Structure of Inventive Thinking.

1. From thinking to inventive thinking.

G.S.Altshuler many times wrote in his works [1, 2] about the development of qualitative thinking of the human as the final goal of TRIZ training and practice of TRIZ application. At the same time the attempts to create scientific foundations of evolution of thinking lead us to the fields of science, which are far from the object of TRIZ: neurophysiology, sociology, gnoseology (theory of knowledge), theories of personality, etc. In this case the processes are analyzed, which are far from creativity: structure of synapses, structure of teams, structure of communications between the human and his environment, etc.

Creativity is understood as creation of spiritual and material values, for example, sculpture, dancing, pictorial creativity, poetry, etc. This activity includes special skills and habits, which are far from inventive activity: physical training, manual dexterity, knowledge of perspective in pictorial art, etc. It is possible to specify the area of analysis of effective thinking, restricting it, for example, only to creative thinking. However, this specifying, in our opinion, appears to be insufficient for creating scientific foundations for development of thinking based on TRIZ. “Creativity is a complicated process, the regularities of which are various and difficult to formalize. However, specific features of inventive creativity to a certain extent simplifies the task of the researcher.” [3]. Thus, in our work the object of research would be not thinking on the whole, but particularly inventive thinking.

In order to create scientific foundations for development of TRIZ thinking we selected exactly inventive thinking of level 3 and higher – thinking, directed at efficient solution of inventive problems in various areas of human activity. [4, 5]. Inventions of levels 1-2, according to classification offered by G.S.Altshuller don’t

require any inventive thinking, in order to create them, it is sufficient to apply the habits of divergent (creative) thinking.

2. Specific features of studying the inventive thinking using TRIZ methods.

The sciences, which study intellect, thinking and creativity (psychology, pedagogic, neurophysiology, etc.) passed a long way of evolution from the ideas of inheriting the creative capacity, as a privilege of elite of society till studies of creative thinking, as a stage in the evolution of the human thinking. Modern research enable to classify the types of creative activity, single out the stages of creative process (the most important of which is insight or intuition), trace the influence upon the creative process of fairly different phenomena (like emotions, age, sex, cosmic physical factors, etc.) to diagnose the cognitive style (as a general cognitive capacity) and creativity (as a degree of being generally creatively gifted) [6].

However, the application of methods of diagnostics, which were created based on this research, does not enable to solve a number of important tasks:

- model the process of inventive creativity, as a process of inventive problem solving, based not on trial and error method, but on logical use of trends of systems evolution;
- identify the features of thinking – structural elements of inventive creativity model– ensuring a possibility to solve inventive problems of high levels;
- create training programs, directed at formation of inventive thinking qualities;
- control the quality of TRIZ education (TRIZ training);
- identify the regularities of phylogenesis of inventive thinking;
- forecast further development of inventive thinking in ontho- and phylogenesis.

The application of TRIZ fundamentally changes the approach to studying inventive thinking. “In any kind of human activity the transition to a novelty,

which is currently being implemented by "creativity", should be inevitably substituted by a corresponding theory of evolution" [7].Inventive activity is characterized by such specific features, which offer a possibility of creating high-quality models of inventive thinking process: inventions develop and improve the system only in such cases, when they correspond to the trends of systems evolution.. Inventive thinking is formed only as a result of practical inventive activity and should correspond to the regularities of systems evolution.

According to the definition offered by the Big Soviet Encyclopedia, «INVENTIVE ACTIVITY is a creative process, which leads to a new solution of the problem in any field of engineering, culture, health protection or defense, which gives a positive effect"[8].

Inventive activity relates both to material and non-material activity.

«INVENTIVE ACTIVITY is a creative process directed at resolving the contradiction between the necessity for attainment of relevant goals and absence of sufficient means for that. The result of inventive activity is the invention as means of resolving the said contradiction. Depending upon the goals of creation and sphere of use, inventions could be embodies in materials objects and become objects of labor (kinds of raw materials and other materials created by the humans) or tools (machines, power tools and equipment), or initially be characterized by non-material nature (new ways of economic and other activity of the human), which does not exclude the obtainment of tangible, also material results»[9].

