Phylogenies of Inventive Thinking.

The goal of the present article is to show the phylogenies of forming and development of inventive thinking. Typology of inventive thinking is proposed and characteristic features of every type are analyzed.

1. Model of inventive thinking.

Inventive thinking will be described by us in the form of three interacting constituents: analysis of existing system, synthesis of a new system and evaluation of proposed solution (Fig.1). The key issue of inventive thinking is the identification and resolving of contradictions [1].

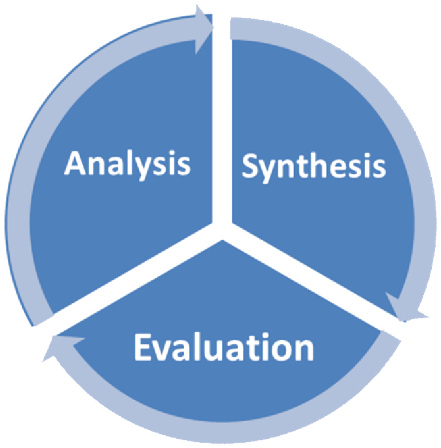

Fig. 1. Model of inventive thinking.

In order to create a more detailed model we singled out the basic features of inventive thinking, and the levels of their development are taken into account (the structure of inventive thinking is analyzed in greater detail in the article by N.V.Rubina “Structure of inventive thinking”, which is also published in this collection of articles).

Such model enables to consider inventive thinking as a problem-solving process, in which individual features could manifest themselves at different levels. Inventive thinking develops only in the course of training and practical solving of inventive problems of level 3 and higher, according to classification offered by G.S.Altshuller.

We propose to consider inventive thinking as a stage in evolution of the human thinking, as a tool of transformation and development (evolution) of the systems, transformation of natural ambience into an artificial environment, (Fig. 2).

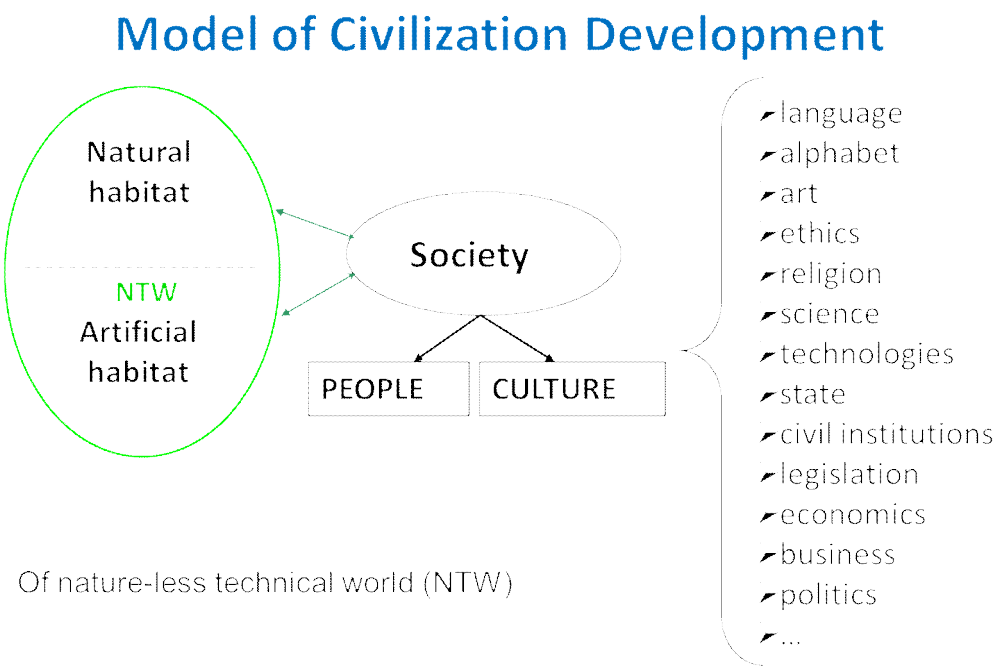

Fig. 2 Model of evolution of civilization includes natural environment, artificial environment and society, transforming the former into the latter.

2. Inventive thinking is a stage in evolution of thinking characterizing the living matter.

Formation of inventive thinking is a complicated evolutionary process. There is an opinion that particularly the specific features of thinking singled out the hominids among all animals. The presence of controlled imagination and divergent thinking enabled Homo sapiens to make a huge jump in social evolution.

