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Cognitive Styles in Solving Educational Tasks

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Abstract

The article considers the influence of cognitive styles and individual features of perception and coding information on teaching geometry. Cognitive styles can determine success in learning, as they are manifested in the individual characteristics of the cognitive processes of students, their ways of perception, thinking, and action. Special attention is paid to the problems of connection of cognitive styles with interhemispheric brain asymmetry, level of intelligence, and motivation of a personality. The article underlines a very important for the learning process individual characteristic of a student. It is 'differentiation of the field', which means the influence of differences of the external environment on human decision-making. Differentiation of the field is described in terms of field dependence – field independence. Field dependence as a cognitive style means dominance of the whole, a lack of differentiation of parts in an image of perception, a disability to overcome the context, to select separate stimuli from the background. Field independence is an ability to resist the influence of conflicting background signs in the perception of visual forms and ties, an ability to perceive the whole, to allocate parts from complex figures, to choose stimuli from a context. In the conducted experimental research there were offered examples of tasks that allow to form cognitive 'flexibility' and overcome difficulties of students in analyzing geometric problems text. There were highlighted types of such tasks that were characterized by an educational effect. The conclusions from the experiment show that taking into account the parameters of cognitive styles with regular use of the system of developed tasks has a positive impact on the achievement of subject results in teaching students. The analysis of scientific and educational literature was carried out in order to make the understanding of the categories in this insufficiently researched area available to a wide range of school teachers.

Keywords: Teaching, decision-making strategy, cognitive style, field differentiation, field dependence – field independence, the right brain hemisphere, intellectual education.

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Introduction

At the beginning of the 21st century, there were proclaimed new trends in the Russian education system: a shift from the subject-oriented paradigm to the personality-oriented one, the humanization and humanitarianization of the learning process. The main results of training in Russia have long been considered to be subject knowledge, skills, and abilities. But after numerous reforms, the education system is faced with a new problem in teaching schoolchildren. The results of the State's final certification in mathematics in recent years have demonstrated that Russian schoolchildren face significant difficulties in solving problems in geometry. At the same time, there is a tendency of reducing the number of graduates who choose the solution of geometric problems as final exams.

The results of the TIMSS (Trends in Mathematics and Science Study) and PISA (Program for International Student Assessment) studies of recent years have shown that Russian eighth-graders also have difficulties in applying the knowledge gained at school when performing practice-oriented tasks related to solving real problems described in a statement of a problem. Tasks used in PISA studies assess mathematical literacy and competence in problem-solving, identify difficulties in the use of cognitive skills. The application of cognitive skills requires from students the ability of analytical reasoning (Bozhenkova, 2017). Analytical skills are formed in the course of the most important stage of work with a mathematical problem – in the process of searching for its solution. Analysis of the problem text and logical argumentation are an integral part of solving a mathematical problem.

In their everyday life, people are constantly faced with tasks that require solutions. Such tasks can be simple ones, as for example those related to thinking over a schedule of transport changes and the time of arrival into some settlement. And they can be complex professional ones that require certain search strategies for their solution. Any task is a situation that needs a solution, and the way to this solution is unknown in advance.

Most of the tasks contained in school textbooks are typical. Mastering a certain method, students receive a 'piggy bank of tools' that allow them to 'recognize' the problem and apply the appropriate algorithm to it. In this case, the task ceases to be a problem that requires clarification. Then the solution process is reduced to determining the type of task and the certain sequence of actions.

Problems associated with the solution of mathematical problems occupy a crucial place in the methodology of teaching mathematics. The importance of this activity for the intellectual development of a student cannot be overestimated because the intellectual abilities of people are a key factor in the progressive development of society. The priority goal of the modern school is the intellectual education of students, which requires such a form of organization of educational activities that provides conditions for flourishing and improvement of individual intellectual resources of each student (Kholodnaya & Gel'fman, 2016).