The specific features of inventive thinking enable us to clearly define the model and structure of inventive thinking. This model should correspond both to the regularities of systems evolution and to the regularities of the evolution of thinking. In TRIZ there is a tool, which could be taken for a reference pattern of thinking process in solving a creative problem – this is ARIZ.

Inventive thinking is a dynamic system. The qualities of inventive thinking gradually develop and are characterized by individual differences. An important

constituent of the system of qualities of inventive thinking is a scale of levels of these qualities.

3. Inventive thinking as a term.

In any field of the human activity there is a constituent, which is associated with obtainment of new results of activity, new method for obtainment of material and non-material products, etc. such activity is conventionally called “creative”. In order to explain the phenomenon of creative activity, various notions are used: creativity, inventiveness, talent, brilliance, etc.

Creative activity is studied by different fields of science, in this case different aspects of creative activity appear to be in the center of attention.

Such notions as genius, talented person (brilliant and talented thinking) are often destined to provoke bright emotional reaction, create an impression of exclusivity. In this case, if the activity of the human is evaluated as a manifestation of his brilliance or talent, decisive role can be played not by the novelty and uniqueness of his ideas, but the force of action of the human himself upon the persons from his environment. The talent first of all implies the manifestations of specific natural features of the human in different spheres of activity. The genius is the highest manifestation of talent and in the same way the natural features of the human form the foundation for the manifestation of brilliance.

The wide scope of application of these terms – a brilliant singer, artist, engineer, teacher, swindler – hinders the understanding of the nature of phenomenon, does not enable to disclose the mechanism for obtaining new ideas. Both the obtainment of new ideas and inventive activity constitute only one facet of manifestation of brilliance and talent and by far not always the most important.

What is the nature of inventive thinking? How does it differ from constructive and creative thinking?

The most popular theory concerning the nature of creative thinking is the model proposed by Gilford and implying the existence of two types of thinking:

convergent (or abstract-logical) and divergent (or creative). The main difference between these two types of thinking consists in the method for transforming the information. In case with convergent thinking the human uses conventional, standardized methods of transforming the information and gets a standardized solution and more than that: the only right solution. Divergent thinking implies the presence of such thinking qualities as sensitivity to contradictions, variabilities, unusual associations. The result of transforming the information in case with divergent thinking should be several solutions, which are characterized by novelty.

Creative thinking is very often looked upon as a synonym of constructive thinking. The difference of creative thinking consists in high motivation, demand of the humans for creative activity, a desire to quickly receive many variants of the problem solution..

Inventive thinking is a result of integration and development of elements of divergent thinking (sensitivity to contradictions, variability, row of associated images, etc.) and creative thinking (high motivation for creative activity, flexibility, etc.).

The most important characteristics of inventive thinking are the capacity to forecast the systems evolution based on the analysis and resolving of contradictions. The combination of three stages – analysis, synthesis and evaluation – distinguishes inventive thinking and inventive creativity from other kinds of creative activity.

Thus, inventive thinking includes divergent thinking, and creativity is one of the constituents of divergent (creative) thinking.

4. Structure of inventive thinking.

Based on the analysis of all modifications of ARIZ we singled out theree stages of inventive problem solving: ANALYSIS of the system, SYNTHESIS of the new system, evaluation of attainment of the goal, which is traced in the logics of all modifications of ARIZ.

At the stage of **analysis** the elements and the structure of a system are singled out, interconnections and interdependencies within the system are identified, existing contradictions are found and the ideal model of the system is created. The stage of **synthesis** is the transformation of source system in keeping with the necessary requirements, search for analogs, application of techniques for transformation of the systems. At the stage of **evaluation** the obtained solutions pass through a test for possible negative consequences and the possibility of wide use of these solutions. [4].

