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## **Science Education: Development of Environmental Thinking**

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**Abstract:**

*The revealed feature of natural sciences school education today is related to the need for the systemic development of scientific environmental thinking in the structure of environmental competence for a sustainable development.*

*Environmental thinking is viewed as a unity of scientific systems` thinking in the field of natural sciences and corresponding practical activities within sustainable humans` life environment development.*

*Indicators of environmental thinking of teenagers, corresponding principles and pedagogical guidelines for the development of environmental thinking have been theoretically substantiated and experimentally approved.*

*Educational, motivational and behavioral indicators of environmental thinking and four pedagogical guidelines were singled out.*

*Systemic integration of educational, gaming, working and public environmental activities of pupils are proposed. A systemic activity approach strengthening the research orientation and the reflexive nature of the project environmental protection activities of pupils is studied.*

*This approach takes into consideration the age features of pupils when developing a system of practical environmental protection, the organization of joint methodological and educational activities of teachers and the pedagogical characteristics of the education institutions.*

**Keywords:** *Science education, environmental thinking, environmental orientation, environmental competence, nature protection activities, integration, interdisciplinarity, environmental consciousness.*

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## 1. Introduction

Systemic research of modern natural science education requires the use of a set of mutually related fundamental top level concepts, such as world, human, society, life, natural as well as technical and social environment of humans' life. Finally, the concept of education as specially gained life experience for life follows (Broks, 2016). The question arises: "What kind of education is necessary today and for what kind of life?"

In the current socio-economic conditions of the global aggravation of the ecological situation in the world as a result of anthropogenic impact on nature, when the ecological purity of food and life on the planet is threatened, the answer is obvious: *"We need modern natural science education for sustainable development of society, when environmental competence is referred to Key competencies of a person"*. However, according to Brämer, classical ecological education does not change a lot the behavior of adolescents (Brämer, 2006). It is necessary to form ecological thinking among them, based on natural science concepts and laws.

Thus, the peculiarity of modern natural science school education is to satisfy the need for the systemic development of environmental thinking in the structure of environmental competence of students for sustainable development of society. The problem of the development of environmental thinking within modern natural science education stands before the school. The high intensity of the study of natural science disciplines makes it actual to form an environmental thinking in the unity of educational and extracurricular nature protection activities.

## 2. Literature Review

The problem of the organization of environmental work in theory and practice of environmental education is built on nurturing the personal qualities and it is systemic. The personal qualities which contribute to the successful formation of the psychological readiness of man to environmental work are considered in a coherent manner. Thus, according to the scientists Lamanauskas and Augiene (2016 and 2017) and Likhachev (2003), there is a need on focus on positive attitude (motivational readiness); a high level of arbitrariness of conduct (volitional preparedness), i.e. the ability to engage in a task in environmental protection, to plan and control their actions; availability of environmental knowledge and skills (educational readiness); the development of qualities that ensure the ability to establish team relationships (communication readiness). Since environmental work is a psycho-pedagogical and socio-economic problem, it has its own peculiarities, according to the vector city – village.

Moreover, according to research (Makarova, 2014), the most favorable period for the formation of environmental activities skills is adolescence. Thus, solving the questions of environmental education should be considered as actual and first priority

goal of the organization environmental activities with the aim of forming environmental thinking based on the realities of today. Today is important new perspective on the environmental work of young villagers as on the competence, but on the environmental thinking as a necessary quality of the personality of modern man.

Fundamental approaches to the study of thinking (Brushlinsky, 1996; Matyushkin, 2008; Rubinstein, 2003) determine the effectiveness of the formation of environmental thinking in the environmental competence structure. The concept of the action-related approach to the formation of thinking (Lomov, 1984; Meerovich and Shragina, 2016) reveals the logical connection between the identified problems in the work activity, decision making and its implementation. However, the above works do not provide a solution to the pedagogical multicomponent problem of the formation of environmental thinking among students in the conditions of modern natural science education. The study of the environmental orientation of the teacher's thinking showed that its formation should be systematic. Some aspects of system thinking and its formation in students and schoolchildren have been examined (Broks, 2016; Fedoseeva, 2009; Gilmanshin and Gilmanshina, 2016; Ivanchina, 2005; O'Connor and McDermott, 1997; Sychev, 2009; Guskova *et al.*, 2016).

