EXPLANATION AS A LEARNING COGNITION METHOD AND THE STAGES OF ITS DEVELOPMENT IN SENIOR STUDENTS

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Abstract: Abstract. This paper discusses the problem of stimulating the cognitive activity of senior students at general education schools with the help of the method of explanation. It may be described as a method of comprehending the essence of studied objects through mental operations of analytical-synthetical type. The description and explanation is provided for the concepts without which the indicated method cannot be applied – types, object and procedure of explanation. The pedagogical experiment reflected a step-by-step process of learning of the method of explanation including its structural, functional, genetic and causal types. It resulted in the description and analysis of learning achievements of senior students.

Keywords: general education school, senior students, method of explanation, cognition in learning.

1 Introduction

In the emerging post-industrial culture, the pedagogical community is increasingly recognizing the importance of each person mastering scientific knowledge in order to apply it effectively in various spheres of life. In connection therewith, the younger generation should prepare themselves for various productive activities already from the school days. According to a fair assertion of domestic and foreign researchers, cognitive activity is recognized as one of the priorities (Asmolov & Volodarskaya, 2017; Crawford & Saul, 2005; Davydov, 2004; Grey, 2000; Robinson, 2004). It fuels the eagerness of schoolchildren to explore the surrounding reality, which is impossible without the intellectual actions of complex nature. As recognized by scientists, there are no doubts that explanation belongs to such kind of actions (Nikiforov & Tarusina, 1987; Cassirer, 2006; Yudin, 1980). It stands to reason that in the sphere of modern general education explanation is recognized as a kind of tool in the hands of schoolchildren when it is used as a method of scientific cognition in the organized cognitive activity. This fully applies to all subjects, including biology. As is known, it studies the objects of animate nature of different levels of organization - cells, tissues, organs, organ systems, organisms, populations and communities. Each of these objects has its certain structure, is characterized by certain interactions between elements and peculiarities of functioning as a result of natural organization. Without penetrating into their essence, in other words, without explanation consisting in identification and interpretation of the most significant features of and connections between the said objects, the full life of man and society is not possible. The explanation is the key to understanding the relationship between all living objects on the planet, the regularities in the impact of environment on them, the need to maintain the ecological balance for the future of mankind. Moreover, it is through explanation that the fundamental processes of the human organism become clear, without which a reasonable living, observance of the rules for preservation of health, prevention of diseases and bad habits and the social well-being would become impossible (Yakunchev et al., 2020; Pokhlebaev, 2010). As it was revealed, a large part of senior students turned out to be insufficiently prepared to use explanation for mastering the learning content in the field of biology. This is manifested in their poor understanding of the meaning of explanation as a scientific method of cognition, find it difficult to correctly name the types of explanation generally accepted in the school, doubt the designation of elements of the general procedure of explanation for its application in learning situations when studying the subject content (Yakunchev et al., 2018). Therefore, the chosen research topic appears as relevant and requires deeper exploration.

2 Literature Review

Many researchers focus on examining explanation as a method of cognition of objects of the surrounding reality by general school students from different perspectives. Several of them are important for our study:

1. philosophical - representation of explanation as a method of scientific cognition outlining the prospects of its use in various spheres, including education;
2. pedagogical - representation of explanation as a method of cognition in learning outlining its possibilities for training, education and mental development of school students;
3. methodical - representation of means for using the method of explanation in subject training of school students for providing them the knowledge and develop their abilities to use it in educational situations and everyday life.

As concerns the first one, the philosophical perspective, we found the highest value in the works of specialists in the field of philosophy, in particular gnoseology, which offer different definitions of explanation as a method of scientific cognition, types of its implementation from the position of explanandum and explanans (Apel, 1986; Hempel, 1965; Ivic, 2008; Nikitin, 1970; Nikiforov & Tarusina, 1987; Nikolaeva, 2019; Rusavin, 2017). They allowed us to express the essence of explanation for its use in the general education. Moreover, based on the mentioned works we provided an overview of the characteristics of structural, functional, genetic and causal explanation as most common types of explanation.

