Invention of Knowledge in TRIZ-based Education
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Abstract—The paper considers possibilities of performance of new requirements to an education system, connected with formation of a global innovative society. The cores from these requirements – formation of trainees’ ability to generate ideas and to solve problems. The paper considers potential of the innovative educational technologies created by this time and gives classification of these technologies by levels depending on degree of performance of the named requirements. Now only one technology sufficiently corresponds to the named requirements. It is TRIZ-pedagogic consisting in integration of studying of various disciplines and subjects with studying of Theory of Inventive Problems Solving (TRIZ). Earlier as a part of TRIZ-pedagogic there was a method of creative tasks at which studying of a new material still had reproductive character. Authors of the paper have added TRIZ-pedagogic a method of the invention of knowledge that has allowed to apply this system of innovative education at all stages of educational process. In this method each studied system (under any curriculum) is considered as the result of overcoming contradictions in system – its progenitor. The method can be applied at studying both anthropogenous, and not anthropogenous systems as laws of overcoming of contradictions at their development are identical.

Keywords-Innovative Education; Methodology of Creativity; Training for Generation of Ideas; TRIZ-pedagogic.

I. INTRODUCTION

The issues of education modernization in accordance with the requirements of the global innovation society being formed in the recent years have become very important for the world society and the heads of the leading states of the world. Thus, these issues were also considered at the G-8 Summit meeting which took place in Saint-Petersburg in July 2006 when the document “Education for innovative societies in the 21st century” [1] was accepted. Besides the range of other objectives the document presents the evident objective of teaching to generate ideas and solve problems.

The formulation of such requirement is a serious event in a number of sciences, including psychology and methodology of creativity. Statement of this requirement by Governments of the world leading states, in essence, means a final refutation of settled (though far from true) opinion that creativity, generation of ideas, solving of problems cannot be taught; that the generation of ideas is possible only on "inspiration", "insight", a trial and error method, search of numerous quantity of variants from which only few appear correct.

The new problem demands search or development of corresponding innovative educational methods, technologies, systems. In the G8 document mentioned above it is told directly: "The Economy based on knowledge demands innovative educational systems …".

This paper considers conformity of existing educational methods to the named requirements and offers a new method based on TRIZ.

II. THE ANALYSIS OF EXISTING INNOVATIVE EDUCATIONAL SYSTEMS

A few dozens of such innovative systems are known now. They are implemented at the secondary, primary and even preschool education, in basic vocational training to greater extent, and to a lesser extent in higher education. It is possible to explain this, in particular, by the fact that in secondary and also in basic professional education the significant part of a contingent of trainees requires special measures for good mastering curriculums. In higher education it is considered (though it is not quite true) that if the contingent of trainees (students) has passed competitive selection, they are capable to study successfully in accordance with the classical system of lectures and seminars. Besides, many innovative systems applied in preuniversity education are aimed at formation of students’ qualities important in a daily life, in less skilled work, but not specific to professionals with higher education.

As the result of such analysis the authors group including authors of this paper developed the scale of different educational technologies innovation level, level of their matching to the task of teaching the ideas generation and problems’ solving [2]:

The 1st level: innovative educational technologies where innovators are scientists and teachers – their authors, but trained persons (pupils and students) develop important, but other qualities than abilities to generate ideas and solve problems as a result of application of these technologies.

The 2nd level: innovative educational technologies where innovations of scientists and teachers are aimed
at development of cognitive sphere of trainees: theoretical thinking, functional literacy, etc. (according to the requirements of the International Comparative Research of Educational Achievements PISA, but not above them).

The 3rd level: innovative educational technologies which provide psychological conditions for ideas generation and problems solving where innovators are scientists and teachers – their authors and as the result of their implementation some trainees become innovators (creators of new ideas referred to different fields of knowledge and human activities). We can consider as the example of such technologies the method of projects of J.F. Dewey and W.H. Kilpatrick.

The 4th level: innovative educational technologies giving technological cogitative tools for the development of abilities to generate ideas and solve problems where innovators are scientists and teachers – its authors, finally the innovators (founders of the new ideas concerning various fields of knowledge and human activities) are all the trainees showing purposefulness in mastering and application of these cogitative tools.

Historically the above mentioned levels were created, in general, consistently. One can compare their development with the integrated scheme presented in Fig. 1 [3, 4]. On this scheme the 1st level basically refers to the Past (though it is still widespread in the Present), the 2nd and the 3rd levels refer to the Present, the 4th level – to the Future.

