DIAGNOSTIC TASKS AS THE MEANS OF ASSESSING META-SUBJECT ACHIEVEMENTS OF STUDENTS

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Abstract: This paper is dealing with the problem of assessing the meta-subject learning outcomes of schoolchildren. They were achieved by means of meta-subjects "Method" and "Knowledge" at the formative stage of the pedagogical experiment during the study of biology by high school students. The expected learning outcome of the first meta-subject was the students' readiness to apply empirical and theoretical methods for exploring the objects of animate nature, and of the second meta-subject - their readiness to apply models and forms of building the biological knowledge using the conceptual constructs. Special tasks were used as the objective means of outcomes assessment, which were tested within pedagogical experiment. The results testify a rather high level of meta-subject achievements of high school students.

Keywords: high school students, meta-subject learning, assessment of results, diagnostic tasks.

1 Introduction

Many countries recognize the achievement of high quality as the priority result of modern general education. The researchers connect it with the remarkable and gaining momentum global trends of education development in general (Wolfson, 2013; Machekhina, 2019; Pigozzi, 2004). In this regard, all educators, especially subject teachers, have faced pressing challenges the best way to address which is through collaboration and joint efforts with students. Due to the circumstances, at first in general education schools in developed countries, and later in schools in transition and developing countries, the educational process has become to be directed by the standards orienting the younger generation to receive a high-quality education (Chatin, 2016; Education in China: a Snapshot, 2016; Future of Education Initiative, 2020; Tarasova & Kulakov, 2015; Svetlov, 2020; Yakunchev et al., 2018). It is associated not only with purely subject achievements, but also with meta-subject achievements, because meta-subjects serve as a basis for pedagogics of mental and action approach, which has recently been gaining increasing relevance. It should be understood as a combination of intellectual, practical and communicative actions included in the context of specially organized efforts of schoolchildren (Gromyko, 2000). The key point is that meta-subjects must be designed in accordance with the underlying patterns of thinking represented by different forms of thinking (concepts, opinions, conclusions), types of thinking (objective-active, figurative-imaginative, abstract), and thinking operations (analysis, generalization, comparison, systematization, classification). Therefore, in the pedagogics of mental and action approach various meta-subjects are being developed, the most popular of which are "Object", "Knowledge", "Method", "Sign", "Value", "Problem", "Culture" (Gromyko, 2001; Papaleontiou-Louca, 2003; Shrou et al., 2006). Unfortunately, with regard to school biology their educational potential has remained untapped until recently, due to which high school students experience difficulties in applying common techniques, methods, schemes, thinking patterns for mastering the learning content and rationally applying it for solving tasks. The results of our own publications, as well as data from other researchers (Yakunchev et al., 2020; Yakunchev & Semenova, 2021; Carnoy & Khavenson, 2016) provide evidence for this. Consequently, there exists an objective need to explore the topic we have chosen for this research.

2 Literature Review

For the objective presentation of information in this paper, it was important to rely on the literary sources. We found highly relevant the studies by educators/researchers from different countries, which we divided in three groups.

The studies of the first group focusing on the essence of meta-subject and the importance of its use in the training of students were analyzed from two aspects. Most interesting as concerns the first aspect were the publications by (Gromyko, 2011; Khutorskoy, 2012a, 2012b, 2012c, 2012d) and as concerns the second aspect most relevant were the works of (Khutorskoy, 2012a, 2012b, 2012c, 2012d; Cross & Paris, 1988; Kaberman & Dori, 2009). Taken in totality, they helped to express our own idea of the meaning of meta-subject as one of the pillars of pedagogics of mental and action approach with a special emphasis on its cognitive component. Thus, meta-subject training opens up great opportunities for students to master intellectual and communicative actions of universal purpose. Therefore, the indicated direction has been developed by us on the basis of search for and use in the training of high school students of the effective ways of action, in particular, on the basis of analysis, generalization, comparison, systematization, classification, induction, deduction, monologue, dialogue. They can be applied both to a specific school subject and all other subjects to ensure a desire learning outcome.

The second group of studies dealing with the achieving of meta-subject results by students was also analyzed from two aspects. In terms of the theoretical aspect, most important were the studies that helped to define the categories of meta-subject results - readiness to perform the actions of universal purpose, expression and characteristics of components of the technique to foster it in schoolchildren, designing of an integral procedure for meta-subject training during the study of the subject content (Khutorskoy, 2012a, 2012b, 2012c, 2012d). In terms of the applied aspect, most appealing were the works pointing to the effective achievement of meta-subject results through intellectual and communicative actions (Jordan, 2011; Branigan & Donaldson, 2019). However, these studies, unfortunately, did not provide the optimal combination of the actions referred to above for effective meta-subject training of high school students based on the subject content.