However, there are no works devoted to the study of regularities in the systemic formation of environmental thinking in the structure of environmental competence of schoolchildren. As a result, in science there is no complete analysis of the features of the formation of environmental thinking in the structure of environmental competence of schoolchildren; pedagogical ideas about the principles, conditions, methods and techniques of organization of work on the formation of environmental thinking of schoolchildren in the conditions of modern natural science education in the unity of educational and extracurricular activities are not detailed.

The problem of this research is what is the theory and practice for the formation of environmental thinking in the structure of environmental competence of modern natural science school education. The wording of the scientific problem made it possible to determine the purpose of the research: to theoretically substantiate and experimentally prove the pedagogical conditions for the formation of environmental thinking in the structure of environmental competence in the conditions of modern natural science school education (Pastukhov *et al.*, 2018).

Some tasks have been defined in accordance with this purpose: theoretically develop principles for the formation of environmental thinking in the structure of environmental competence; theoretically develop pedagogical conditions for the formation of environmental thinking among adolescents in the unity of educational and extracurricular nature protection activities; carry out an experimental check of the developed pedagogical conditions of formation of environmental thinking in the conditions of modern natural science education.

### **3. Research Methodology**

Leading approaches to the study of this problem are the systemic activity and competence-based approaches. The notion of the systemic active approach emerged as a result of the association of the systems and activity approaches. The basic position of the activity approach is due to the fact that a man's psychological abilities are the result of the transformation of external substantive activity into internal mental activity through successive changes. Personality development is determined, first of all, by the nature of the organization of educational and extracurricular activities. The activity approach is well combined with modern educational technologies, such as information and communication technologies, project work and problem-based learning. As part of this study, the systemic active approach is expressed in the development of such pedagogical guidelines that would create situations inclusion teenagers in various types of environmental activities in order to form an environmentally oriented way of thinking.

The competence approach allows to consider the problem of general cultural and subject training of students comprehensively, to orient education on the development of the individual, its growth. In our studies, we rely on the following definition. Competence as person's ability to meaningful implementation of a particular kind of activity should include appropriate knowledge, skills, ways of thinking, reflection, self-awareness. This article does not address professional competence as a characteristic of a person, such as the ecologist. We are talking about the competence, hireable for the realization of publicly available environmental action any country citizens.

Thus, the effectiveness of the application of the competence approach is characterized, first of all, by a personal new growth (environmental thinking) - a needed component of the environmental competence of schoolchildren. This process is shown in conditions of teaching natural science subjects (botany, zoology, natural science, geography, regional history, physics, chemistry). Two groups of students participated in the experiment - control and experimental (total, including questionnaires, 384 schoolchildren) and more than 500 students at the stage of pedagogical observation.

The difficulty of experimental research was determined by the fact that environmental thinking is characterized by different characteristics. Diagnosis of all possible characteristics requires a lot of time and a special in-depth study. Building on theoretical research, the characteristics, such as educational, motivational-activity, behavioral- activity is chosen as criteria for the formation of environmental thinking among schoolchildren. Indicators of the educational level were the abilities: apply natural science knowledge to explain the relationship of natural phenomena; to foresee the consequences of human activity in the natural environment. Indicators of the motivational and activity level: a steady interest in environmental protection; active participation in labor activity in the study and protection of the nature of their

locality. Indicators of the behavioral-activity level were the skills: independently choose the method of environmental protection; to critically evaluate the completed task.

Preparation and organization of the experimental study included the stages: preliminary, initial diagnostic, forming didactic and final diagnosing. In qualitative and quantitative analysis of the results of the experimental study, a median criterion was used to check statistical hypotheses (for the significance level  $\alpha=0,05$  and one degree of freedom). Data were grouped according to their values, the distribution of the frequencies of these values was constructed, and the obtained data were grouped by intervals. The marked descriptive statistics procedures were applied to obtain an objective picture of the initial and final levels of the main indicators of environmental thinking. We managed to conduct several cycles of the formative stage of the experiment, each of which clarified and deepened various aspects.