The main difference between problem-solving activities and other activities is determined by the fact that there are only general recommendations for problem-solving and a certain sequence of stages of doing it. The method of problem-solving was first developed in a general form by George

Polya and described by him in his book “How to Solve a Problem”. It is based on a heuristic model, which represents a four-stage plan for solving a problem:

– understanding the essence of the task,

– scheduling,

– implementation of the plan,

– evaluation of the found solution (Polya, 1959).

Into the first stage, G. I. Sarantsev includes such actions as the selection of the conditions and requirements of the problem, of objects and relations between them; the implementation of a figure, a brief record of the statement and the conclusion of the problem (Sarantsev, 2002). In the textbook “Theory and Practice of Solving Text Problems” the authors considered each stage in a more detailed way and compiled methodological devices of their implementation (Demidova & Tonkikh, 2002).

The key aspect of the whole process is in the selection of a suitable solution strategy. “The real skill is not in applying the standard method all the time, but in finding the most appropriate even unusual way of solution” (Posamentier & Krulik, 2018).

Algebraization of the school mathematics course led to the substitution of a search for strategies by widespread use of the algebraic method for solving problems. The analysis of school mathematics lessons in the course of our investigation showed that, despite the change of educational results due to the introduction of the new State standards and the updated content of textbooks, teachers adhere to the traditional methods of solving problems. The reason for the fears of excessive algebraization of the school course by teachers of mathematics was determined not only by the results of entrance tests of applicants to the Correspondence Department of the Pedagogical University but also by practical classes with school teachers for solving school problems in the framework of improving pedagogical skills courses. Most teachers of mathematics, especially with long teaching experience, adhere to the algebraic method of solving problems and find it difficult to identify the causes of difficulties students have in the process of solving geometric problems.

Researchers of school education problems see one of the effective ways to overcome the difficulties of students in learning mathematics in the design of a learning process which will take into account individual characteristics of students.

Materials and Methods

Each person perceives, processes, and interprets information in their own way depending on their psychophysiological characteristics. A famous Russian psychologist V. A. Krutetskiy, studying the psychology of mathematical abilities of schoolchildren, came to the belief that there are no children “absolutely incapable of mathematics”. Errors in the perception of educational information can be associated with a mismatch of the style of presentation of information with the peculiarities of a student’s perception (Krutetskiy, 1972). Individualization and differentiation of training require updating methodical means which will allow to achieve positive results in modern mathematical education only taking into account psychophysiological features of pupils. But this is still very poorly realized. A. L. Sirotyuk in his research notes that school methods do not take into account the peculiarities of the right brain hemisphere and the possibility of its development (Sirotyuk, 2003).

Accounting cognitive styles in the individualization of mathematics learning is an important issue but it is under-researched at present. The problems of the connection of cognitive styles with hemispheric brain asymmetry, the level of intelligence, temperament properties, and motivation of an individual are especially serious. Manifested in stable individual characteristics of cognitive processes, ways of perception, thinking, and action, cognitive styles affect success in learning. Knowledge of cognitive styles will help a teacher to understand the essence of students' reasoning in solving problems and it will help to identify the causes of their difficulties.

The analysis of the school practice of teaching mathematics shows that logical thinking is the main object of influence for a teacher. School methods develop mainly the left brain hemisphere, ignoring the second half of the mental capabilities of a child. Representatives of neuro-pedagogics (the science of a differentiated approach to learning, taking into account the psychophysiological and neuropsychological characteristics of students and teachers) associate the problems of modern education with the organization of the learning process without taking into account the specifics of the left and right brain hemispheres. The discovery in 1981 by the American neuro-psychologist R. Sperry of functional asymmetry of the brain led to the necessity to reassess the established views on the system of mathematical education in the direction of imaginative thinking of students (Dahlinger, 2019).

