumulate in the biosphere.</p>

<p>Natural sources of hydrocarbons (Oil, gas and coal)</p>	<p>Global Warming greenhouse effect acid rain smog alternative fuels</p>	<p>Through the air, POPs are transported over long distances and thus can cause significant negative consequences for human health or the environment near or far from their sources. Aware of the need to taking global action against the effects of POPs, in 2001 the Stockholm Convention was signed in Sweden to limit the production and use of these substances. The list of banned POPs includes DDT and hexachlorobenzene.</p> <p>1.11. The problem of the consequences of using pesticides in agriculture, based on aromatic hydrocarbons, on living nature (reduction of species diversity and the number of individuals, changes in behavior, reproduction, etc.).</p> <p>1.12. Biological methods of pest control, as an alternative to chemical ones.</p> <p>1.13. Natural sources of hydrocarbons and the products obtained during their processing in relation to the potential danger of pollution of the natural environment.</p> <p>1.14. The problems of global warming of the planet (climate changes) and the consequences for the natural environment and man.</p> <p>1.15. Pollution of the atmosphere with the products of natural gas, oil and coal processing and their use as fuels - carbon dioxide - greenhouse effect, nitrogen and sulfur oxides - acid rain, fine dust particles, carbon monoxide, etc.</p> <p>1.16. The problems associated with depletion of non-renewable natural energy sources.</p> <p>1.17. Consequences of the pollution of the World Ocean with oil and oil products (disruption of the biological balance in the hydrosphere, making photosynthesis difficult of blue-green algae, reduction in reproduction of aquatic animals, manifestation of pathogenic deviations in plants and animals).</p> <p>1.18. Environmental pollution from the exhaust gases of internal combustion engines.</p> <p>1.19. Alternative fuels and sustainable development using natural resources.</p>
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The experiment went through several stages. The first stage aims to establish the students' attitude towards environmental problems at the beginning of targeted work. For this purpose, a written survey was conducted. Its results served in the organization of the actual pedagogical experiment.

The second stage aims to develop and implement ecologically oriented specific constructions in the methods of organic chemistry learning process, which will assist in realizing the ideas of environmental education and education for sustainable development. Based on the goals, in the course of the experimental work, additional lesson fragments with an ecological and health focus and independent lessons on important environmental issues were developed and included in the learning process. In order to activate the students' work and form a responsible attitude to nature, to their own health and that of others, along with traditional methods and forms of education, modern interactive methods and forms of education were used - project work, solving cases, brainstorming, discussions, etc. During the preparation of the lessons, the students wrote announcements, compiled schemes, presentations, videos and clips.

The following specific constructions of lessons from the material studied in organic chemistry in the 9th grade illustrate an opportunity to implement environmental education and education for sustainable development in education.

The „Hydrocarbons“ section provides an opportunity to enrich and expand students' knowledge with information about halogen derivatives of hydrocarbons. The problems caused by the use of halogenated products are mainly related to the thinning of the ozone layer. Given the importance of this global

environmental problem, one of the summary lessons in the section was devoted to it. We present the methodological development:

Halogen derivatives of hydrocarbons

Objectives:

1. To consolidate and expand knowledge about the role of freons in destroying the ozone layer, the toxic effect on the human organism of polyvinyl chloride and persistent organic pollutants for plant protection.

2. To form a skill for assessing the impact of certain substances on life processes, human health and the environment and for formulating conclusions about environmental problems related to their use.

3. To form a positive attitude towards the environment.

Methods: talk, avalanche, project method, discussion, essay

Preliminary preparation: Before studying one of the general lesson topics „Hydrocarbons“, which is intended for work on environmental problems, students are given the task of writing an essay on the topic: "Is it possible for humanity to exist in the XXI century without freons, PVC and highly resistant chemical preparations for plant protection?". The teacher also provides the following information in advance in the form of an information card:

Information card:

The ozone layer in the stratosphere protects the earth's surface from harmful ultraviolet rays. Ozone in the lower layers of the atmosphere is a pollutant: it is a greenhouse gas; is a much stronger oxidizer than O₂ and can damage plants and lung tissue in living organisms. Freons are air pollutants that contain fluorine, chlorine and carbon. They are used in the production of plastics, aerosol packaging, in refrigerators and air conditioners. The main reason for the thinning of the ozone layer is precisely freons. They are chemically inert in the lower layers of the atmosphere, but when they reach the stratosphere, they break down with the release of chlorine under the action of ultraviolet rays. Chlorine catalyzes the conversion of O₃ to O₂. Nitrogen oxides (N₂O, NO, NO₂) also affect the ozone layer.

