BIO Web of Conferences **116**, 04001 (2024) https://doi.org/10.1051/bioconf/202411604001
EBWFF 2024

Formation of environmental literacy through the study of green chemistry

Assel Seisova[1*], *Sholpan* Khamzina[1], *Maral* Khassenova[1], and *Roza* Mukanova[1]

[1]Higher School of Natural Sciences, Pavlodar Pedagogical University named after Alkey Margulan, 14000 Pavlodar, Kazakhstan

Abstract. The article deals with the relevance of formation of environmental literacy among school students. Recently there has been a need to balance the requirements for the ability of students to consciously plan their future life in society. This is explained by the emergence of various global problems, for which modern man should be ready and able to solve them. Environmental literacy can be integrated into the study of the environment, more specifically environmental chemistry, in a modern context with green chemistry. The article also studies the definition of "green chemistry" and its principles. The analysis of the content of normative documents regulating the system of general secondary education in terms of providing learning outcomes for the development of ecological literacy in terms of its component of natural science literacy in chemistry lessons within the framework of a shortened curriculum makes it possible to introduce into the variable part of the educational curriculum programs and methods for the development of functional literacy, including ecological literacy.

1 Introduction

Recently, there has been a need to balance the requirements for students' ability to consciously plan their future life in society. This is explained by the emergence of various global problems, for which a modern person must be ready and be able to solve them. There are many such problems such as global warming, climate change, deforestation, depletion of water resources, and so on. A particularly widespread problem around the world is pollution, which has a serious impact on life. The environmental problems that are taking place nowadays affect the reduction of environmental quality. It should be noted that the quality of human life depends on the quality of the environment. The quality of human life depends on the quality of the environment. Currently, the level of environmental quality is falling in our country and in the world, and this is becoming an indicator of alertness [1]. Therefore, one of the most important and urgent problems is the environmental issue, namely the protection of the environment for the future generation. We believe that the problem requires serious attention of all those who have to do with it, including in the sphere of education, because it is from school that the conscious adult education of children, inculcation of moral, spiritual and global values begins. At the moment, the study and implementation of necessary

* Corresponding author: aselseisova@gmail.com

educational programs, methods and technologies is relevant for the development of necessary competencies of students in this area.

Environmental education in the framework of the 21st century in schools of the Republic of Kazakhstan is not considered as the main subject in the educational program, however, in our opinion, it is relevant to introduce it into the education system, as it is the basis of environmental literacy. In this regard, mastering of ecological literacy is currently important. Entering the global competition, it is necessary to properly prepare students to become communicative, cooperative, creative, innovative, critical and analytical thinkers, as well as to have the ability to effectively solve real problems, including environmental ones.

Environmental literacy is important in any context, although environmental literacy is a concept that is difficult to define [2]. In the source analysis, environmental literacy is the understanding and ability to solve environmental problems through a thoughtful and appropriate process of analysis, synthesis, evaluation and decision making by a citizen of a country. This means that an environmentally literate person is able to solve environmental problems in both work and daily life and has all the necessary knowledge and skills to do so.

Environmental literacy can be integrated into the study of the environment, more specifically into the study of environmental chemistry, in the modern concept with green chemistry [3]. In the modern sense, "green chemistry" is the development and practice of chemical science and production in such a way that they are sustainable, safe and environmentally friendly, consume a minimum of materials and energy and produce a minimum of waste. The very concept of "green chemistry" is borrowed from organic, inorganic, biochemical and analytical chemistry. This concept generally finds application in industrial sectors. It follows here that green chemistry is different from environmental chemistry. The difference is that green chemistry focuses more on ways to reduce pollutant pollution and improve the efficiency of chemical use. Meanwhile, environmental chemists are paying more attention to environmental phenomena that are contaminated by chemicals. [4].

It is known that 12 principles of "green chemistry" have been developed, some of them can be taken as the basis for human behavior and character in the environment. Based on these principles, it is possible to introduce a method of problem-based learning with tasks for the formation and development of functional literacy among students. The principle of green chemistry as a science is also defined, aimed at preserving environmental values in order to introduce green education through project-based learning. Studying it can develop the creative abilities of students in schools by creating projects on topics such as "smart energy", "smart water", "smart garbage" and others [5].