From the second perspective, pedagogical, we concentrated on the studies viewing explanation as a method of cognition in learning (Blegvad, 1977; Perminova, 2006; Ruben, 1991; Seliverstova, 2006; Sohor, 1988). They correctly define it as a way of comprehending the essence of the studied objects and assert the importance of its application in the educational process. Being in agreement with this approach and having performed an analysis of the works of the named authors we have been able to find out the didactic potential of explanation for its use in a pedagogical experiment. It is characterized by penetration into the essence of the studied object, structuring of the knowledge about it, independent use of explanation skills in learning situations and everyday life.

From the third, methodological, perspective, the works dealing with the procedural aspect of using explanation as a method of cognition in learning (Andreeva & Azizova, 2019; Nilson et al., 2013; Pokhlebaev, 2010; Robinson, 2004; Shaporinsky, 1981; Shcherbakov, 2007) were paramount for us. They rightfully point to the introduction of various means into the learning process, among which are visual aids, technical and informational materials, and paper handouts. The procedure based on the psychological approach appears as a generally accepted procedure for teaching schoolchildren. Without denying them, drawing on the analysis of the literature in the indicated field, we identified the elements of the procedure for providing knowledge to senior school students about explanation on a didactic basis. Moreover, based on the works of the named authors, we were able to identify and test in the experiment the learning tasks as the priority means helpful in teaching the explanation.

3 Research Methodological Framework

The research purpose consists in substantiating explanation as the method of cognition in learning and elaborating a procedure for developing explanation skills in the senior students of

general education school. For its accomplishment two objectives were identified:

1. clarify the essence of explanation as a method of cognition in learning through the prism of its didactic purpose;
2. identify and test in a pedagogical experiment the stages of explanation skills development in senior school students during the study of biology.

The research employed the methods of two levels. Methods of theoretical level as the way of comprehending, reconsidering and presenting the scientific content: literature analysis, generalization and systematization of data on the essence of explanation with indication of its types, its presentation as an educational method for comprehending objects of the surrounding world, as well as a step-by-step procedure for strengthening the knowledge of senior school students in structural, functional, genetic and causal explanation. Methods of empirical level as the way of obtaining scientific content on the basis of sensual perception of didactic experience and its comprehension – pedagogical observation, questionnaire survey of and interviews with senior school students to find out their ability and readiness to use the method of explanation in learning situations and everyday life. The pedagogical experiment was conducted on the basis of secondary schools Nos. 2, 8, 16, 24 in the city of Saransk of the Republic of Mordovia, the Russian Federation. The control group included 79 tenth-graders from the first two schools, and experimental group was made of 81 tenth-graders from two other schools. The experiment lasted for the academic year 2020-2021. At the end of the experiment students from both groups answered the following questions of the questionnaire to check the results:

1. What is the meaning of explanation as a method of cognition?
2. What kinds of explanations are important for better understanding of the learning content?
3. What is the procedure of explaining the essence of the studied objects?
4. What is the role of explanation in achieving personal learning outcomes?