We singled out the following specific features of inventive thinking.

I. Analysis.

A. Component analysis.

B. Entrance into supersystem.

C. Singling out the interconnections and interactions.

D. Variation of the system in time.

E. Sensitivity to contradictions.

F. Ideal modeling.

II. Synthesis.

G. Use of resources.

H. Use of analogies.

I. Flexibility (ability to generate a large number of various ideas).

J. Application of techniques for resolving contradictions.

III. Evaluation.

K. Sensitivity to resolving the contradictions.

L. Criticality.

M. Uniqueness.

The scale of levels of inventive thinking features evolution has been developed based on “structural scheme of inventive creativity process” [10]. For example, in terms of selection of problem, the levels are distributed in the following way:

Level 1 – ready-to-solve problem, search concept, solution or structure, etc.;

Level 2 – selection of the problem, object, concept or structure, etc.;

Level 3 – partial variation of the object, concept or structure, etc.;

Level 4 – finding a new problem and a new solution or complete change of the old one;

Level 5 – finding a fundamentally new problem and creation of a new complex of objects.

Thinking, as all higher psychic functions of the human, are not inherited by the human, but develop gradually in the course of individual development (onthogenesis). This development passes through definite stages, repeating the stages of evolution of the thinking of mankind in a condensed form (phylogenesis). Evolution of thinking, like the evolution of all high psychic functions, should be directed in order that the human might make use of it as a well-controlled tool of high level, not as an accidental set of steps, like a trials and errors method or free associations. The earlier this directed development begins, the better results could be expected. It is necessary to develop inventive thinking comprehensively, paying attention to all its features, starting with the lower levels and gradually passing to higher levels.

5. System of Inventive Thinking Features (SITF).

Table 1. It offers a system of inventive thinking features and levels of development of these features [11].

Table 1. System of inventive thinking features.

	Level 1	Level 2	Level 3	3 level	Level 4	Level 5
I. Analytical Stage.						
A. component analysis.	Cannot single out system elements.	The elements are singled out without a system.	Arranges the system elements into chains according to the lowering of ranks.	Singles out the elements with similar features.	Singles out the elements, which are required fio performance of a certain function .	May separate functions from their carrier.
B. Transition to supersystem.	Cannot integrate elements into a system and/or supersystem.	Only external features are used for integration.	System elements are arranged into chains according to the increasing of ranks.	Elements are integrated based on common feature.	Elements are integrated based on common functions.	Can implement different functions on various resource bases.
C. Singling out the interconnections and interactions.	Interconnections and interactions are not integrated.	"One-link" interconnections and interactions are integrated.	Selection of interconnection and interaction, which are necessary for solving the problem.	Existing mutual connections and interactions are changed.	New interconnections and interactions are introduced.	Interconnections and interactions are studied, which are not characteristic of the given system.
D. Variation of the system in time.	Does not imagine the past and the future of the system.	Can imagine, how the system looked like during a short period of time and what form this system may take.	Can imagine how the given system appeared and how long it could exist (onthogenesis).	Can imagine, how the first system appeared and to forecast, how such systems could develop.	Can imagine, how the similar systems looked like in the past and forecast the evolution of such systems in future (phylogenesis).	Can imagine how the function of the given system was performed in the past and to forecast, how this function will be performed in future (system phylogenesis).
E. Sensitivity to contradictions.	Does not single out the conflict in a proposed problem.	Singles out contradictory requirements within the system.	Singles out the elements and systems, which are associated with conflicting requirements.	Singles out contradictory features within a system.	Singles out conflicting functions.	Can aggravate the condition of the elements of conflict.