## **4. Results**

### **4.1 Principles for the formation of environmental thinking in the structure of environmental competence**

Environmental competence we consider as ability of the person with the environmental thinking to actively use the scientific and ecological and legal knowledge in conservation of nature and as a social characteristic of a person, a citizen with high spirituality and morality, based on creativity and cultural growth. Developed conceptual model of environmental thinking as the unity of scientific thinking in the natural sciences and practical thinking in the field of environmental activities allowed us to formulate principles of formation of the environmental thinking in the structure of environmental competence.

The first principle – the principle of didactic interpretation of the logic and methods of natural science the sciences used in educational institutions. It's essence in the application of the principles of didactics taking into account actual capabilities of students, using specifically designed educational tasks of the disciplines. The second principle is the training the moral, environmental and legal environmental management, taking into account psychological laws of mastering of system of ecological concepts by pupils. The essence of the second principle is the use of integrated courses aimed at the formation of the environmental thinking, and system of a problem ecological and legal problems and tasks with reflection of moral contradictions, problems, and concepts in rational use of natural resources system, and also in teaching the logic and methods of the description, explanations of the studied phenomena and their prediction, research techniques.

The third principle is the propaganda of active working life for the study and nature conservation (propaganda activities, greening schools and settlements, restoration

and protection of forests, protection of soils from erosion, protection of useful insects, protection and attraction of birds, protection of bodies of water, etc.).

#### **4.2 Pedagogical conditions for the formation of environmental thinking among adolescents in the unity of educational and extracurricular nature protection activities**

Because the environmental thinking is a multi-component personal education with a complex structure, insofar its formation is a long process of gradual implementation of a number of interrelated sub-goals. Today in conditions of competence approach in education is an invariant of the system of intermediate objectives is the requirement of gradual transition of intellectual activity of pupils from the reproductive level to the level of creative nature protection activity. This transition is associated with the following stages teacher's activity: developing student's skills to analyze and summarize the experimental data; training a logical explanation of science theories and definitions; put thoughts out, hypotheses on the solution of the educational environmental problem; training in the solution of real complex environmental tasks and critical self-assessment (Gilmanshina *et al.*, 2016; Gilmanshina and Gilmanshin, 2015). Among didactic methods and technologies, providing efficient targeted development of environmental thinking in the structure of environmental competence of students, we highlight the technology of problem-based learning on the basis of inter subject connections. In general, for the systemic formation of environmental thinking, pedagogical technologies are needed to ensure the unity of natural science and environmental education, moral, civic-labor, spiritual and aesthetic education.

The first condition is the integration of the educational, gaming, labor, public environmental activities of students on the basis of the systemically active approach. Its essence lies in the fact that the formation of environmentally oriented thinking is influenced by environmental, natural science, ecological legal knowledge in the complex. At the same time, the mutual supplement of the above-mentioned activities is explained by one object of activity (nature and natural objects); general subject of activity (adolescents, teachers, supplementary education teachers); the interconnectedness of these types of activities (gaming in the form of role-playing game, the pageant harmoniously goes into the educational and labor, educational activities of nature protection in the form of writing an abstract, protection of the research project - in environmental activities). In the conditions of modern natural science education, the integration of these types of activities of adolescents makes it possible to form a stable interest in them and conviction of the need for environmental protection.

The second condition is the strengthening of the research orientation and the reflexive nature of the project nature conservation activities of students. In the conditions of modern natural science education, this condition assumes adolescents' involvement in independent design and research activities in the nature of their

native land, which develops the ability to critically evaluate their environmental activities. Its organization is possible using a system of methods accessible to schoolchildren of this age: observations, descriptions, experiments. The method of description is expedient to use at the initial stage of the organization of the environmental project work during outside school hours.

For environmental observations as a method of scientific knowledge of the surrounding reality, it is characterized by taking into account changes in abiotic, biotic and anthropogenic factors. Short-term or long-term observations of natural objects are possible depending on the result of human exposure. They are most valuable observations that help adolescents to draw a conclusion about the importance of natural objects in human life, to assess their condition in the territory of their native land. A more complex phase of the research focus of environmental project work is an experiment involving measurements and monitoring. In general, the strengthening of the research orientation and the reflexive nature of the environmental project work of students allows them to be trained in the application of theoretical natural science knowledge in the practice of protecting the nature of the native land in order to explain the interconnection of natural phenomena, predicting the consequences of human activities in the natural environment and to form the basis for research skills and skills in choosing the method of protection environment.