Table 1 generalizes phylogenetic row, which leads to inventive thinking of the human, which starts with the fundamental capacity of the living organism to give answers to irritators from the ambience (Stage 1) [2]. The complication of the organism itself (generation of multi-cellular structures) requires the complication of the nervous system.

The achievements of stage are 2 synapses – connections between nervous cells. To achieve movability and capacity to avoid harmful factors of the environment (Stage 3) special organs get developed with animals – sensors and successive (logical) programs of behavior get stabilized (unconditional reflexes).

Table 1. Phylogenies of Thinking in Living Matter.

Stage	Feature	Form of manifestation	Examples
Stage 1	Irritability	Tropisms, kinesis	Protozoa
Stage 2	Sensitivity	Sensor reaction, taxes	Coelenterates, mollusk
Stage 3	Unconditioned reflexes	Instinctive behavior, sensor capacities	Nematode worms, sub-insects
Stage 4	Conditional reflexes	Capacity to learn, manipulation	Annelid worms, social insects
Stage 5	Higher nervous activity	Perception, first signal system, memory	Fishes, amphibian, reptiles
Stage 6	Cerebral activity	Communication, social behavior	Birds, mammals
Stage 7	Visual-and-action thinking	Assimilation and accommodation	High primates
Stage 8	Imaginative thinking	Integrity of perception, imagination, second signal system	Pithecanthropus Neanderthal men
Stage9	Inductive thinking	Drawing analogies, modeling, game	Primeval tribes
Stage10	Deductive thinking	Identification of regularities	Early societies of agriculturists
Stage 11	Abstract-logical, convergent thinking	Abstract thinking, creation of schemes (patterns) of processes	Sumerians, Babylonians
Stage12	Divergent thinking	Creativity. Dialectics of thinking	Ancient Egypt
Stage13	Inventive thinking	Systematics, model quality, criticality, prognostic nature of thinking	Ancient China, ancient Greece and Rome, New times

Conquest by living organisms of such habitation areas, which are dramatically different in terms of their features (water, earth, air), active interaction with habitation environment lead to cephalization and complication of behavior. Important achievement of stage 4 – ability for learning and manipulation. At stage

5 high activity of animals, dramatic increase in parameters of ambience and growing competition in struggle for resources led to formation of higher nervous activity. The achievements of the stage are first signal system and memory. Further complication of behavior (Stage 6) takes place both due to complication of the brain and due to complicated forms of social behavior. [3].

Numerous cycles of research were aimed at finding the answer to the question concerning the difference in brain activity of the animals and brain activity of the humans. Starting with Stage 3, the activity of the nervous system is sub-divided into two different directions: monitoring of life-sustaining activity (heart rate, vermiculation and other physiological processes) and active interaction with ambience (from simple sensor reactions of approaching and avoidance to complicated forms of social behavior).

The development of thinking with the humans occurs under the influence and in the context of social-and-cultural interaction not only with the environment, but mainly with the social setting [4]. The presence of the second signal system and abstract-and-logical (symbolic) thinking, which is closely connected with it, creates fundamentally different opportunities for development of self-identification, imagination and next stages of evolution of thinking [5].

In the same way as structure, created by the child of toy cubes (elements) gradually become more complicated, complicated forms of self-identification, behavior and thinking are gradually formed in the process of evolution from simple neurophysiological elements – “cubes”.

At the stage of visual and action-oriented thinking of hominids and primeval men (stages 7 and 8), the evolution took place due to the increase in brain size and the differentiation of its parts. Having evidently attained energy limits with Neanderthal people, thinking started to evolve as a social process – both due to the increase of the number of mental operations, accessible to a particular individual person, and due to social-and-cultural and scientific experience of the preceding generations of the humans. [6].

We propose to introduce the new stage – stage 13 of thinking evolution – formation of inventive thinking (which in broad sense of the word is applicable to all types of human activity). This stage is characterized by system character (systematics), model quality, criticality, prognostic nature of thinking. Such a combination of thinking characteristics is necessary in solving open, multi-variant problems, containing contradictory requirements. Such type of thinking is formed with the human under favorable conditions for evolution and in case a demand for inventive activity is generated.

In the course of evolution the following was required from the human for the generation of inventive thinking:

- to form model-based, abstract thinking with the humans (second signal system);

- capacity to hold (in one image) different models, which are to a certain extent contradictory;

- capacity to change (modify) the models of ideas, so that these contradictions would be resolved.

The generation of models, which are contradictory one to another, leads to psychological tension. When the contradiction is resolved, the tension disappears and human gets satisfaction from the solved problem [7].