The work of the left hemisphere allows a person to understand written and oral speech, manipulate formal abstractions. It also allows a person to freely operate with numbers and mathematical formulae. Studies of psychologists have shown that the left hemisphere is specialized in operating with conventional signs, and the right – on operating with images of real objects. Psychologists attribute the work of the right brain hemisphere to a synthetic mode of thinking, which manifests a holistic view of perception, and the work of the left hemisphere – to an analytical way of thinking. Analytical abilities allow us to consistently and fragmentarily learn the objects of study. However, A. N. Zakharov argues that every third person does not have a distinctive feature of the work of one of the hemispheres (Zakharov, 1996).

For our study of particular interest are works of psychologists aimed at studying features of thinking associated with activities of the right and left hemispheres of the brain. V. S. Rotenberg believes that "a predominant development of functions of this or that hemisphere has a huge impact on the human mind" (Rotenberg, 1989). Training that does not develop imaginative thinking taking into account psychophysiological features leads to problems in geometry. This author also points to the difficulties of students in learning mathematics due to the lack of attention of a teacher to the imaginative thinking of students and to the development of their cognitive abilities. Teachers in the process of finding the reasons for the low performance of the class should ask themselves the question: "What blocks the ability of my students in the learning process?" (Rotenberg, 1989).

A well-known American psychologist and educator Betty Lou Leaver notes that "a student-centered teaching system that requires of a teacher to be attentive to learning styles goes beyond the method, beyond the textbook, beyond the classroom, and even beyond the teacher since it is focused on the source of success or failure in learning – on the student himself" (Leaver, 1994).

One of the most developed and important issues for understanding the learning process is 'the differentiation of the field' with the parameters 'field dependence–field independence'. A number of studies by German psychologists have shown that with a clearly expressed parameter 'field dependence – field independence' children demonstrate different achievements in solving

problems. Representatives of the dependent style trust visual impressions more when assessing what is happening and hardly overcome the visible field when it is necessary to detail and structure a situation. Representatives of the independent style, on the contrary, rely on their inner experience and easily overcome the influence of the field, quickly and accurately highlighting details of a holistic spatial situation. The greatest impact of cognitive styles, namely field dependence and field independence, on the success in learning mathematics occurs with solution of geometric problems. The analysis of strategies of solving geometric problems by field-dependent students in the course of our studies allowed us to conclude that in their work there was observed the predominance of the strategy of sequential nomination and verification of hypotheses, while field-independent students actively used the strategy of changing the information structure. In the process of solving geometric problems students constantly have to select the necessary figures in the drawing, removing the other elements as the background. It is these tasks with a lot of additional elements in drawings that cause difficulties at the basic secondary school. In the course of these studies, while designing methodological materials for geometry lessons, there were worked out tasks focused on the selection of an object from the background.

Teaching students to solve geometric problems taking into account students' individual characteristics is one of the key ones in modern research on methodological issues. The analysis of studies on problems of school education showed that one of the effective ways to overcome difficulties of students in the use of cognitive skills is to organize the learning process taking into account students' individual characteristics. In the last 5-6 years, there has been observed activity in the publication of textbooks on the methodology of teaching mathematics for students of pedagogical universities. Thus, in a textbook for students of pedagogical universities there appeared examples of tasks in algebra that take into account individual characteristics of students. In this work, there are private techniques with examples of tasks for students taking into account their individual characteristics (Podkhodova, 2018). The author rightly assumes that the knowledge of cognitive styles and application of methodological recommendations of researchers-psychologists in some particular cases will help a teacher to identify the strategy of educational actions of the student. Understanding the psychological basis of behavioral reactions in solving a problem will help to detect the causes of students' difficulties in solving mathematical problems.