4 Results and Discussion

The first objective was addressed predominantly through the use of theoretical research methods. It was established that in the theory and practice of general education different methods are recognized as the means of cognition in learning as the way to facilitate orderly and interrelated activities of teacher and students directed at achieving the goals of education - training, character building and mental development. Recently, in domestic and foreign schools, more and more attention is paid to the methods that encourage senior school students to independently and proactively master the studied content for its expression in their individual way, its better memorization and use in different learning situations and everyday life (Berwick, 2015; China's 2020 Education Reform Strategy, 2020; Minchenkov, 2020; Yakunchev et al., 2020; Yakunchev et al., 2018). With reference to the above sources we may assert that such methods include those performing the functions of scientific cognition and incorporated by the teacher in the purposefully organized process of cognitive activity of students of the said category. Among the indicated group of methods a special place undoubtedly takes explanation, which we find highly useful for the sphere of general education as a way of penetrating into the essence of a studied object, revealing the characteristic features of its structure and regularities of its functioning, relationships with other objects of the surrounding reality through the use of mental operations of analytical-synthetical type. As we found out, the most common types of explanation are structural, functional, genetic and causal explanation. The need of using explanation is reinforced by its cognitive potential, which should be presented in a didactic way. Explanation allows senior school students, first, to comprehend the object under study based on its essential features; second, to understand the object under study in light of already existing knowledge; third, to present knowledge about the object under study in logical and structural way; fourth, to predict the future state of the object under study and its certain aspects; fifth, to create own explanations of the object under study. Therefore, it is fairly reasonable to teach explanation as a way of cognition in learning, because it may serve as one of the important factors in successful acquisition by senior school students of theoretical knowledge and skills for creating new products of educational activity, which is consistent with the imperatives of postindustrial culture.

The second objective was achieved by resorting to a combination of empirical and theoretical research methods. This allowed us to define and test the procedure for developing explanation skills in senior school students during the study of biology, and to present the analytical data on the results obtained in the experimental group as compared to the control group. First we would like to present a step-by-step description of our pedagogical experiment.

First stage. Organizing learning activities of senior school students with the use of the explanatory concepts to clarify their role in cognition of objects under study.

Such concepts as "explanation", "types of explanation", "object of explanation", "procedure of explanation" are important for understanding cognition in learning in terms of explanation. As the experiment has shown, senior school students may explain the first concept based on their experience. Therefore, at the introductory lessons the meaning of this concept is only refreshed and expressed by the statement "explanation is a detailed description or clarification of the essence of any object for its better understanding". As it turned out, the majority of senior school students are not able to define the essence of the object of explanation. In these same lessons the object is presented by the teacher as any body or phenomenon of the surrounding world to be cognized and used in the practical activities of people. Information about the object should be made more specific by using such terms as item, phenomenon and process. For their better understanding during the study of biology examples are given and commented on: objects - cell, organism, community, etc., phenomena - metabolism, reproduction, development, etc., processes - transfer of hereditary information, blood circulation, digestion, etc. Next, the attention of senior school students is fixed on the types of explanation. As applied to general education, it is enough to state that according to the nature of the explanans or the type of relationships between objects the genetic, causal, structural and functional types of explanation are distinguished, and according to the nature of the explanandum or the explained object - factual, nomological and theoriological types of explanation are distinguished. In the study of biology the types of explanations of the first group are most often used, so further the focus shifts to them. Senior school students should be acquainted with the procedure of educational explanation. In general, it is presented as the below sequence of actions:

1. identify the object of explanation;
2. determine the type of explanation for the chosen object;
3. construct a verbal or other interpretation of the essence of the chosen object by its most essential features;
4. formulate a conclusion about the object of explanation.

The teacher should always demonstrate how to use this procedure in relation to biological objects.

Learning outcomes of senior school students: ability to express concepts of explanatory meaning and their role for the study of any objects, including biological objects; readiness to create a creative product - own versions of frames in the form of logical and semantic schemes on the principle of "top-down reasoning" for structural reflection of knowledge coming from explanation as a method of cognizing the objects of the surrounding world.

Second stage. Organizing the learning activities of senior school students with the use of teacher's materials and content of the textbook to identify the types of explanation and characteristic features of its structure; organization.

When studying the content relating to biology, the work should be organized in two directions.