F. Ideal modeling.	Cannot mentally change the image.	Mentally change the features of the given system.	Selection of method for varying the features.	Variation of the system in the zone of the conflict.	Variation of the system in keeping with the required features and functions.	Complete change of the system in keeping with the ideal image.
II. Operational stage.						
G. Use of resources	Resources are not used.	Internal resources of the system, offered in the conditions of the problem, are used.	Targeted selection of resources for solving this problem.	Uses resources, which are not included with the system described in the problem.	Creates productive resources out of all available resources.	Resources, which were heretofore unknown (as applied to the given problem) are used.
H. Use of analogies	Analogies are not used.	Use of analogies and comparisons with similar systems.	Analogy is selected based on the given contradiction or a way of solving it).	Similar solutions are changed in keeping with the desired function.	Analogy with IFR is used.	New principles for drawing analogies are identified.
I. Flexibility	No ideas for solving.	Uses known solutions.	Uses several known solutions.	Develops known solutions.	Proposes new solutions.	Proposes new principles of solution.
J. Application of techniques for resolving contradictions.	Does not use the techniques.	Uses techniques, which are known as tools for solving this problem.	Uses known combination of techniques.	Uses new combination of techniques.	Uses the techniques, which had not been used for solving this problem before.	New ideas or effects are found.
III. Synthetic stage.						
K. Sensitivity to resolving contradictions	Proposed solutions don't resolve the contradictions.	Proposed solutions partly resolve the contradiction.	Is selected with the least negative consequences.	The main contradiction of this problem is resolved.	The main contradiction for system evolution in phylogenesis is resolved.	Generalized contradiction is formulated.
L. Criticism.	Does not evaluate the found solutions.	Evaluates according to analogy with known solutions.	Selects a solution, which is closest to ideal	Found solution is changed in keeping with the ideal solution.	Identified solution is evaluated from the standpoint of applicability in solving other problems.	Identified solution is the basis for obtainment of the new principle.
M. Uniqueness	Stereotype solution (in keeping with the vector of inertia).	Known solution is used.	Several solutions are proposed.	Known solutions are changed.	New solution is found.	New solving principle is found.

6. Methods of inventive thinking diagnostics based on SITF.

The methodology of inventive thinking development has been created based on SITF (System of Inventive Thinking Features). This methodology of diagnostics is created in such a way that enables to trace the gradual evolution of inventive thinking level with trainees of different age (from 6 to 60 years and older) and different directions of activity [12].

We performed the research on application of diagnostics methodology to solving of different problems:

- evaluation of initial level of development of inventive thinking features. Introductory diagnostics. Now, judging by the first introductory diagnostics we can decide, what should be the level of the seminar (or a program), which this group of trainees need.

- evaluation of training efficiency. A system for monitoring the development of separate inventive thinking features in the course of training process has been prepared. Such monitoring is necessary for correcting the programs and registering the individual specific features of the trainees. Final diagnostics is also important – it enables to draw conclusions concerning the results of training and the possibilities of using new thinking habits for practical activity.

- Selection of specialists for working in a team. According to our observations, the efficient operation of the group requires such selection of persons that in one team there should be participants, who at the initial stage of training were characterized (based on diagnostics) by higher level of development of thinking features, related to different stages of problem solving. In other words, ther should be an “analyst”, “transformer” and “critic” in the group. Such selection of specialists provides for most efficient operation of the group.

- Individual diagnostics. This is the expert evaluation of changes in level of inventive thinking features evolution during not only training period, but also the time of practical work of the specialist. The experience gained in the course of perfoming such a research, enables to draw conclusions regarding the changes in

inventive thinking structure with trainees of different age, with different professional experience;

- evaluation of methodologies, which develop creative capacities. As of today, there are many different approaches to developing creative capacities, it happens often that it is very difficult to select particular methods, which will yield the best result. If the main goal of training is the development particularly of inventive thinking, then, using the diagnostics methodology it is possible to evaluate, what particular thinking features it could develop and at what level.

Two types of diagnostic methodologies were developed.