Just these innovative educational technologies of the 4th level correspond to requirements of training for ideas generation and problems’ solving presented in the document "Education for innovative societies in the 21st century".

**Fig. 1.** Evolution of educational technologies

### III. TRIZ-PEDAGOGIC

The innovative educational system of the 4th level is known and is developing quickly now – TRIZ-pedagogic [5] based on applying in education the Theory of the Invention Problems Solving (TRIZ) created by the Russian scientist G.S. Altshuller (1926 – 1998) [6, 7] and developed by his scientific school. TRIZ considers the process of solution inventive and, in general, problematic tasks as dialectic process of overcoming contradictions in improved systems, and contains, in addition to classical dialectics, tool methods of contradictions overcoming.

Modern TRIZ-pedagogic has a goal to, first of all, develop the ability of trainees to solve evidently problematic tasks in their professional and other fields of activity, and also to solve other topical problems of modern and future education by means of TRIZ.

TRIZ-pedagogic reaches these purposes mainly by integration of TRIZ (the modern name – applied dialectics) with a teaching material stipulated by programs of other disciplines and subjects.

### IV. METHOD OF CREATIVE TASKS

The most famous way of such integration is the Method of Creative Tasks (Timokhov, 1996, 2000 – 2010, Modestov, 1998).

Creative tasks are locally problem tasks (that means that the mankind knows how to solve them, but not the trainees) demanding application of TRIZ and knowledge which is studied under the program of a corresponding subject or discipline. The solution of a task can fall out of the limits of the studied subject or discipline but the solution consists of application of knowledge which is stipulated by the program of this subject. Most of all such tasks are now created in the field of biology, but there are also tasks from other areas [8 – 10].

The method of creative tasks is aimed directly at the development of the trainees’ abilities to generate ideas and solve problems. This method has allowed to start the process of integrating various disciplines and subjects with TRIZ. At the same time this method has not occupied the whole class (may be except for some lessons and classes totally devoted to creative tasks). Implementation of a new material under study only as the "funds of effects" in order to solve creative tasks most of the time preserved the reproductive character of the learning the material stipulated by the programmes.

### V. METHOD OF KNOWLEDGE INVENTION

To expand the implementation of the TRIZ method for all stages of education process the authors of this paper have developed and successfully tested the method of knowledge invention. A number of ideas which initiated the development of this method were represented by V.A. Bukhvalov and Y.S. Murashkovsky, the authors of some creative tasks, in their book “Inventing a Turtle” [11].

“Invention of knowledge” is a mode of training, in which each studied system (under any curriculum) is considered as the result of overcoming contradictions in system – its progenitor. (For example, the predecessor of the internal combustion engine is the steam engine, of the Einstein’s theory of relativity – mechanics of Newton, of arithmetic operation of multiplication – operation of addition, of birds – amphibious, etc.).
At “Invention of knowledge” trainees can find other, unexpected, but effective, solutions. In such cases development of these solutions can be continued: in high schools – in research work of students, at secondary schools – in additional education.

During development of lessons and classes using the method of knowledge invention some methodological issues appear, while the objects of study in various sciences and corresponding academic and school programmes are totally different systems. Only some of these systems are anthropogenic, i.e. created by people. And the TRIZ science has been created for people, for them to create new systems more perfect than existing ones.

Such issues do not appear only during studying of anthropogenic systems (for example, technical). Almost each anthropogenic system has its predecessor, also created by people. And even if the anthropogenic system under study was created without application of TRIZ (and most of systems are such while TRIZ science is very young), nevertheless during its creation contradictions were overcoming using laws (not realizing, on intuition) which now are known as TRIZ methods. Studying such system it is mostly important to determine these accidentally found methods which now are known as TRIZ methods. Trainees under supervision of the teacher pass “an intellectual way” of the first inventors of these systems, pass much more quickly and effectively, due to TRIZ application.

One of methodological problems being worked on by the scientific team which includes the authors of this report as well arises during the study of non-anthropogenic systems. People have not taken part in their creation. In this case, one cannot mention even accidental, non conscientious implementation of TRIZ methods. Nevertheless, the authors of the “Inventing a turtle” book mentioned above successfully “re-invent” using the TRIZ methods the existing living beings having taken as the prototypes the organisms created earlier by the evolution. This fact allows to suggest a hypothesis: behind each TRIZ method some real world regularity stands functioning as in anthropogenic, so in non-anthropogenic world. Its “work” in the anthropogenic world reflects in the TRIZ methods, and in non-anthropogenic – in similar regularities.