This research design of teaching using Green Chemistry, focused on improving one of the types of functional literacy, ecological literacy, can be implemented in the study of chemistry through integration into the variable part of the curriculum in specialized schools. The early stages of the study analysed the significance of green chemistry in the formation of ecological literacy in learning in the modern educational process and how the principles of green chemistry can be integrated into the learning process.

2. Materials and methods

In the course of the study, a wide range of general scientific methods was used, the most representative of which is the analysis of literary sources recognized in the scientific community. In particular, on the basis of this analysis, the main directions of the problem under study were identified and issues for the development of methodological and didactic materials for the purpose of developing functional literacy in students were outlined.

The study also monitored PISA and MODO (Monitoring of educational achievements of students) tasks in order to develop necessary methodological tasks and techniques both in

chemistry lessons and in its variative part. As it is known, functional literacy includes several especially important types, such as reading, math and science literacy. At this stage of the study the task was to determine the level of science literacy. In grades 9 on the basis of specialized schools the education department conducted monitoring of educational achievements of students, which includes tasks to determine reading, mathematical and scientific literacy. The tasks were offered from the development bank of the Ministry of Education and Science of the Republic of Kazakhstan. A total of 120 students of 8-9 grades of specialized schools, where in addition to general education disciplines students study special subjects related to the specifics of the educational institution (music, military, sports) took part in the study.

3 Results and discussion

Green chemistry, also called sustainable chemistry, is considered as a chemical philosophy that encourages or plans products or processes to reduce, minimize or eliminate the use of materials and the formation of harmful compounds. The chemical environment can be considered as the natural environment and green chemistry in the natural environment serves to eliminate, minimize or prevent the formation of contaminants directly from the source. The concept that is reflected in green chemistry is effective because its principles apply innovative scientific solutions to the global environmental situation. The twelve principles of green chemistry are as follows:

1. Waste prevention
2. nuclear economy
3. Development of synthesis process using less hazardous chemicals
4. Development of safer chemicals/development of chemicals and safe chemical products
5. Safer solvents and excipients, use safe solvents and reagents
6. Energy efficiency
7. Utilization of renewable raw material reserves
8. Reduce or avoid the use of chemical derivatives
9. Use of a catalyst rather than a stoichiometric reaction
10. Design for decomposition and biodegradable products after use.
11. real-time analysis to prevent contamination
12. Inherently safer chemistry to prevent accidents [4].

An analysis of educational and methodological complexes and manuals, on the basis of which work is being carried out on teaching chemistry at school, was carried out for the availability of accessible information on environmental topics in them, and a discrepancy was found between the volume and form of presentation of environmental-oriented material. There is not enough material in school textbooks aimed at the formation of environmental literacy, this material is not systematized everywhere, the information and cognitive level of training of students prevails - the level of enlightenment and obtaining certain knowledge. Certainly, we believe that this is also due to the insufficient number of hours of teaching chemistry in specialized schools, which puts teachers in strict time limits and allows them to explain only the basic material. Therefore, it is especially important to introduce programs and methods for the development of functional literacy, including environmental literacy, into the variable part of the educational program. According to the standard curriculum, as well as studied chemistry textbooks published in the Republic of Kazakhstan, "Green chemistry" is studied as one section of the 10-11th grade, but in our opinion it is necessary to teach the knowledge of environmental chemistry earlier starting from the 8th grade, as it is from this age there is a steady formation of functional, including ecological, literacy in students.

The results of monitoring the educational achievements of students showed low indicators of the quality of knowledge in chemistry, which amounted to 48.9%, which influenced the indicator of below average level of natural science literacy. According to the definition, natural science literacy is the ability of a person to take an active civic position on socially significant issues related to the natural sciences. Therefore, it is not difficult for a natural science literate person to participate in global civil issues in the field of natural sciences and technologies.