6.1. Standardized quantitative tests.

These are methodologies, enabling to evaluate the level of formation of certain thinking features with an entire group of people in restricted time (correction of training being performed). The tests should correspond to certain parameters. These are validity (correspondence of the test to the feature being measured), reliability (protection from incidental circumstances), representativeness (that is, to what extent the sampling of standardization enables to apply the test to a broad population).

6.2. Personalized qualitative methodologies.

Such methodologies enable to define the structure of capacities of a particular person, single out a group of gifted children. For this methodology it is necessary to determine the conditions, under which it is possible to provide for maximally individual approach in researching the creative capacities. These are such conditions as:

- unrestricted time of performing the tasks;
- individual approach in evaluating the results;
- minimum influence of competitiveness in performing the diagnostics;
- it is desirable that the research of creative capacities should be performed in a usual situation from everyday life, when the tested person can have free access to additional information in the relevant field relating to the tasks.

Methodologies of diagnostics of creative capacities should take into account the age peculiarities of the tested persons (for example, pre-notional thinking of 3-7-year children is characterized by non-sensitivity to contradictions, which does not in any way testify to absence of creative capacities with this category of tested persons).

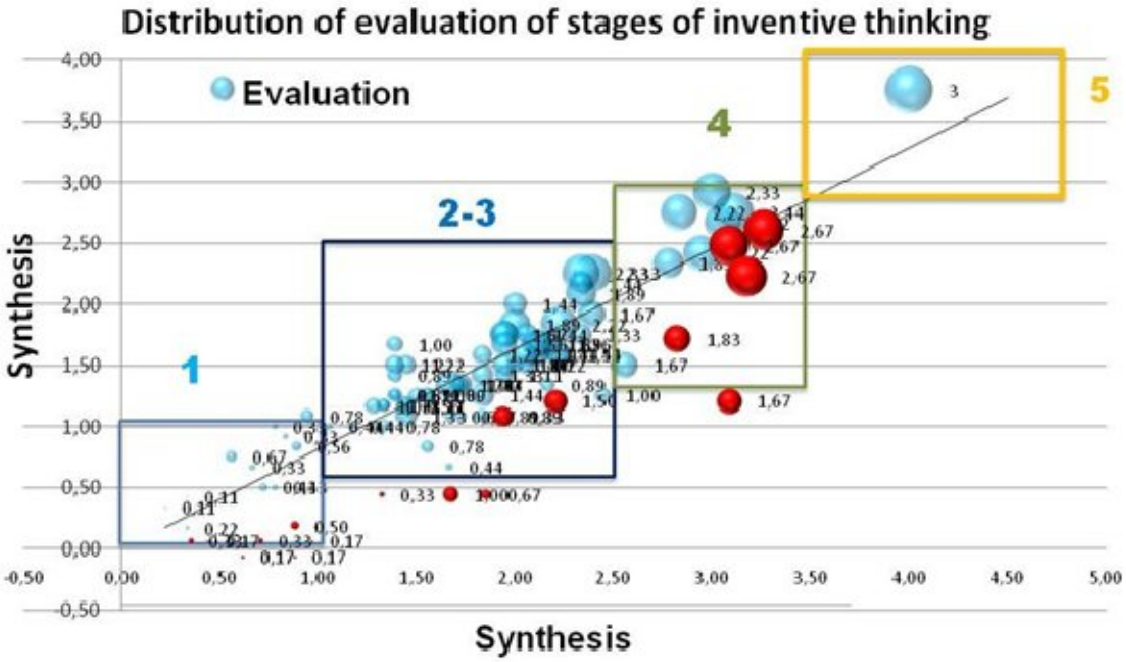


Fig. 1. Distribution of evaluation of inventive thinking stages.

Each feature of thinking is evaluated within a scale from 0 to 5 points. In order to evaluate the level of creative thinking average marks are used, which are distributed according to 4 levels: low, average, high, the highest (Table 2).