The first direction concerns the review of new material when teacher focuses on examples of different types of explanations. Thus, the best way to express the essence of structural explanation and its features is by using the material about biological systems – a cell, an organ, an organism, a population and a community. The structure of each of them should be shown from the angle of internal organization of elements, as well as from the angle of regular connections between them existing as an orderly organized integral unity. The most efficient way to help students understand the functional explanation is while studying the physiological content. Its consideration provides understanding of the role of a certain element of the object or the object as a whole. A conspicuous example is explanation of the mechanisms of growth and development of organisms, blood formation and circulation, assimilation and dissimilation, biological progress and regress. The most rational way to convey the essence of genetic explanation is while studying evolutionary content. Cognizable objects, in particular species of living creatures, including human sapiens, should be interpreted from the historical perspective, covering their emergence, development, and formation. The meaning of causal explanation may be most optimally demonstrated when studying the ecological content. It provides a possibility to establish and characterize the origination of one phenomenon from the other on the pattern "cause - effect - result". It is important to highlight here that this type of explanation reveals the causality of the ecologic al objects under study, for which environmental factors and conditions act as causes.

The second direction concerns work with the textbook when students upon teacher's instruction are compelled to analyze texts from the perspective of their structure for explanation purposes. In doing so they should be basing on the knowledge of the essence of explanation as a method of cognition and types of explanation applicable to the objects of animate nature. The senior school students found out that texts can be descriptive, explanatory, and combined, when the text contains both a description and an explanation of objects. The texts of current biology textbooks are predominantly based on causal and structural explanations, but without strict adherence to the procedural actions characteristic of them. Such learning activities allowed senior school students to accumulate experience of deeper cognition of the studied objects and to reveal their essential features.

Learning outcomes of senior school students: ability to identify types of explanations by their essential features, including peculiarities of their structural organization; readiness to produce a creative product - own versions of frames in the form of semantic networks indicating connections between objects of cognition. Their names may be as follows: "Structure of knowledge about natural selection on the basis of genetic explanation", "Structure of knowledge about ontogenesis on the basis of functional explanation", "Structure of knowledge about anthropogenic changes of forest community on the basis of causal explanation", "Structure of knowledge about organization of animal cell on the basis of structural explanation". Such cognitive constructs were used by senior school students with respect to other objects under study as well.

Third stage. Organizing the learning activities of senior school students with the use of algorithmic tasks for cognizing the studied objects from the perspective of explanation.

The refreshed and obtained knowledge of the essence of explanatory concepts, as well as processing of the subject content in order to identify the types of explanation are the basis for coping with the learning tasks. The experiment showed that they should be seen as an important condition for a deeper cognition of the studied biological objects from the perspective of explanation. Initially, high school students should be taught how to cope with tasks based on algorithms that together may be seen as invariant constructs.

In the case of a structural explanation the algorithm for performing the tasks is as follows:

1. identify and name the biological object to be explained;
2. find out of which elements this biological object consists;
3. identify and briefly describe connections between elements forming part of the biological object, and between the object and the environment;
4. formulate a conclusion about structural organization of the biological object.

An example of a task involving structural explanation of an animal cell might be as follows. In the textbook, the text and the illustration to its present a biological object. Carefully read the text and name the object of study. Based on the text and the illustration, identify components of the object of study. Identify how these components are related to each other in the object. How is the object of study related to the environment? Formulate a conclusion about structural organization of the object. Similar tasks were performed for other biological objects. It is important for senior school students to understand that structural explanation in general, and as applied to the study of biology in particular, is concerned with finding an answer to the question: "How is the object under cognition organized".

In the case of functional explanation, the algorithm for performing the tasks, is as follows:

1. identify and name the biological object to be explained;
2. find out how the biological object "functions";
3. describe in brief the mechanism of "functioning" of the biological object;
4. formulate a conclusion about the "functioning" of the biological object.

An example of a task dealing with inhalation might be as follows.

Read carefully a text presenting an important phenomenon in the human body. Identify and name the object of explanation. Find out the principle of its functioning. Describe the mechanism of functioning of the object of explanation, consisting of several processes and ensuring vital functions of the human body. Formulate a conclusion about "functioning" of the object. Similar tasks were performed for other physiological phenomena.

It is important for senior school students to understand that functional explanation in general, and as applied to the study of biology in particular, is concerned with finding an answer to the question: "How does the cognized object function?"