However, for this it is necessary to have significant competencies, such as scientific explanation and understanding of the main features of natural science research, interpretation of knowledge gained during training, data and approbation of scientific evidence for subsequent conclusions [5]. The requirements for tasks to assess the level of scientific literacy should be based on the ability to solve real life situations. A typical block of tasks includes a description of a real situation, presented, as a rule, in a problematic way, and a number of task questions that are related to the resolution of this situation. Tasks are classified according to many parameters. It is proposed to consider such a parameter as competence or skills. An equal sign is placed between these concepts, since according to studies of the second half of the 20th century, the generally accepted "skills" meant the content of the modern concept of "competence". In particular, in the works of S. Rubinstein notes the presence of "automated actions and operations that merge into a single, holistically flowing act, called skill" [7].

Table 1. Relationship between competencies and tasks for their mastering.

Competence	Evaluated competence	Characteristics of the training task
Explanation of phenomena from the point of view of science	Apply to explain a scientific phenomenon	Description of a standard situation using program material
	Recognize, use and create models and representations	Description of a non-standard situation
	Predict and justify a prediction	Justify the further development of events
	Explain the operation of a technical structure or technology	Summarize the scientific knowledge of the presented technical design or technology
Understanding the characteristics of scientific inquiry	Understand the purpose	Clearly formulate the purpose
	Evaluate the way of scientific knowledge	Formulate the idea of the research, the stages of the research
	Produce a hypothesis and suggest ways to test it.	Formulate and suggest possible ways to test the hypothesis
	Describe and evaluate ways to ensure the validity of data	Characterize certain elements of the study that ensure its reliability
Interpreting data and using evidence to draw conclusions	Analyze, interpret	Formulate conclusions based on data interpretation
	Transform data	

	Recognize evidence and reasoning in scientific text Evaluate arguments and evidence from a variety of scientific sources	Transform the presentation of scientific data Characterize types of scientific texts: proof, reasoning, assumption Evaluate the correctness and persuasiveness of statements from various scientific sources

The table below shows the types of competencies that are subject to assessment and their corresponding training tasks, its characteristics. Based on the presented table, it is possible to determine the goals and specific tasks of the educational process in secondary school at chemistry lessons.

It seems possible to develop tasks that would ensure the development of competencies, which include: scientific explanation of phenomena, understanding of the features of scientific research; interpretation of data and the use of evidence to draw conclusions. Tasks for the formation of competencies-skills are represented by competencies that are supposed to be possible to evaluate. To master the competencies, it is proposed to develop tasks that must meet certain characteristics.

Currently, we propose to introduce various practice-oriented problem tasks on the topic of "green chemistry" in the practical part of the lessons in order to form natural science, and more precisely ecological literacy. Below we present sample tasks for the development of ecological literacy of students in grades 8-9 of a specialized school with a reduced teaching load.

Assignment 1

In Pavlodar region in the north-east of Kazakhstan are located the main industrial facilities that decide the economy of the region. The graph shows statistical data from scientific research on the number of small mammals on the steppes of north-western Kazakhstan near industrial plants (technogenic zone) and away from plants (control zone) [8].

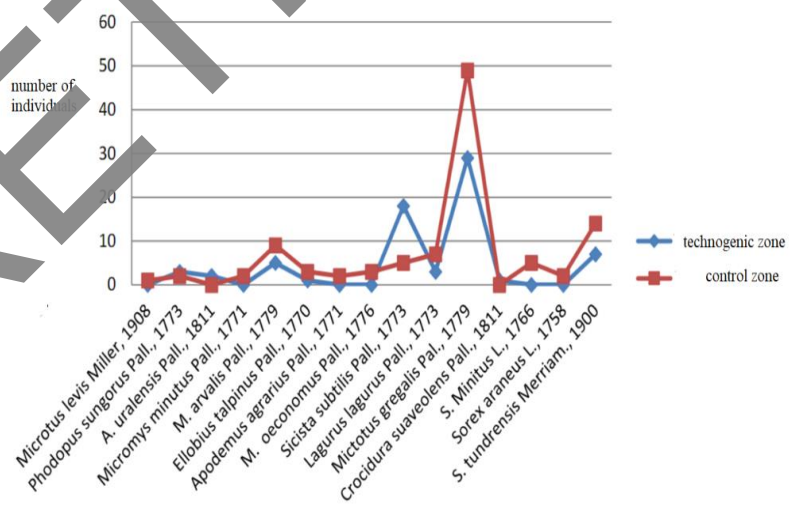

Fig.1. Abundance of small mammal species

What does the data in the graph indicate? What are the reasons for the differences in the number of mammals in different zones? In your opinion, how can this situation be corrected? Why is it important to study the distribution of small mammals in the anthropogenic zone?