In 1987 was signed the Montreal Protocol, which limited the production and use of substances that, passing into the atmosphere, destroy the ozone layer. According to the protocol, Freon 12 and Freon 11 are on the list of controlled substances. Vinyl chloride is used as a monomer in the production of polyvinyl chloride (PVC). In 1974, its toxic effect on the human body was proven.

Persistent organic pollutants (POPs) have toxic properties. They persist for a long time in the environment and accumulate in the biosphere. Through the air, POPs are transported over long distances and thus can cause significant negative consequences for human health or for the environment near or far from their sources. Being aware of the need for taking global action against the effects of POPs, in 2001 in Sweden is signed the Stockholm Convention to limit the production and use of these substances. The list of banned POPs includes DDT and hexachlorobenzene (HCB) [8].

For the three rows of students, three groups of sheets with different questions for each group are prepared:

Group I: What are the chemical structure, physical properties and environmental problems associated with the use of Freon 12 and Freon 11?

Group II: What are the health and environmental problems that arise from the use of vinyl chloride?

Group III: What are persistent organic pollutants and why are they a serious threat to human health?

Course of the lesson:

At the beginning of the lesson, the text of the question, which was asked as a task for writing an essay, is written on the board: „Is it possible for humanity to exist in the 21st century without freons, PVC and highly resistant chemical preparations for plant protection?“. Question papers are released at the beginning of each row by group. Each team has 10 minutes to write down all possible answers on their sheet. The interactive method „Avalanche“ is implemented.

After completing the work, the last student reads what the group has written. If there are additions, they are added and the results are written down on the board in three columns and discussed (10-15 min.)

The question written on the board is asked and the students are given the floor to read their essays as an answer. (15 min). Another issue of environmental importance suitable for discussion in the study of hydrocarbons is the possibility of their use as fuel and the environmental problems that arise in doing so. This problem was the subject of consideration in the topic "Natural sources of hydrocarbons", realized with the help of the project method.

Natural sources of hydrocarbons

Objectives:

1. To learn about coal, oil and natural gas as the main non-renewable sources for hydrocarbon extraction and to present possible ways to reduce CO₂ and CH₄ emissions.
2. To form skills for detecting and formulating environmental problems and, using different approaches, to propose options for their solution.
3. To teach students to evaluate the impact of natural sources of hydrocarbons on life processes, human health and the environment and to draw conclusions about environmental problems related to their use.
4. To form skills for extracting and evaluating information on substances and processes, presented through text, models, tables, graphs and diagrams, according to set indicators.
5. To form skills to present research results and draw conclusions and conclusions.
6. To develop the following competencies:
 - cooperation skills;
 - critical thinking;
 - responsibility to society;
 - ability to defend one's own positions and values.

Methods: design method; discussions, talk, survey, work with scientific literature, solving a case study, brainstorming, content analysis of a text.

Organization:

Each group must submit an original video that complies with the topic. The below-mentioned steps are followed during the preparation:

- choosing a suitable environmental problem;
- researching the chosen topic and systematization of the information (for the purpose of shooting a video film, the camera of a mobile device can be used); for filming the video, ideas can be taken from popular science films or series.
- selecting the place of shooting the film (it can be at school, on the street, at home).
- the content of the video can be an attitude expressed on the problem and its solution, to be told about in front of the camera, or a specific situation to be filmed. For example: polluted areas in the park, on the port, on the beach, etc. You can also use a personal example to capture how a given area is cleaned.

During the presentation, the other teams evaluate the presenting team using the given table.