The third condition is to take into account the age characteristics of students when developing complexes of practical environmental protection activities. For adolescents mastering the system of knowledge about interaction in the system of nature - man - society, about sustainable development and environmental problems of the present is the opportunity for self-affirmation by including in the world of adults as a result of mastering the experience of real accessible environmental activities. After-school activities contain activities designed for different age features of students. Each event is conducted both for acquaintance with this or that ecological problem, and for development of interest of teenagers to nature protection questions taking into account their age and upbringing, ability to critical comprehension of their nature protection actions.

The fourth condition is the organization of joint methodical and educational activities by teachers and educators of supplementary educational institutions. Since supplementary education programs for children are being finalized and adjusted taking into account the ecological peculiarities of their native land, an effective adjustment of the teenagers' environmentally oriented thinking requires an adjustment of the joint activity of teachers and educators in applying traditional and innovative forms of interaction with the natural environment of their native land.

The leading goal at all stages of the systemic formation of environmentally oriented thinking is the purposeful formation of the personality of student, his worldview, beliefs, value orientations, will, character. The first stage is connected with the

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involvement of students in the substantive-transforming activity in ecosystem beyond school hours (collective forms of activity prevail with emphasis on the formation of abilities to consult with comrades, to help them, to combine business and personal interests, to aim at the rules of behavior in the ecosystem. On the second stage the educational activities of students are the leading activities (the main focus is on the theoretical justification of environmental activities in the ecosystem and the synthesis of environmental knowledge). At the third stage of the formation of the unity of educational and extracurricular activities, it is necessary to involve students in the solution of educational and research problems of ecological content, emphasizing the theoretical justification and forecasting of the nature protection activities of the native land. The developed system of formation of environmental thinking among secondary school students has two subsystems (educational and non-educational). A continuous environmental education serves as a channel for the interaction of subsystems.

The first subsystem includes the teaching and upbringing process at the lessons, provides for interdisciplinary, the ecologization of the basic educational programs of subjects in the natural science cycle. Within the framework of this subsystem, during the course of the study of natural science disciplines the accumulation of theoretical knowledge about the environment, on the scientific bases of rational nature management and nature protection, the interconnection of natural phenomena, the explanation and forecasting of the consequences of human activities in the natural environment.

The second subsystem "extra-curricular" contains extracurricular activities of students under the guidance of the class teacher, additional environmental education for adolescents (in the system of additional education for children) and their participation in public environmental activities on the native area. The substantive component is associated with the deepening and expansion of knowledge on the protection of nature from the negative impact of agricultural work objects (sewage of livestock farms, vault of mineral fertilizers and pesticides, landfills, dumping of liquid waste into rivers, erosion of soils and their compaction under the weight of machinery, etc.) and other constructions that impact on the nature of their native land. This component includes students' knowledge of natural science and environmental and legal knowledge, the ability to explain and forecast extreme environmental situations; the ability to protect against the negative impact of industrial and agricultural production and other objects on the ecology of the native area; the ability to research and work on conservation of nature; skills to critically comprehend practical environmental activities, etc.

Since the quality of the area greatly affects the ecological purity of agricultural and livestock products, the procedural component of extracurricular activities includes raids for collecting information on the state of the nature of the native land in general, the sites of agricultural work sites with subsequent critical analysis and all possible nature conservation activities. At the same time, a set of various methods,



techniques and forms are used (environmental research projects, weeks of ecology, Olympiads, environmental contests, press conferences, raids, clubs such as the school society "green" and others).

**4.3 Experimental verification of the developed pedagogical conditions for the formation of environmental thinking in the conditions of modern natural science education**

The initial diagnostic stage showed that in the experimental and control groups, prior to the beginning of the experiment, a low level of environmentally oriented thinking prevailed. There were no significant differences in the levels of its formation in the students of the experimental and control groups. During the didactic experiment, as a result of the analysis of intermediate results, it was established the possibility of phased formation of environmental thinking in students - gradual transfer of schoolchildren from one level to another, higher. The final diagnostic stage revealed significant shifts and differences in the experimental (EG) and control (CG) groups in the levels of the formation of the main indicators of environmental thinking. The analysis of the results is presented in Table 1.