Table 2. Distribution of evaluation according to levels of inventive thinking development.

	Analysis	Synthesis	Evaluation
Low level	0.0 – 1.0	0.0 – 1.0	0.0 – 1.0
Average level	1.1 – 2.5	1.1 – 2.0	1.1 – 2.0
High level	2.6 – 3.5	2.1 – 3.0	2.1 – 3.0
Highest level	3.6 – 5.0	3.1 – 5.0	3.1 – 5.0

The formation of inventive thinking is a long process, which requires systematic work on practical application of inventive thinking habits to different spheres of

activity. Exactly such research could constitute the basis for identifying the regularities of thinking evolution.

7. Dynamics of variation of inventive thinking structure according to the results of SITF-based diagnostics.

According to the observations of numerous specialists and the opinions of the teachers and trainees, who took part in the seminars, TRIZ changes the mode of thinking of the people. What in particular changes in human mentality? What particular features of thinking change? What are the principles of arranging a training session , so that the result should be the best?

We could trace the process of gradual formation of inventive thinking habits reviewing the results of SITF-based diagnostics.

In 2011/2012 school year research was performed on studying the inventive thinking formation with children of 6.5 – 7 years. Prior to the beginning of studies and vbased on the results of training sessions diagnostics was performed using the tests “The Magic Cloud” and “The Invader”. The tests were compiled in such a way that they enable to trace the variation of the same features of inventive thinking.

The tests imply that it is proposed to the children to combine contradictory features and to depict the Magic cloud and the Invader, so that they should be:

Big, as a house; ***small***, as a gnome;

Cheerful as a clown; ***sad,*** as a rain in autumn;

Hard, as stone; ***soft***, as cotton

Black, as harsh smoke, and ***white***, as snow flocks;

Noisy, as a powerful ocean, and ***silent***, like a rivulet in the forest;

Warm, as sun rays, and ***cold***, as sprinkling drops of the fountain.

Let us review several works in greater detail.

1. Pupil A.

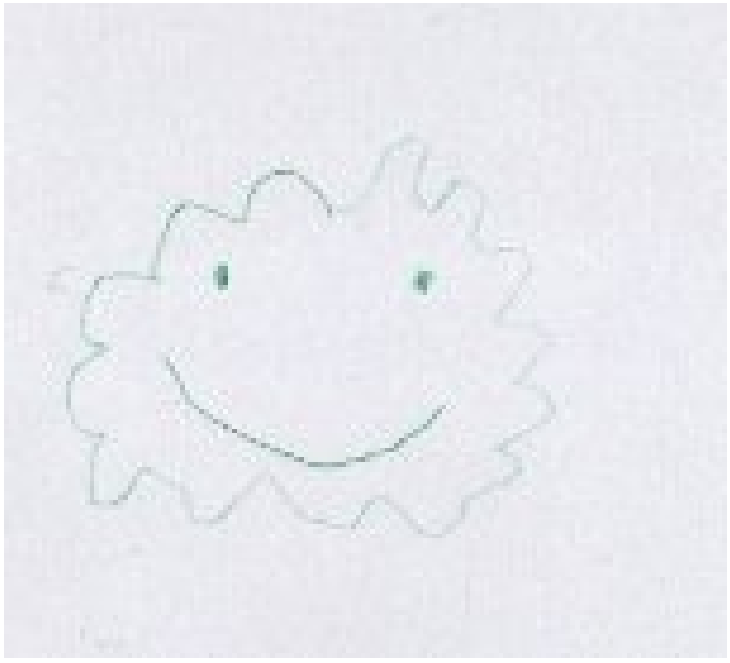


Fig. 2. "Magic cloud" - P-A Fig. 3. "The Invader" - P-A

Figure 2 presents a work, which is typical for children of 6.5-7 years: the cloud, not changed in keeping with the requirements of the task, could have details in the form of human face.