In psychology, cognitive style is understood as a peculiarity of a person's life path, structured by setting and achieving goals (Kholodnaya, 1990). The very concept of 'cognitive style' was introduced and used by H. A. Witkin in the 1950s and 1960s. He understood cognitive style as the way of perception, processing, analysis, systematization, and structuring of information. He believed that an individual's cognitive style could be determined by solving standardized problems (Witkin, 1962). In a broader sense of meaning these mechanisms make possible mental activity in general, work with new data and learning in particular. Some authors of psychological researches connect cognitive styles with intelligence, and from the point of view of a number of other scientists they are an integral part of it (Shkuratova, 1994). G. Olport considered cognitive style as an integral system of the personality of instrumental nature that is as ways and means to achieve goals (Olport, 2002).

Our analysis of modern studies on the influence of cognitive styles and individual features of perception and coding information on the learning process of geometry showed that the problem is insufficiently investigated and disclosed in the literature available to a wide range of schoolteachers. Most of the research is devoted to the connection of cognitive styles with interhemispheric asymmetry, level of intelligence, temperament properties and motivation of a personality. Cognitive

styles can determine success in learning, as they are manifested in the individual characteristics of cognitive processes, ways of perception, thinking, and action.

Results and discussions

The majority of researches of foreign scientists-psychologists are devoted to such important individual characteristics for the process of training as 'differentiation of the field', namely to the parameters ‘field dependence – field independence’.

The concept of ‘field differentiation’ was also introduced by H. A. Witkin. The sequence of experiments on the study of the peculiarities of perception and processing of the results allowed him to establish the idea that within a certain circle of people the results of experiments depended on the background against which they perceived an object. This group showing such a peculiarity later became known as field-dependent. The concept of field-independent people was attributed to those ones who perceived and processed information regardless of the context, i.e. they were able to quickly select a figure from the background. For example, dependent children can easily find height in an acute triangle, but the task of performing similar actions in an obtuse triangle causes them serious difficulties. Representatives of the so-called ‘field-dependent style' trust their visual impressions when assessing what is happening and hardly overcome the visible field when it is necessary to detail and structure the situation. On the contrary, 'field-independent' ones more often rely on their inner experience. They are easily abstracted from the influence of the background, quickly and accurately highlighting the necessary detail of the holistic spatial situation

Undoubtedly the reflection of individual characteristics such as field dependence and field independence when solving geometric problems is manifested in the ability to distinguish figures from the background, which is the main, elementary action.

In the process of solving geometric problems there should be selected the necessary figures in the finished drawing, and the remaining elements should be removed as a background. As practice shows tasks with a ‘loaded’ drawing, burdened with a large number of additional elements cause difficulties at the basic school. It is important not only to show students the problem with an 'overloaded' drawing but also to discuss possible difficulties in analyzing the process of solving a geometric problem. For individualization of independent self-work, it is necessary to include tasks on inventing problems on the basis of ready-made drawings. In order to improve the efficiency of learning mathematics methodologists propose to develop field independence by various techniques (Podkhodova, 2018).

It is problems with a large number of additional elements in the construction of a geometric figure that cause difficulties at the basic school. Here is an example of an analysis of a typical geometric problem with a search for the solution.

Task 1. The height AH of the ABCD rhombus divides the CD side into segments: DH = 12 and CH = 1. Find the height of the rhombus.

1. A problem condition is all statements that are before the problem question.

Given: ABCD is a rhombus, AH – height, DH=12, CH=1

To find: AH.

2. It is necessary to make a drawing. We construct a rhombus ABCD

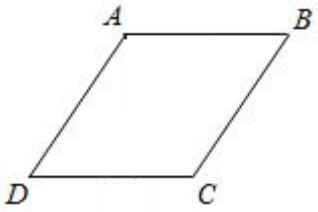


Figure 1.

We draw the line of height AH.

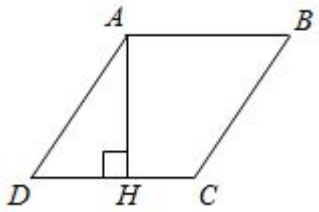


Figure 2.

We mark the sought quantities in the drawing.