**Table 1.** Mean values of the main indicators of environmental thinking among schoolchildren of the experimental and control groups (the final diagnostic stage of the experiment)

Indicators of educational level	Mean values		Indicators of the motivational and activity level	Mean values		Indicators of the behavioral-activity level	Mean values	
	Experimental group	Control group		Experimental group	Control group		Experimental group	Control group
The application of natural science knowledge to explain the interconnection of natural phenomena	3,23	2,32	Strong interest in environmental activities (motivation)	3,78	2,84	Self-selection of the method of environmental protection	3,42	2,43
Forecasting the consequences of human	3,21	2,50	Participation in active labor activity	3,40	2,46	Critical self-assessment of the completed	3,66	2,87

activities in the natural environment			in the study and protection of the nature of its locality			task		
Average values of indicators of environmental thinking :								
Educational	3,22	2,41	Motivational and activity	3,59	2,65	Behavioral-activity	3,54	2,65

*Source: Authors.*

The results indicate that there is a significant increase in the indices - skills of the students of the experimental group compared with the adolescents of the control group. For example, 89% of students from the experimental group and 40% from the control group, have improved the ability to predict the consequences of human activity in the natural environment; 87% (EG) and 44% (CG) have improved the ability to apply natural science knowledge to explain the interrelation of natural phenomena; steady interest in environmental activities - 93% (EG) and 36% (CG); active participation in labor activity on study and protection of the nature of the locality - 91% (EG) and 28% (KG); the ability to independently choose the method of environmental protection - 84% (EG) and 24% (KG); critical self-assessment of the completed task - 90% (EG) and 32% (KG). In general, 89% of students from the experimental group managed to transfer to a higher level of environmental thinking (in the control group, this figure corresponds to 34%). Thus, during the course and the completion of the didactic experiment, a significant increase in the corresponding indices in schoolchildren of the experimental group was established in comparison with the control group.

## 5. Discussion

The analysis of the scientific pedagogical literature testifies to the wide discussion of the problem of ecological education and ecological culture of schoolchildren, where environmental thinking is mentioned (Argunova, 2010; Moiseeva and Fairushina, 2010; Tregubova, 2015; Zaborina, 2015). However, the authors only state the importance of environmental thinking, not focusing on its formation. So, in a solid monograph (Moiseeva and Fairushina, 2010) alternative models of ecological education for schoolchildren are proposed, taking into account the socio-natural environment of educational institutions. However, environmental thinking is mentioned only as an element of ecological mentality, justifying it by the fact that mental stereotypes are manifested in human thinking. In the study (Tregubova, 2015) the issues of phased education of the ecological culture of fifth graders were

studied, the conclusion was made about the greatest expression of its emotional component. The work of Zaborina (2015) is devoted to the development of the pedagogical conditions for the ecological education of college students, emphasizing the students' readiness to practice-oriented environmental activities and its moral and ecological aspects.

As an interdisciplinary direction of modernization of school education, environmental education is considered in order to sustainable development in work (Argunova, 2010). In the same place, the technology of environmental education for sustainable development has been designed, aimed at formation ecological competence, which the author attributed to the key educational competencies of students in grades 10-11. The importance of the formation in the school among the growing generation of environmental awareness and civic responsibility for the preservation of the natural environment in order that in the future they could form a society functioning on a sustainable basis is said in (Collins, 2017). Scientists investigated the impact of school environmental education on the sustainable development of Serbia (Andevski *et al.*, 2012). In general, the concept of sustainable development of society (World Commission on Environment and Development, 1987), which today is the fundamental principle of human development, certainly includes the formation of environmental thinking and environmental competence among the population.