3. Phylogenies of Inventive Thinking.

Animals can solve problems. These are the problems, which are associated with direct survival. Infusorium and euglenas from the world of protozoa can “learn” certain behavioral reactions [8]. The animals surprise us with their capacities to get adapted to survival in aggressive artificial environment, created by the humans. It is possible to quote numerous examples of using historical architectural edifices by the birds and small mammals for creating nests; getting food at the “plantations” created of everyday household rubbish; complicated kinds of communication, mastered by the animals in the course of long-term contacts with the humans.

The boundary of opportunities of brain activity of the animals passes at the level of a possibility to form the second signal system, to operate with abstract notions, to control imaginary notions, possibility to model and to predict (to forecast). Recently many new publications resulting from various kinds of research appeared, which broaden our impression of the possibilities of brain activity of animals. These investigations offer a possibility to analyze the operation principle and the initial actions stages of forming human mentality, as well as to identify the degree of influence of social-and-cultural influence of the human society upon the formation of all stages of development of thinking in phylo- and ontogenesis.

The research, aimed at studying the individual development (ontogenesis) of the human thought, prove that the initial stages of thinking of a child are rather similar to the development of thinking of high primates. However, at the earlier stages of ontogenesis of thinking a decisive role is played by the contacts between the child and grown-ups surrounding him. Further on, the development of thinking takes place under the influence of two forces, which mutually complement each other: hereditary characteristics and social-and-cultural environment. Each person in his or her development should gradually acquire all most important achievements of subsequent stages in the evolution of thinking. It also relates to the evolution of all features of inventive thinking.

System, which is called “SITF” (system of inventive thinking features), reflects gradual development of inventive thinking in phylo- and ontogenesis.

Stage 1. ***Thrust for knowledge, tendency to independence, search activity.*** These features develop during the period from 0 to 2-3 years based on the achievements of visual-and-action thinking: analysis of features and simplest interactions of objects of the environment. Often the disadvantages of thinking evolution hinder further development. In the course of introductory diagnostic with children of junior school age we can identify particular disadvantages of thinking with a particular child (for example, the children are often unable to single out the existing interconnections within a system, since they cannot imagine what structure it has).

Inventive thinking features develop irregularly. In this case, the more various the impressions obtained from the surrounding world are, the higher is the number of transformations (of particular objects or imaginary entities) the child might perform and the more often the child finds himself in “problem situations” , the more successful and quick his transition to the next stages of development is.

Stage 2. ***Identification of components and interconnections between them, variability.*** Based on main achievements of imaginative thinking such kinds of inventive thinking are formed with the child as component analysis, identification of interactions and interconnections within the system, ideal modeling, use of analogies, flexibility, uniqueness. With children of 3-5 years of age it is very difficult to master transition to the supersystem (characteristic mistake sin classifying objects according to incidental features), mental travel of the objects in time (impossibility to imagine particular periods of time and to coordinate them with the events, that are going on), also sensitivity to contradictions is absent and the techniques for manipulation with objects have not yet converted to techniques of transforming the systems, thinking is not critical.

Stage 3. ***Uniqueness, identification of cause/effect ties.*** Further evolution of inventive thinking includes the generation of induction operations (from particular to the general) and deduction (from general to particular). At this stage (6-7 years) the features of inventive thinking, constituting the analytical stage should attain levels 2-3, except the skill to change the systems in time and sensitivity to contradictions. Such features of inventive thinking should also start to form at this stage, as the use of resources, application of simple techniques and uniqueness.

Stage 4. ***Sensitivity to contradictions.*** At the age level of 7-8 years the borderline of sensitivity to contradictions passes: with the children it is formed gradually and only in the process of overcoming problematic situations. This thinking feature is considered in the works of many specialists to be a most important feature of divergent (constructive or creative) thinking.

Stage 5. ***Abstraction, identification of regularities, application of techniques.*** The most complicated and the latest from the standpoint of evolution

is the stage of abstract-and-logical (or convergent) thinking. The main achievements of this stage are capacities to construct regularities and to identify the observed interconnections within the systems. These thinking features attain full development in youth and mature age, however, without initial stages – capacity to construct cause-effect associations, abstraction, ability to transform systems using consequent operations, forecasting – thinking of the grown up man is further based on particular life experience and has a number of significant disadvantages. Based on these achievements the inventive thinking features could pass to a higher level.

Stage 6. ***Evolution ideas, ideal modeling, criticality, development of all features of preceding stages.*** The most important inventive thinking features are the capacity to transform systems in time, sensitivity to contradictions, ideal modeling, application of techniques for resolving contradictions, criticality are formed only on the basis of divergent thinking and in the process of inventive problem solving.