Figure 3 presents the work of the same pupil, made at the end of school year and reflecting the results of TRIZ studies.

For comparison the characteristics of thinking features are generalized in a table.

Table 3. Dynamics of change of inventive thinking features (Pupil A)

Inventive thinking features	Characteristic (level) based on introductory diagnostics	Characteristic (level) based on summing-up diagnostics
A – component analysis	Cannot single out system elements (level 0)	Can arrange the system elements in chains according to the decrease of the rank (level - 2)
B – transition to supersystem	Cannot integrate elements into a system and/or supersystem (level – 0)	Can integrate the elements into a system and supersystem based on common features (level -3)
C – singling out	Cannot single out interactions and interdependences, available	Can select interdependences within a system and between a

interactions and interdependences	within a system (level – 0)	system and supersystem, which are required for resolving contradictions (level – 2)
D – sensitivity to contradictions	Cannot single out the conflict in the proposed task (level - 0)	Can single out the elements within a system, which are associated with conflicting requirements (level – 2)
E – use of resources	Cannot use resources for problem solving (level – 0)	Can intentionally select resources for resolving contradictions (level -2)
F – flexibility	No ideas for solving the problem (level – 0)	As a rule, uses several solutions known for a given problem (level – 2)
G – sensitivity to resolving contradictions	Cannot resolve contradictions offered in the task (level – 0)	As a rule the contradictions offered in the problem, are resolved (level -3)

2. Pupil B.

Fig. 4 “Magic cloud” - P-B

Fig. 5 “The Invader” - P-B

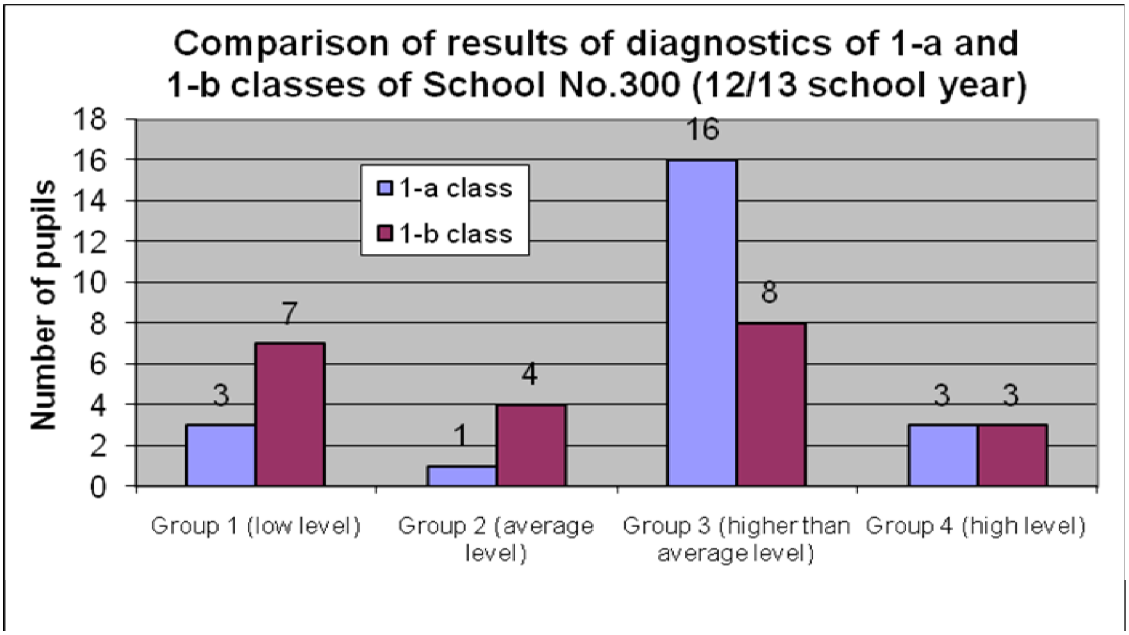
Table 4. Dynamics of variation of inventive thinking features (Pupil B)