The expected answer should explain that in the anthropogenic zone the number of these mammals is much less due to the impact of toxic emissions into the environment, propose your own ways of solving this problem using knowledge of the principles of "green chemistry". Also explain the study of small rodents of especially polluted areas of the city by their physiological proximity to humans and the possibility of drawing parallels.

Assignment 2.

Wickliffe Chisutia Wanyonyi, Ph.D., of Nairobi, has developed a technology for processing chicken feathers into organic substances (amino acids, proteins and peptides) for further use. Previously, feathers were burned or buried in the ground. 1) Explain why burning or burying chicken feathers in the ground is not consistent with the concept of "green chemistry."

2) Make a hypothesis about what the products of chicken feathers could be used for.

An approximate correct answer may include the following statements: 1) the student explains about the release of gases containing harmful substances and odors that pollute the air, and burying them in the ground will lead to the appearance of pathogenic microorganisms 2) the product can be used to prepare animal feed.

Assignment 3

Studying the properties of oxygen, D. Priestley sets experiments.

Here is how he describes one of them: "I took a quantity of air spoiled by the breath of a mouse, which died in it; having divided it into two parts, I introduced one into a vessel immersed in water, and into the other part of it, also enclosed in a vessel of water, I introduced a branch of mint. This was done in the beginning of August, 1771. In 8 or 9 days I found that the mouse could live perfectly well in that part of the air in which the branch of mint was growing, but instantly perished in the other part of it. Within 7 days of being in the vessel with the tainted air, the shoot had grown nearly 3 inches on the old branches." Why did the mouse in the vessel with the mint branch remain alive? Why did it perish in the second vessel?. All assignments are practice-oriented and develop science literacy, including ecological literacy.

4 Conclusion

The development and use of practice-oriented tasks at chemistry lessons and in its variant part should be introduced gradually from simple questions, which can be answered in one lesson, to more complex ones, carried out for a long time. Pupils are most interested in topics that are related to life, and the rapidly growing environmental problems cannot leave the younger generation indifferent.

Therefore, when organizing lesson and extracurricular activities, it is advisable to link the disciplines of chemistry and ecology, which gives learning an applied orientation, as well as forms environmental knowledge in students.

References

1. Mitarlis, & Ibnu, Suhadi & Rahayu, Sri & Sutrisno, Sutrisno. (2017). *Environmental literacy with green chemistry oriented in 21st century learning*. AIP Conference Proceedings.
2. Partnership 21st Century Skills, Framework for 21st Century Learning (2007)
3. Carnegie Mellon University, What is Environmental Literacy. CMU, (2003).

4. S.E. Manahan, Green Chemistry and The Ten Commandments of Sustainability. 2nd ed. ChemChar Research, Inc. (Publishers Columbia, Missouri, U.S.A. 2006), pp. 9-10
5. ZHidkin V.I., Sul'dina T.I. // Fundamental'nye issledovaniya. – 2014. – № **3-4.** – S. 822-826;
6. Rubenstein S. L. Fundamentals of general psychology : in 2 volumes. M. : Pedagogy. - **Vol. 2**. - 328 p (2020)
7. Zakanova, A., Erzhanov, N., Litvinov, YU., Sergazinova, Z. (2022).. Vestnik Evrazijskogo nacional'nogo universiteta imeni L.N. Gumileva. Seriya Biologicheskie nauki, **139(2),** 15–28.
8. Collection of tasks in preparing students to the international research TIMSS and PISA. –Astana: NAE named after Y.Altynsarin, 2016