In order to attain level 5 of all inventive thinking features it is necessary to posses the skills of creating abstract models, present the evolutionary variations of classes of the objects, aggravate and surpass conflict situations and find new principles for creating analogies and new principles for solving.

4. Social nature of inventive thinking.

History and evolution of civilizations show that the efficient connections between people (members of society), live and non-live nature appear to be more important for evolution than thinking of particular individuals. Since the time of Neanderthal men the development of thinking became a less important fact than the evolution of social-and-cultural connections. In reality the development of connections between the elements is a stable vector of evolution, which existed long before the origination of mankind and live nature on the whole.

Evolution of social-and-cultural systems (SCS) continues the tendency of complication of interconnections in the process of substance evolution: from elementary particles to atoms, from atoms to molecules, from molecules to

organisms, etc. In the same way in society the people are united into families and communities (SCS of Level 1), integration of different communities creates tribes and unions of tribes (SCS of level 2), which are integrated into a supersystem structure (SCS of level 3): nations, peoples, states [6]. The process of SCS development is directly associated with the development of quantity and variety of bonds between people and society, live and non-live nature. Thinking cannot be formed outside social-and-cultural bonds and actually is a tool for development of these bonds.

Inventive thinking, as part of thinking in general, is directed at the enhancement of efficiency of forming and development of bonds in SCS. In order to create and maintain social-and-cultural relations great expenditures of energy are required. Inventive thinking is able to create and to maintain the maximum number of efficient bonds in SCS at minimum expenditures.

Inventive thinking is a part of social-and-cultural environment and at the same time a tool of its development. It is formed under the influence of social and cultural fields of interaction, which are available in a given place and at a given moment. And vice versa: inventive thinking of the personality through it social-and-cultural relations influences culture on the whole. Thus, inventive thinking is a form of interaction between people as well as between people and environment.

5. Structure of social-and-cultural fields of interaction as a resource for forming and resolving contradictions.

Social-and-cultural systems appear based on fields of social-and-cultural interaction. People and line and non-live elements could be included with this system as elements, however, the basic carriers of SCS fields are people.

The fields of social-and-cultural interaction are characterized by a number of features:

1. SCS-fields integrate elements of social-and-cultural system into one whole and always have an evaluation component. With different people or communities of this system the evaluation could be different: positive, negative or neutral. [9].

2. Different evaluation components in SCS-fields inevitably lead to contradictions within the systems. Engineering contradictions are a particular case of social-and-cultural contradictions.

3. SCS-fields of interaction of one level consist of SCS-fields of a lower level (the channels constituting the field of interaction) and at the same time they can form SCS-fields of a higher level. For example, the relation of one person to another person or team could be formed of a sum of impressions, which were obtained from different perception channels (visual, audial, tactile, and olfactory, etc.).

4. Individual channels of SCS-fields of interaction could be joined into an integral evaluation and are characterized by the feature of inertia.

5. One of the perception channels could appear to be dominating for this or that person or a representative of a certain social-and-cultural community.

6. SCS-fields are also characterized by the feature of induction, i.e., they could be transferred from one carrier to another. The evaluation is made based on cause/effect chains and induction (transfer of features of one subject to the evaluation of another subject).

The entire system of SCS-fields and evaluations (feelings) in social-and-cultural systems influences the formation and selection of inventive problems. These systems of evaluation could lead to contradictions of requirements, however, at the same time they are also resources for elimination of these contradictions. The change of the system of values could be one of the techniques for resolving contradictions of requirements. The system of teaching values, control over feelings and sensations becomes part of the resources for resolving contradictions in social-and-cultural milieu.

6. Typology of inventive thinking.

Inventive activity is a many-faceted, multi-aspect and many-sided activity. For examples, it happens often that the pans and the sauce-pans, which are arranged like a “nested doll” and the creation of the first device for cooking are both related to inventive activity. In TRIZ “inventions” of the first type are not

considered at all, while the entire variety of inventions imply the scale of inventive activity levels.

Analysis of the results of diagnostics based on sampling of more than 500 people, the age of who stays within the scope of 6 to 60 years and whose profession and education level enabled us to single out 4 basic types of inventive thinking.