The studies classified in the third group describing the diagnostic tools were analyzed from three aspects. The first aspect concerned finding out the essence of the phenomenon of diagnostics as a combination of control and evaluation actions aimed at finding out the level of students' training and improving the educational process (Ingekamp, 1991; Bitinas & Kataeva, 1993; Sycheva, 2008). The second aspect concerned finding out the specific features of relevant diagnostic tasks, which allowed us to determine their invariant basis and develop original tasks from the perspective of international practice (Ambartsumova & Dyukova, 2017; Flavell, 1979). The third aspect concerned finding out the features of quantitative measurement of the achieved results in meta-subject training of high school students (Carnoy & Khavenson, 2016; Gam & Buzina, 2012).

3 Research Methodological Framework

The purpose of this research is to present original diagnostic tasks for targeted assessment of the training results of high school students achieved with the help of meta-subjects "Method" and "Knowledge". This purpose broke down into several objectives:

1. develop and test the procedure for fostering the readiness of high school students to use certain methods for studying the objects of cognition and the ways of objective reflection of knowledge through its conceptual constructs based on the use of the biology subject content;

2. develop and test diagnostic tasks for assessing the meta-subject achievements from the aspects of the essence of method as a way to cognize the diversity of animate nature objects and express the idea about them using conceptual constructs in the nonstandard situations.

For performing the study and reflecting its results in the form of a paper certain categories of methods were used. The methods of theoretical purpose included the analysis of literary sources, modeling of the step-by-step process of meta-subject training of students, systematization and consolidation of the obtained results of theoretical and practical nature. The empirical methods included formative and diagnostic pedagogical experiments, pedagogical observation, mathematical calculations for diagnosing the meta-subject achievements of high school students based on the biology subject content in the context of such meta-subjects as "Method" and "Knowledge". The pedagogical experiment was organized and conducted in the 2019-2020 academic year on the basis of general education schools Nos. 17, 39 in Saransk and Nos. 4, 7 in Ruzaevka in the Republic of Mordovia, the Russian Federation. The research involved 102 tenth-graders, who in the end of the pedagogical experiment completed diagnostic tasks which helped to assess their meta-subject results.

4 Results and Discussion

In the global practice of general education, including the practice of Russian schools, meta-subjects may be included in the curriculum as a separate line. But, at the same time, in order to study the expected outcomes of meta-subjects it is possible to use the potential of traditional subjects in determining the place of introduction, interpretation of the essence of knowledge and general ways of knowledge - universal actions (China's 2020 Education Reform Strategy, 2020; Asmolov, 2014). The second direction is being developed and tested by us, among others, when teaching a systematic course "Biology" for students of the 10th grade. The experiment with high school students was carried out using the materials of two meta-subjects “Method” and “Knowledge”. This choice was not accidental, they help not only to convey the knowledge of general ways of thinking activity when using the above-mentioned basic forms of thinking, but also to strengthen the skills of communication in the form of monologue and dialogue, and the skills of rational presentation of the subject content for its memorization, actualization and use in various situations. This choice was also supported by the fact that today knowledge from the field of natural sciences, and biology is forming their integral part, in the global practice of general education is obtained through the intellectual and practical ways of action based on the use of the most relevant information (Saribas & Bayram, 2016; Tarasova & Kulakov, 2015).

Let us provide the general overview of our pedagogical experiment, which included two stages, formative and diagnostic. In view of the purpose of this publication, and in particular, presenting the tasks as the means of assessing meta-subject results of students achieved in subject training, we will provide a brief description of the formative stage of the experiment, while the diagnostic stage will be described in more detail.

The formative stage of the experiment was carried out in two directions, the first of which concerned teaching high school students how to use the tools of the "Method" meta-subject, and the second concerned the tools of the "Knowledge" meta-subject for studying the objects of animate nature.

The meta-subject "Method" was aimed to foster the readiness of high school students to use different methods for studying the objects of cognition. Therefore, at the beginning of the school year, students’ attention was focused on the essence of the scientific method as a combination of different methods and operations used to build any scientific knowledge, including biological knowledge. Further it was underscored that the methods may differ depending on the type of cognition. In joint work with the teacher, high school students identified and wrote down in their workbooks the attributes of empirical and theoretical methods, as well as their role in obtaining the objective knowledge. Since students had difficulty with understanding the meaning of the term "object", some work was done with them to fix that. In exploratory conversation it was revealed that this term indicates a part of the surrounding world nominally chosen for cognition, including the world of animate nature, which has relative independence, integrity, presence of components and their functional interrelation. It was noted that the object of cognition is described with the help of other terms, namely "subject", "phenomenon" and "process". Groups of objects from school biology were named and explained: living systems of different levels of organization; processes and phenomena in functioning of living systems; systematic taxa; theoretical foundations of biology as a science; methods of cognition in biology. Examples of objects, phenomena and processes were given in relation to each of the designated groups. The variety of methods and objects was also presented implicitly as we moved from one topic to another. In the course of the experiment in the context of the discussed meta-subject high school students tried general methods useful for cognition of the animate nature. These were as follows:

1. identification or recognition of a certain method of cognition of an object among others;
2. finding correlation between the used method and the chosen object of cognition;
3. determination of a combination of the methods of cognition for optimal study of a specific object;
4. description of a structure of the method of cognition for its correct application in terms of procedure. In the process of training, the essence of each of the methods and their structure were explained to high school students, conditions were created for their use in educational situations in accordance with the general procedure of cognition.

The result of the experiment: readiness of high school students to use knowledge about scientific methods, empirical and theoretical, important for the study of objects of animate nature, as well as learning methods for the study of objects of cognition within the scope of school biology.

The meta-subject "Knowledge" was aimed to foster the readiness of high school students to use the methods of objective reflection of knowledge through its conceptual constructs. At introductory lessons, they achieved a better understanding of the essence of scientific knowledge as a result of objective cognition of the living, existing in the form of systems of ideal images. It was emphasized that out of the multitude of ways to express knowledge the concepts have a particular significance. This is not accidental, because the concepts as one of the forms of human thinking reflect general and essential features of any object of cognition. Therefore, by learning the concepts and then using them the thinking activity is prompted, giving an impetus to the search for truth to penetrate into their essence. Taking into account the age of students and the subject content, different groups of concepts - empirical, theoretical, special and universal - were explained to students. For example, when working with empirical concepts the best way is to refer to the method of analysis and comparison in combination with inductive basis of the content presentation. When working with theoretical concepts, generalization and systematization methods will be the most appropriate, but with presentation of the corresponding content on a deductive basis. At the formative stage of the experiment throughout the school year we successfully tested the technique of purposeful organization of work of high school students with different concepts from school biology. When developing it, we relied on the tenets of J. Bruner's theory (2015) of the concept formation in the part of the strategy of conservative concentration. The technique may be presented as a sequence of the below actions:

1. specifying the object in relation to which the term is used as a word or phrase indicating a name of the concept to be defined;

2. identifying and naming all discovered attributes of the selected object;
3. picking and specifying the most essential attributes of the selected object;
4. expressing a preliminary idea reflecting generalized essence of the selected object based on its essential attributes;
5. formulating a definition of the concept in its finalized form;
6. constructing a structure of the concept and revealing its possible connections with other concepts;
7. determining the scientific and practical sense of the formulated concept.

The experiment showed that high school students cope with the first five actions without much difficulty, and it is important to teach them to cope with the sixth and seventh actions using the categories of meta-subject sense. In this connection, we carried out the targeted work to refine students' knowledge of analysis, generalization, systematization, comparison, deduction and induction. Students were guided to the conclusion that without this knowledge, it is not possible to build biological knowledge. Further together with them the models were identified for building conceptual constructs, in particular the graphical, frame, and semantic models. The first of them helped to reflect essence of the concept through its volume and content with the use of such forms as structural logical chart, cognitive map, cluster picture, denotative graph; the second one, a frame model, helped to represent knowledge by organizing it around the selected concept with the use of such forms as a flow chart, a logical semantic matrix, a reference node diagram; the third one, a semantic model, opened access to productive work with concepts through semantic interpretation of the meaning of words and word combinations within the studied concept with the use of such forms as semantic, structural, causal, functional networks; unary and binary expressions. It should be noted that in the process of training, the essence of each of the models and forms was explained, their structures were described, and conditions for their use in educational situations were created.

*The result of the experimen*t: readiness of high school students to use the obtained knowledge of meta-subjects - about the concept, structure of the concept, technique of mastering concepts, models and forms of creating the concepts for objective reflection of the studied objects, expression of information about them on a scientific basis using conceptual constructs.