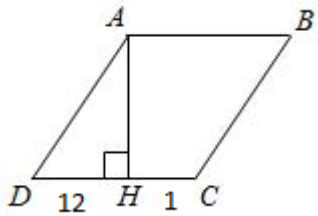


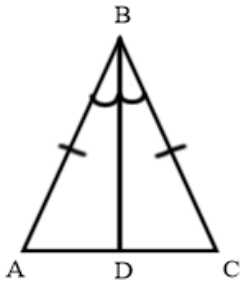
Figure 3.

1. To answer the question of the task it is necessary to find out what else is the height AH. Since the segment AH is a leg within the right triangle DAH, perhaps we can apply the Pythagorean theorem if the other two sides are known. We need to know the lengths of the segments AD and DH.
2. To find the hypotenuse AD it is necessary to recall the property of a rhombus sides: AD=DC. We can find DC as the sum of the segments into which it is divided by the point H. Hence, AD=DC=DH+HC=12+1=13.
3. Now we are able to answer the question of the task by substituting all the necessary data into the formula from the Pythagorean theorem: AH=√AD2-DH2=√132-122=√25=5.

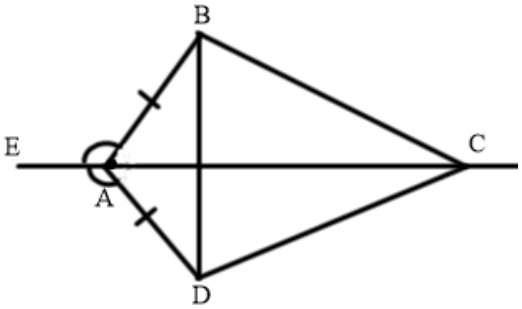
   Answer: AH=5 cm

Let us consider the formulation of another problem: “Write down what is the segment BD in this drawing. Can you offer different answers?”

As a task for homework, you can offer to make another drawing which will suit the given formulation, using a quadrangle. A discussion on geometric shapes will update theoretical issues on the course of school geometry.



The following formulation of the task allows you to develop students' analytical skills and transfer students into another modality: "Write down 6 different segments and give them names, using the words: bisector, median, side, height, base, leg".



Testing of the suggested tasks showed that only about half of the students are able to cope with these tasks without a teacher's help. The majority of these children happened to be field-independent. As a test, we used a simple problem to count the number of triangles in the drawing. A possible reason for the difficulty in solving this problem could be the inability to distinguish between the object and the background. S. L. Rubinstein argued that the selection of a figure from the background is the basic action in the perception of any object (Rubinshtein, 1973). A number of studies by German psychologists have shown that with a clearly expressed parameter 'field-dependent – field-independent' children demonstrate different success in solving problems. When analyzing errors in solving the above-mentioned tasks, the teachers found out the parameters of field differentiation of their students. The reason for the failure in geometry in experimental classes was the predominance of the field-dependence of the majority of students. This conclusion was confirmed by the results of our study conducted during the pedagogical training of students of Naberezhnye Chelny pedagogical University at schools.

In the course of this research, there were developed and tested tasks on:

– 'reading' drawings;

– selecting an object from the background;

– determining the main and secondary objects in the 'loaded' drawings;

– considering all possible cases of the location of objects;

– preparing tasks by students according to ready-made drawings;

– application of tasks-‘traps’.

Here is an example of a ‘trap’ problem for field-dependent students. “Find the area of a rectangular isosceles triangle with a leg equal to 5 cm and a hypotenuse equal to 11 cm.” Most often students begin to solve this problem without analyzing the numerical data.