In the case of a genetic explanation, the algorithm for performing the tasks is as follows:

1. identify and name the biological object to be explained;
2. find out how the biological object originated and developed;
3. describe in brief the stages of its development;
4. formulate a conclusion about origination of the biological object.

An example of a task concerning origin of the human's ability to walk upright might be as follows.

Carefully read a text presenting an important phenomenon in the evolution of homo sapiens and look at the illustrations to it. Identify and name the object of explanation. Find out the historical stages in the development of this object. Formulate a conclusion about origination of a new object. Similar tasks were performed for other evolutionary phenomena.

It is important for senior school students to understand that genetic explanation in general, and as applied to the study of biology in particular, is concerned with finding an answer to the question: "How the object under cognition did originate, developed and evolved?"

In the case of a causal explanation, the algorithm for performing the tasks is as follows:

1. identify and name the biological object of explanation;
2. find out why and how new biological objects appear;
3. describe how one biological object is emerging from the other one;
4. formulate a conclusion about the causality of a biological object.

An example of a task concerning the impact of trampling on a suburban forest community might be as follows.

Read materials reflecting changes in a biological object under the impact of one of the anthropogenic factors. Watch also a short video clip. Identify and name the object of explanation. Find out what phenomenon was the "trigger" for the change in the condition of the suburban forest. How else could it be called? What new phenomena appeared in the forest community? Express schematically how one phenomenon originated from the other phenomenon. Formulate a conclusion about dependence of one phenomenon on another in the forest community. Similar tasks were performed for other ecological objects.

It is important for senior school students to understand that causal explanation in general, and as applied to the study of biology in particular, is concerned with finding an answer to the question: “Why and how do new objects appear?”

Learning outcomes of senior school students: ability to name and describe algorithms for performing tasks as the key to coping with them; readiness to perform tasks based on examples and algorithmic sequences of actions for structural, functional, genetic, and causal explanations with regard to biological objects.

Fourth stage. Organizing the learning activities of senior school students with the use of creative tasks for self-directed cognition of objects under study from the perspective of explanation.

The knowledge gained in the field of explanation and actions performed using this knowledge in relation to texts from the textbook, performance of tasks based on the algorithms help senior school students to cognize biological objects at a deeper level. As the experiment showed, this is facilitated by tasks of creative nature that require independence and initiative. Here are a few examples.

In terms of structural explanation the materials of anatomical and morphological content may be helpful. It is about anatomy of organs and organ systems of humans and other living creatures.

First example: *Watch a video showing structure of the human heart. Identify its parts, establish connections between them, and indicate their role for maintaining integrity of this organ. Present your own frame of a biological structure named "Structure of the Human Heart”. How significant is the knowledge of the heart structure for humans?*

Second example: *The knowledge about structure of the DNA (deoxyribonucleic acid) molecule is important for every intelligent person. Based on material from the school textbook and other sources in your workbooks, express your own schematic drawing representing structure of the DNA molecule. Indicate and explain connections between its elements. Why is it important for humans to know about structure of the DNA molecule?*

For a functional explanation, the materials about the vital activity of the human body may be used. The experiment revealed that senior school students show high interest in practical tasks.

First example: *The neurologist doctor "checks" the knee reflex in most patients with a special hammer. Write down its elements in the correct order. Explain the mechanism of the knee reflex as a physiological phenomenon and make a schematic drawing with explanations. For which purpose the knee reflex is checked in medical practice?*

Second example: *During the plane takeoff and landing, passengers get an unpleasant feeling of their ears popping. Explain the physiological meaning of this phenomenon and make your own explanatory notes. Why are passengers offered lollipops at these moments?*

In terms of genetic explanation, the materials of historical-biological and evolutionary content may be helpful.