The diagnostic stage of the experiment took place at the end of the school year and was intended to check the outcomes of students' training in the context of meta-subjects "Method" and "Knowledge". It was important for us to find out the readiness of high school students to independently apply the acquired knowledge and methods of action in nonstandard learning situations. For this purpose, it was necessary to pick a diagnostic tool in order to get objective data from students who took part in the formative experiment. As proven by practice, specially developed tasks which involve intellectual, practical and communicative actions as key elements of pedagogics of mental and action approach may be used as such a tool. Therefore, we have developed an invariant structure of such tasks, taking into account the requirements of PISA, which are in many respects convergent with the meta-disciplinary foundations of training at school (PISA – 2018, 2019). The elements of the named structure are as follows:

1. stimulus as a factor of immersion in the essence of a task and its motivated completion;
2. formulation of a task as an assignment with certain requirements to the activities to be taken;
3. expression of a generalized conclusion summarizing the activities performed to cope with the task.

It should be noted that tasks were multi-component in order to check the knowledge, ways of action and communication skills. A task was considered completed if a student scored at least one point for any part of it. No points were given for incorrect (erroneous) answers. The partially competed tasks also received no points. A student received a "satisfactory" mark (3) for one point, a "good" mark (4) for two points, and an "excellent" mark (5) for three points. It was a five-mark grading system. The results of the tasks were entered in the table with the names of students, total scores received for the tasks and the arithmetic mean.

Tasks for the meta-subject "Method" in general were supposed to check and assess the knowledge of the essence of method as a way to cognize a variety of objects, determine its place and purpose in relation to objects (objects, phenomena and processes) of surrounding reality, including the objects of cognition in the field of biology.

Task 1. It is known that everybody should have a clear idea of the real world, its objects, their inner arrangement, functioning, development and significance for the purposeful organization of own life and life of society as a whole. Recall information about the fundamentals for selecting the objects of cognition. *This element of the task acts as a stimulus.*

Look carefully at the pictures below which depict "certain parts" of the surrounding reality and provide your brief comments to them. Name all these parts by one common term, and then divide them into groups ascribing each group its own heading. Think and answer the question: "What did you see in these pictures, objects in the form of processes or objects in the form of phenomena? Using the list of cognitive methods, choose most appropriate methods to study the objects of the animate nature and social world. *This element of the task is an encouragement for thinking activity in the intellectual (analysis, synthesis, systematization) and communicative (monologue) aspects.*

Formulate a written conclusion concerning reasoning for the choice of appropriate methods to study the objects of the surrounding world. *This element of the task is concerned with summarizing the results of performed actions.*

Results: the majority of students received three points. Major difficulties were caused by classification of objects in the form of things and objects in the form of phenomena.

Task 2. It is known that every scientist-biologist in the study of animate nature distinguishes between objects and subjects. This also applies to such branch of biology as cytology, or otherwise the science of cells. *This element of the task acts as a stimulus.*

Carefully look through the suggested list of terms and select those which can be a subject of the research focusing on the plant cell: acrosome, collenchyma, central vacuole, nucleus, petiole, chloroplast, root, cell wall, resin duct, division spindle, water photolysis, interconversion of leucoplasts and chloroplasts. Think and by using the analytical framework of reasoning express with the help of a logic diagram the potential subjects of a research on the plant cell structure. Suggest your own diagram. The diagram should reflect at least three judgments. Provide brief written comments to explain the essence of your diagram. *This element of the task is an encouragement for thinking activity in the intellectual (analysis, synthesis, deduction, systematization) and communicative (monologue) aspects.*

Formulate a written conclusion concerning importance of identifying the research subjects. *This element of the task is concerned with summarizing the results of performed actions.*

Results: the majority of students received three points. The most difficult part was to divide terms into structural components and processes.

Task 3 Every person builds their scientific reasoning and expresses own thoughts based on certain fundamental principles. In applying these principles highly useful are certain procedures, for example, induction and deduction. *This element of the task acts as a stimulus.*

Based on the procedure of inductive inference, offer your own version of a text table with different columns. There should be at least three columns. Fill in the columns of the table. For doing this, use the following topics: observation of the population of

the May lily, experiment to prove G. Mendel's first law, analysis of literature data on the significance of mutations in nature, explanation of the results of the effect of organic fertilizers on potato yields, calculation of the results of the experiment on growing bacterial colonies, graphic depiction on the dynamics in the population of a rare plant species. *This element of the task is an encouragement for thinking activity in the intellectual (analysis, generalization, classification) and communicative (monologue) aspects.*

Formulate a conclusion concerning reasoning for the choice of names to the table columns; write it down in your workbooks. *This element of the task is concerned with summarizing the results of performed actions.*

Results: the majority of students received two points. Most difficulties were associated with the search for the classification basis.

Tasks for the meta-subject "Knowledge" in general involved checking and assessing understandings of what knowledge is, why concepts are used as its descriptors, which models and forms they can be expressed through, and what their role for people is. Below we would like to provide some sample tasks which we used as the assessment means during the experiment.