We can judge about inventive thinking level of the human by the products of his inventive activity. A creative personality does not manifest his or her inventive thinking at one and the same level during his or her life. And still creative activity of one and the same person is characterized by the predominance of inventive thinking features, which are included with one of three stages of inventive problem solving. Thus, it is possible to single out characteristic features of inventive thinking of a certain type. In order to illustrate the typology of inventive thinking, we selected the biographies of famous creative personalities and analyzed their most important achievements. The results are given in Table 2.

Table 2. Typology of inventive thinking.

Level / TYPE	Highest	High	Average	Low
Professional	1.1 – Tesla	1.2 – Leonardo da Vinci	1.3 – Watson and Crick	1.4 – “Phyleas Fogg”
Analyst	2.1 – Darwin	2.2 – Vavilov	2.3 –Lynnaeus	2.4 – “Paganel”
Transformer	3.1 – Hippocrates, Zander	3.2 – Paracelsus, Korolyov	3.3 – Pasteur, Kotelnickov	3.4 – “Glenarvan”
Critic	4.1 – Einstein	4.2 – Copernicus	4.3 – Lomonosov	4.4 – “Captain Nemo”

Main characteristics of inventive thinking types:

1.1 – fundamental discoveries in various fields of knowledge, broad erudition, system-based transformations in time and space;

1.2 – significant inventions in different areas of knowledge; modeling of ideally functioning systems, evolution-based approach to system development;

1.3 – significant inventions and discoveries in relevant fields; application of effects and new operation principles; use of unusual resources;

1.4 – selection of unusual techniques and resources; unusual use of resources; forecasting of possible consequences of proposed solutions;

2.1 – explanation of reasons of evolution, identification of trends, utopias as ideal models;

2.2 – skills of identifying the essence of phenomena, periodization of historical events, dialectic character of thinking;

2.3 – skills of finding cause/effect associations, skills for constructing schemes (patterns) of the processes, creating hierarchies as foundations for classification;

2.4 – tendency to logical classification, skills of combining new images from already known parts, tendency to improve known mechanisms, low variability;

3.1 – identification of new operation principles, new discoveries, transgressing the boundaries of new known fields of knowledge (often the discovery of new kinds of engineering, new kinds of art, etc.);

3.2 – transgressing the boundaries of new known fields of knowledge, finding integrated solutions;

3.3 – high variability and flexibility of thinking, various analogies, transfer of known solutions to new fields;

3.4 – developed intuition and confidence in it, use of superfluous analogies and search for well-tested solutions, tendency to propose many variants of one and the same solution with insignificant variations;

4.1 – evaluation of preceding stages of development, generalization, new theories.

4.2 – erudition, transfer of principles, techniques and effects, obtained by other inventors, to new areas of knowledge.

4.3 – ability to identify the strongest and most rational solutions, confidence in authoritative inventors, ability to identify a successful solution as a technique and to apply it once again;

4.4 – high level of competence, confidence in authoritative inventors, carefulness, and low variability;

It is important to note that the distribution of known creative personalities according to inventive thinking types in table 4 is fairly conventional and could require a more detailed study of their contribution to development of this or that field of science, engineering and art. The overall evaluation of a creative personality is composed of the novelty of the problems stated, uniqueness of proposed solutions, broadness of scope of ideas, which were obtained as a result of work, of the influence of these ideas or solutions upon the life of a great number of people and finally, on the subjective evaluation of “charm” and “charisma” of a particular person.

Last four types of inventive thinking are well known to everyone by the characters of science fiction and by typical patterns of behavior of bright personalities in the teams and even by “roles”, which we usually play in a company of friends or in our families. That is the very level of inventive thinking and forms of its manifestation, which are necessary for us for resolving usual situations of everyday life.

CONCLUSIONS

1. In order to study specific features of inventive thinking forming in phylo- and ontogenesis, the model was used, which consists of three interacting components: analysis, synthesis and evaluation.

2. Model of phylogenies of thinking as applied to living matter is proposed. Inventive thinking is considered in this model as a logical stage in the evolution of thinking.

3. A model of phylogenies of inventive thinking, including 6 main stages, is proposed.

4. Inventive thinking appears only in social-and-cultural systems in order to enhance the efficiency of ties between the members of society as well as between the said society members and natural and artificial environment. Inventive thinking is a part of social-and-cultural environment and at the same time a tool of its evolution.

4. The fields of social-and-cultural interaction are the basis of social-and-cultural systems and possess a number of features, which pre-determine the peculiarities of functioning of these systems. The change in the system of value could be one of the means for resolving contradictions of the requirements.

5. 4 main types of inventive thinking are singled out, which reflect the peculiarities of inventive activity at different levels.

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