Inventive thinking features	Characteristic (level) based on introductory diagnostics	Characteristic (level) based on summing-up diagnostics
A – component analysis	System elements are single out without a system (level 1)	Can arrange the system elements in chains according to the decrease of the rank (level - 2)
B – transition to supersystem	Cannot integrate elements into a system and/or supersystem (Level – 0)	Can integrate the elements into a system and supersystem based on common features (level -3)
C – singling out interconnections and interactions	Can single out "one chain" interconnections and interactions in a system (Level – 1)	Can select interconnections within a system and supersystem, which are required for resolving contradictions (level – 2)
D – sensitivity to contradictions	Can single out elements, which are associated with conflicting requirements (Level - 2)	Can single out elements within the system, which are associated with conflicting requirements (level – 2)
E – use of resources	Can intentionally select resources for problem solving (level – 2)	Can intentionally select resources for resolving contradictions (level -2)
F – flexibility	Uses standard solutions (Level – 1)	As a rule, uses several solutions, known for a given problem (level – 2)
G – sensitivity to resolving contradictions	Proposed solutions partly resolve contradictions (Level – 1)	As a rule, the contradictions, offered in the problem, are resolved (level -3)

The development of each of inventive thinking features could be traced separately and the training program could be augmented by necessary exercises.

We also tried to show in our research, that the TRIZ training sessions particularly form the inventive thinking features in a more reliable way and quicker than any other types of training. If we draw a comparison with the reference group, we shall notice: main part of the group was characterized by the increase in level of inventive thinking; when the children are watched in the course of TRIZ training session (in particularly, during the discussion and solving of simple inventive problems) it noteworthy that the children can quickly analyze the system and

identify the elements, associated with the conflict, as well as choose the optimal elements out of them (see Figure 6).



Fg. 6 Comparison of results of summing-up diagnostics of the TRIZ group with a reference group.

8. Evolution and typology of inventive thinking

Inventiveness is a feature of thinking, which in all historical periods distinguished characters of heroic epic and of folk tales, and characters of folk tales, it was ascribed to wise rulers and saved entire nations from disasters. Inventiveness is necessary for the human in fairly different spheres of his activity. Even the oldest representatives of Homo manifested the feature of thinking in a very wide scale: from obtainment of fire, manufacturing tools and hunting to finding the methods for creating images in petroglyph art (cave drawings) and invention of new ways of communication. The world of contemporary man is complicated and contradictory: the achievements of civilization liberated us from hard physical labor, however brought us to ecological problems, which are a real menace to our life and health; telecommunication systems crated the possibility of communication, which surpasses space and time, however, they often deprive the human of direct perception of reality, foist the stereotypes of behavior and multiply

social conflicts. In such a complicated world the human always has to find new non-standard solutions, take into account a vast number of factors, which are often contradictory, in other words, demonstrate *inventiveness*.

The presence of well developed ***inventive thinking*** becomes one of the main conditions of survival.

The TRIZ-based approach to studying phylogenesis of inventive thinking, stages of forming inventive thinking as well as inventive thinking typology are analyzed in greater detail in the article by M.S.Rubin and N.V.Rubina "Phylogenesis of inventive thinking" included with the present collection of articles.

CONCLUSIONS

1. To achieve a stricter and more scientific approach, it has been proposed to consider inventive thinking, not thinking in general as an object of research.

2. It has also been proposed to use TRIZ methods as a methodological approach, and, in particular, ARIZ, as a reference pattern of inventive thinking.

3. Qualitative model of inventive thinking – SITF has been created based on TRIZ methods.

4. SITF-based methodology of inventive thinking diagnostics has been created. This diagnostics methodology enables to evaluate initial level and dynamics of development of inventive thinking features; to evaluate the efficiency of training; to evaluate methodologies, which develop creative capacities from the standpoint of inventive thinking formation.

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