Task 1. Knowledge as a result of cognition of the reality is of great importance in various fields of human activity. For better understanding of the essence of various objects, the best way to present knowledge is in the form of concepts. *This element of the task acts as a stimulus.*

For several lessons you have studied one of the central phenomena of the biological science and school subject - the types of reproduction of multicellular organisms. A deductive framework is helpful in expressing the scope and content of any concepts, and a structural logical chart (an ideal model) helps to generalize and systematize them. Make such a chart for the concept “types of reproduction". Choose of the types of plant reproduction and provide its description. *This element of the task is an encouragement for thinking activity in the intellectual (analysis, modelling, deduction, induction) and communicative (monologue) aspects.*

Formulate a conclusion reflecting your own view of the concept "types of reproduction" based on the created structural-logical chart; write it down in your workbooks. *This element of the task is concerned with summarizing the results of performed actions.*

Results: the majority of students received two points. The difficulties were associated with filling certain blocks of the structural logical chart with the content.

Task 2. As is known, knowledge acquired by a person may be expressed in various forms. It is selected in a way as to ensure that it is convenient to perceive the essence of the object reflected by means of concepts. One of such forms may be a reference node diagram. *This element of the task acts as a stimulus.*

Refresh your knowledge of the reference node diagram and based on it, present a generalized picture of the learning content organized around the concept "ecosystem" ensuring that it is structurally complete. Reflect the obtained result as your own creative product in your workbook. Discuss with your desk mate the composition of the mixed forest and lake ecosystems. Each of you should determine which component is more important for the ecosystem and write down in your workbook your conclusion. Give examples of woody plant species in an urban park ecosystem. *This element of the task is an encouragement for thinking activity in the intellectual (analysis, systematization, generalization) and communicative (dialogue) aspects.*

Formulate a conclusion concerning the importance of expressing concepts with the help of a reference node diagram as a reflection of the frame. *This element of the task is concerned with summarizing the results of performed actions.*

Results: the majority of students received two points. The most difficult part was associated with listing the plant species and the ecosystem components.

Task 3 Many scientists rightly assert that students work effectively by interpreting the meaning of words and word combinations within the studied concepts. *This element of the task acts as a stimulus.*

Revise the fundamental principles of work with the concepts and create a semantic cause-and-effect network on the topic "Changes in the Biocenosis of the Local Pond Caused by Human Economic Activities". Specify the three major, in your opinion, negative human impacts on the indicated ecosystem Indicate three possible sources of pond pollution with iron compounds. *This element of the task is an encouragement for thinking activity in the intellectual (analysis, systematization, description) and communicative (monologue) aspects.*

Formulate a conclusion regarding the importance of expressing concepts using a semantic network for meaningful interpretation of the essence of the objects under study. *This element of the task is concerned with summarizing the results of performed actions.*

Results: the majority of students received two points. The difficulties were associated with indicating the possible sources of pond pollution with the iron compounds.

5 Conclusion

Training of high school students on the basis of meta-subjects "Method" and "Knowledge" is seen as a promising direction of general education training. This has been proven by the evidence collected in the conducted pedagogical experiment with regard to the meta-subject achievements of high school students, which have been assessed with the help of specially developed diagnostic tasks. Certain circumstances are important for successful implementation of meta-disciplinary training at the formative stage. The dedicated training procedures should be used to foster:

1. the readiness to use the obtained knowledge from the meta-subject domain - about concept, structure of concept, technique for learning concepts, models and forms of concept-building for objective reflection of studied objects, presentation of information about them on scientific basis through the use of conceptual constructs;
2. the readiness to use knowledge about scientific methods, both empirical and theoretical, essential for studying objects of animate nature, as well as methods for studying objects of cognition from the school biology.

It is important to have diagnostic tools at hand in the form of special tasks appropriate for the corresponding meta-subjects, the tasks which in the educational practices, globally and in Russia, have not been sufficiently developed as yet. As for the meta-subject "Method", the tasks should be aimed at checking and assessing knowledge about the essence of a method as a way of cognition of diverse objects, determining its place and purpose in relation to other objects (things, phenomena and processes) of surrounding reality, including the objects of cognition in biology, and as for the meta-subject "Knowledge", the aim of diagnostic tasks should be to check and assess the students’ idea about knowledge as such, concepts as its descriptors, models and forms of concept-building, meaning of knowledge for a person. The diagnostic tasks proposed by the authors helped to prove the positive impact of experimental training of high school students in biology on their meta-subject learning outcomes. Out of the maximum possible 18 points, most students got 14 points for the performed tasks, which indicates the efficiency of the proposed methodological and technological support of the educational process.

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