An Austrian psychologist A. Adler presented the concept of ‘cognitive style’ as a stable individual feature of cognitive processes, predetermining the use of various research strategies (Adler, 2002). An American psychologist J. Bruner also used the concept of strategy as the process of advancing and verifying hypotheses of particular problems. A strategy is an individualized system of methods of operating with information and generating a response behavior, aimed at solving a specific problem and setting the direction of finding a solution, i.e. enclosing its principle. The operational composition of a strategy can be specified in the course of the problem solving. A strategy is a concrete manifestation of cognitive styles in a task specificity (Bruner, 1977). The analysis of strategies for solving geometric problems by field-dependent students allowed making a conclusion about the prevalence of passive strategies of holistic visual field perception. They applied this structure for the solution of the problem using in succession nomination and verification of hypotheses. As for field-independent students, they actively used the strategy of changing the structure of data and analytical information filtering.

Analytical skills are formed in the process of finding a solution to a problem. The solution to a problem is conducted with the help of cognitive logical actions ‘deducing consequences from the condition’ and ‘deducing consequences from requirements’. Application of various schemes in searching for problems solutions will allow to visualize this process, to reveal and understand the reasons of difficulties of pupils, to help them with the solution of problems (Klaus, 1987).

Regular use of the systems of tasks on objects allocation from the background, and also tasks on application of methods of analysis and synthesis in the course of training pupils in geometry and the account of parameters of cognitive styles have positive influence on the achievement of subject results in the course of training. Paired and group forms of training, which are organized in such a way that presuppose a real interaction of field-determined students with field-undetermined ones leads to better results than separate or frontal training.

Stylistic flexibility of schoolchildren is manifested in the ability to perceive, process and assimilate information presented in different forms (imaginary and analytical). The development of style flexibility is facilitated by working in groups. American teacher B.L. leaver formulated the rule of teaching, according to which the introduction of new material should be conducted in the style preferred by the student, and the revision - in the most difficult style for him. Control should be organized in the preferred style.

We analyzed the content of typical tasks for the course of geometry for 7-8 grade pupils in their textbooks for the account of cognitive styles of basic school students. We also examined methodical recommendations for teachers in the manuals on geometry. In the course of ascertaining and teaching experiment, observations of students in the classroom, analyses of their work,

individual conversations with students and teachers, there was collected material characterizing the peculiarities of field-dependent students in solving geometric problems. We were interested, firstly, in the specificity of the images that arise when working with a geometric problem, and, secondly, in the methodical work of the teacher to clarify the difficulties of students and their causes. The results of the experiments show that creation of geometric images based on visual images proceeds differently for different students. There are already revealed vivid individual differences at the level of perception of a geometric pattern. Some students record in detail all the specific features, and then combine them into a single whole. Others examine the entire drawing and then detail it.

In the research works of E.B. Shiyanova there were revealed original ways of data processing. Some students immediately identify in the task the most important elements for the solution, include them in different systems of consideration, rethink them, combine them into groups, fix their basic relations and geometric concepts. They, as it were, from the first moments distinguish the basic geometric shapes and relations, establish essential properties, choose basic concepts and structures, without losing sight of all the problem data and create on this basis a holistically dissected image (Shiyanova, 1989).

Other students fulfill this task slowly, step by step, without clear criteria for analysis, by comparing all geometric objects one by one. They often find it difficult to recognize geometric objects depicted unconventionally. For example, if the height in the triangle is not vertical. Some students 'see' well the necessary element of a drawing and can freely select it in the picture. Other students experience great difficulties in doing this.

Conclusion

The results of experimental research allow us to conclude that regular use of the task system on objects allocation from the background, and also tasks on the application of methods of analysis and synthesis in teaching geometry, taking into account cognitive styles have a positive impact on the achievement of substantial results in the learning process.

The analysis of theoretical psychological and pedagogical theories and experimental data on teaching to find solutions to problems taking into account the peculiarities of cognitive styles leads to the conclusion about prospects of research in this direction. This kind of research will help to better understand the mechanisms of mental activity, to distinguish the abilities and instrumental features of a personality: strategies, tactics, and styles of information processing. The identified links between cognitive styles and learning characteristics may in the future become the basis for individualization of the teaching process in order to increase its effectiveness.

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