The issues of teaching environmental literacy and environmental actions of youth and children are devoted the works of McBride *et al.* (2013), Ritchie *et al.* (2011), and Roesch *et al.* (2015). The influence of the environmental activity of pupils of grades 4-5 on their cognitive achievements was also studied (Dieser and Bogner, 2016). The contribution of chemistry to environmental education is considered in the work of Sjostrom (2013), where it is proposed to combine the teaching of chemistry with the sociocultural context and the critical philosophical approach. In the work by Derjabo and Jasvin (1996) which became a classic, the main goal of environmental education is the formation of a person with an ecocentric type of ecological consciousness. Ecocentric ecological consciousness is characterized by a harmonious development of man and nature, acts as a psychological and pedagogical correction of ecological consciousness (Derjabo and Jasvin, 1996). Psychological characteristics of the features of ecological consciousness in different age groups of children are described by Makarova (2014). The author considers the problems of formation of environmental consciousness in the system of preschool education.

Ecological consciousness assumes that a person "knows", "thinks", "perceives", "behaves" environmentally. These concepts are all connected with high functional and environmental literacy of the person (Chigisheva, 2018; Gilmanshina *et al.*, 2018). It is important to think environmentally and to act environmentally. Otherwise, conscious transformational nature protection activity requires environmental thinking. It should be clarified that the term "environmental thinking" is often used to describe the activities of professional ecologists (Wallington *et al.*,

2005). Therefore, to characterize the ecological orientation of the personality of schoolchildren, it is advisable to talk about ecological oriented thinking and its formation in modern natural science education, focused on the formation of competencies. Thus, the analysis of scientific works devoted to the formation of environmental thinking of adolescents through environmental protection activities is extremely small, and they have the fragmentary and discussion character.

This article presents the theoretical substantiation and experimental verification of the developed pedagogical conditions for the formation of environmental thinking in the structure of environmental competence of adolescents in the conditions of modern natural science education. The analysis of the results revealed a steady trend towards a significant improvement in the basic indicators of the students' environmental thinking, which manifested themselves in the educational and extracurricular nature protection activities. Adolescents managed to transfer from the level of indifferent attitude to nature protection and formal logical generalizations to the level of sustainable interest and meaningful generalizations. And subsequently - on the level of conviction and explanation of cause-effect relationships, forecasting, the ability to apply natural science knowledge in new environmental situations, active participation and conscious implementation of necessary environmental actions and critical self-assessment of their implementation. Such transfer of students was possible due to the purposeful formation of the main indicators of ecological oriented thinking in the unity of educational and extracurricular nature protection activities. At the same time, it should be noted a defined conventionality of the data obtained, related to the specifics of pedagogical science.

## **6. Conclusions**

A feature of modern natural science school education is the need for a systematic formation of environmental thinking in the structure of environmental competence for sustainable development of society. Environmental thinking in the presented article is considered as a unity of scientific thinking in the field of natural sciences and practical thinking in the field of environmental protection. The authors' definition allowed developing three principles for the formation of environmental thinking in the structure of environmental competence. This is the principle of the didactic interpretation of the logic and methods of natural science used in educational institutions; the principle of teaching moral, ecological and legal use of nature, taking into account the psychological patterns of mastering the system of ecological concepts by schoolchildren; the principle of propaganda of active labor activity in the study and protection of the nature of its locality. Consequently, sources of knowledge such as socio-cultural, scientific and applied natural sciences (and environmental ones, including), influencing the criteria for the selection of educational material, influence the formation of this thinking in adolescents.

In general, for the systemic formation of environmental thinking, the structure of environmental competence requires pedagogical technologies that ensure the unity

of natural science and environmental education, moral, civic-labor, spiritual and aesthetic education. The conducted research allowed developing and experimentally proving the effectiveness of the pedagogical conditions that correspond to the technologies providing the unity indicated. This integration of educational, gaming, labor, public environmental activities of students on the basis of the systemically active approach; strengthening the research orientation and reflexive nature of the project nature conservation activities of students; taking into account the age characteristics of students when developing complexes of practical environmental protection; organization of joint methodological and educational activities of teachers and supplementary education teachers for children.

At the same time, a new view on environmental thinking is important as a necessary quality of the personality of a modern person and a system-forming factor upbringing of intelligence and civility, an ecological attitude to nature. The study showed that the problem of the formation of environmental thinking leaves room for solving small matters in the didactic theory of environmental education of students.

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