Table 2. Evaluation of a team presentation on a specific topic [9]

Number of points/ Criteria	1 point	2 points	3 points
Clearly set project goals	vaguely presented goals	goals presented	objectives are clearly and precisely formulated
Creativity and innovation	limited	Moderate	exceptional
Depth of problem research	limited study	partial survey	comprehensive study
Personal attitude to the problem	without personal regard	Partially	clearly expressed
Attractiveness during the presentation emotional impact on the audience	lack of emotional impact and attractiveness	moderate influence and attractiveness	strong emotional impact and attractiveness

Preliminary preparation for the project

Under the guidance of the teacher, four teams are formed to develop project tasks. Each team chooses one of the following topics:

1. *Composition of natural sources for obtaining hydrocarbons.*
2. *Processes in the primary and secondary processing of oil.*
3. *Use of natural resources and environmental pollution.*
4. *Applications of hydrocarbons in industry and in people's lives [8].*

Task 1. Search the library or the Internet for additional materials (scientific articles, popular science articles from newspapers, books, articles from electronic publications, etc.) that will help you prepare for the topic. The requirements for the information is that it is scientifically reliable and scientifically substantiated, as well as that it was published after 2014. For example: Climate change is most often associated with global warming. It is believed that one of the reasons is the increased amount of greenhouse gases released into the atmosphere. The most common greenhouse gases are CO₂, CH₄, water vapor and O₃ (in the troposphere). Other greenhouse gases are freons, CCl₄, CF₄, N₂O, C₂H₆. Global warming, that is. The increase in average temperatures leads to the melting of the ice and the release of gases trapped in the ice with small molecules such as CH₄ and CO₂. It also leads to a decrease in the solubility of CO₂ in water and its release from water surfaces. These processes amplify the greenhouse effect, which in turn amplifies global warming, closing the loop [9].

Task 2. Choose an appropriate title for the presentation, film or poster on the selected topic.

Task 3. When preparing the topic, answer the following questions:

- What impressed you the most about the article and why did you choose it?
- What issues does the article address?
- What conclusions can be drawn?
- What new knowledge related to the application of hydrocarbons in industry and in people's lives did you receive?
- Since the burning of all fuels emits carbon dioxide (CO₂), can we assume that they are environmentally friendly?
- What daily activities related to the application of hydrocarbons in industry can contribute to environmental protection?

Progress of the lesson

1. Each team presents its developed topic in the form of a poster, film or multimedia presentation within 5 minutes - 20 minutes in total.
2. The information provided is discussed within 5 minutes, formulating the main issues that are affected in the presentation, poster or film.
3. The discussion discusses a possibly existing ecological problem that has arisen in our populated area, a result of the processing of oil and the application of hydrocarbons in industry and in people's lives. (10 minutes)
4. Measures to reduce environmental problems and alternative, renewable energy sources are proposed. (5 minutes)
5. A survey is filled in. If possible, a conversation is held with the relevant regional authorities responsible for the environmental situation in the region, discussing the problem and the measures proposed by the group. (5 minutes)

Survey content:

Tick the box that you think comes closest to your actions related to human impact on the environment.

1. After wetting the toothbrush, I turn off the water while I brush my teeth.
2. I turn off the shower while soaping myself.
3. After I'm done using electronics (e.g. microwave or phone charger), I unplug.
4. I sort the waste into organic, plastics, paper, glass and metals and dispose of it in the appropriate containers.
5. I do not use electric lighting during the day.
6. I walk or ride a bike instead of using a vehicle.
7. I avoid buying fruits and vegetables imported from abroad and instead consume those that are in season and grown in our region.
8. One day a week I don't eat meat.

Table 3. Reduction of CO₂ emissions per year (in kilograms)

Answer no	1	2	3	4	5	6
I do this often						
I rarely do this						
I do this sometimes						
Approximate CO ₂ saved per year (in kilograms)						

The third stage - diagnosis of the achieved results is realized at the end of the section with the help of a didactic test and at the end of the school year - with the help of a final survey.

Conclusion

The results obtained from the conducted tests and surveys are proof that as a result of the additional work, the environmental knowledge of the students is enriched, and this also leads to the formation of a responsible attitude towards environmental problems and a willingness to participate in solving them.

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