First example: *Science has several scenarios of the origin of life on our planet. Give your own explanation of this phenomenon from the standpoint of the hypothesis of biochemical evolution; make notes in your workbook. Why does a person need knowledge about the origin of life on Earth?*

Second example: *Many scientists were and still are interested in the question of how the first living cell appeared. There are still many uncertainties regarding this subject, but the general information about the origins of life is already clear. By referring to the basic facts, provide your own version of the story how the living cell emerged from a protocell through intermediate formations to cells of present-day organisms as a convincing foundation for explaining this process.*

In terms of the causal explanation, the materials on the ecology of the biosphere may be used.

The biosphere in science is presented as a global ecological system having certain organizational structure and performing certain functions. It is commonly known that it has changed markedly in recent decades under the impact of human activities. Based on your understanding of explanation as a method of cognition and any sources that reflect global biosphere processes, compose a frame which structure reflects the knowledge organized based on the construct "why and how the biosphere has changed". Express briefly the essence of your construct. What is the role of the causal explanation of negative biospheric change for modern society?

Learning outcomes of senior school students: ability to recognize creative tasks, understand their structure and content; readiness to perform creative tasks showing independence and cognitive initiative in relation to explanation. We would like to present the results obtained in the pedagogical experiment. Senior school students of the general education school who took part in the diagnostic procedures, compared to the control group, demonstrated better results as concerns the aspects of interest. The majority of respondents from the experimental group consisting of 81 students (61 respondents, 76%) stated confidently when filling out the questionnaire and in private conversation that the implemented procedure of training involving the use of explanatory knowledge, helped them to master the general education techniques of structural, functional, genetic, and causal explanations. While in the control group of 79 students only 5 respondents (6%) gave a close to correct answer. The mastery of the general learning techniques allowed the participants in the experimental group to present the learning content in a compact form, and, most importantly, in a structured way and in a logical sequence. At the same time, 72% or 58 respondents in the experimental group against 9 respondents (11%) in the control group mentioned the use of mastered techniques in the study of other school subjects as well. It is noteworthy that 68% or 55 senior school students after the training experiment expressed an opinion that explanation is a kind of tool for cognition of various objects of the surrounding reality which has a meta-disciplinary purpose. Unfortunately, participants in the control group could not formulate their answer correctly. Almost 70% or 56 respondents in the experimental group noted a deeper penetration into the essence of the content studied with the help of explanation in general and its particular types such as structural, functional, genetic, and causal explanation. They stated that it helps to successfully cope with the reproductive and especially creative tasks which ask to provide own versions of the products of learning activity.

Respondents in the control group have difficulties in expressing adequate opinions regarding this aspect. The findings of personal meaning are rather interesting. Most of the respondents (75% or 60 students) in the experimental group noted that they now build their speech more rationally and academically, and that they learnt to make schematic representations of objects and phenomena under study. Respondents in the control group found it difficult to provide an answer regarding this aspect.

5 Conclusion

Explanation as a method of cognition in learning should be recognized as one of the ways to encourage senior school students to explore the essence of studied objects of the surrounding reality. Here it is important for both teacher and students to pay attention to the didactic principles of its use in the educational process. They need to be tied to the definitions of concepts characterizing explanation - "types of explanation", "object of explanation", "actions of explanation", forming the part of explanation as a method of cognition in learning, as well as procedures for teaching high school students how to use this method. As the pedagogical experiment has shown, these are the key principles:

1. work with the concepts characterizing explanation to determine their role in cognition;
2. work with teacher's materials and textbook to identify types of explanation;
3. work with algorithmic tasks to cognize objects in ordinary situations;
4. work with creative tasks for self-directed cognition of objects in extraordinary situations.

The tested procedure has proven to be appropriate for accomplishing educational objectives of meta-subject, subject and personal character. It results in learning achievements of senior students: ability to express knowledge about explanation as a method of cognition in learning, its possibilities for the study of the subject material; readiness to independently carry out procedures of structural, functional, genetic and causal explanation. Therefore, the procedure of using explanation as a method of cognition in learning is rather efficient for improving the quality of subject training of high school students in general education school.

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