The research carried out by the authors has confirmed this hypothesis and has shown that it is possible to learn how to generate ideas, solve problems during studying natural science disciplines and subjects. For example, while studying biology one can “invent” using TRIZ methods the studied living beings, populations, separate organs and systems of organisms, etc. While studying geography one can “invent”, for example, mountains and depressions (as the result of “transfer to another dimension” principle during collision of lithosphere plates), while studying astronomy – to “invent”, for example, ball shape of stars and planets (as the result of the Curvature principle at concentration of interstellar matter), etc.

Thus, the researches and workings out in the field of TRIZ-pedagogy have lead to new results in TRIZ itself and in its distribution on non-anthropogenic systems and allowed to distinguish the concepts of “classical TRIZ” and “applied dialectics” which before have been considered synonyms.

Similar methodological problems exist at studying social systems. A society (all world civilization, the population of any country, collective of employees of firm, a class at school, etc.) is a system consisting of people and, hence, created by people. However, not like, for example, technical systems also created by people, the society, as a rule, only partially grows out of an embodiment of certain human plans, and to some (during some historical epoch considerable) degree is the result of an antagonism of various, often opposite, aspirations of various people, social groups. Therefore, the society has features of both anthropogenic, and non-anthropogenic systems.

Nevertheless, the society as well as other systems, develops under dialectics laws. Laws of applied dialectics "work" in it as well. The mankind history can be considered as a history of the problem tasks solved or not solved (solved not in time) by people: statesmen and politicians, commanders, scientists, art workers, religious figures, etc. When in the next topic of history the successful solution of any figure is being studied it is important to find in this solution display of the laws of systems development contained in TRIZ (though this figure has applied the named laws spontaneously, on inspiration, without knowing and without formulating them). If any unsuccessful solution is being studied, the analysis of other possible solutions on the TRIZ basis is very useful.

The similar approach is possible and appropriate for literature studying. Literary works are, of course, created by people, but in them frequently, on intention of writers, characters make irresponsible or half-responsible actions, or the writer himself does not see, how the character could solve this or that problem successfully. It is typical that the youth often prefers the literature in which characters find way out of problematic situations (detectives, fantasy, etc.) and does not like the literature where main characters do not solve any problems. Interest to studying such literary works can be raised essentially by organizing discussions on the possible solutions the character could have made implementing TRIZ. In these literary works where characters solve the problems, it is very useful to find TRIZ laws which the writers have spontaneously applied.

Reading good fantastic books is, in this respect, extremely important. It was urgently recommended by G.S. Altshuller, the author of TRIZ, who himself, under a pseudonym G. Altov, has written and published a number of fantastic stories: collections “Legends about Star Captains”, “ Burning Mind”, “Created for a Storm”, “Flying in the Universe”, etc. More information on its
can be found on the site [12]. Many fantastic books have been created by his followers thanks to TRIZ.

It is also important, in particular for teaching children of younger age, but for children of other ages as well, to read good fairy tales. The major role of fairy tales in education of children is the formation of the idea that the world can be better, than it is now, a motivation to act to contribute to the world improvement. In many fairy tales problems of characters are solved by means of magic, in a miracle way, but it is important that they are solved. At the same time, various nations have many fairy tales where it is explained how the characters have managed to solve their problem, and these ways always consist in finding and fulfilling extraordinary courageous creative thoughts.

Nowadays the youth often prefers watching screen versions of literary books at cinema, on TV, in video recording to reading these books. Many representatives of the senior generations criticize this state of things, but it should be remembered that the information flow while watching is more intensive than during reading. It does not change the state of things: the relation to the films viewed, and also to theatrical performances can be and shall be created the same way as to literary works.

To sum it up, we can say that plot development in all works mentioned above goes by the S-shaped curve known in TRIZ: 1st stage corresponds to an exposition; 2nd stage – rising action; 3rd stage – the culmination; transition to the following S-shaped curve (in works with the happy termination) or system destruction (in works with the tragical termination) – an outcome.

Even in short literary works (in verses, or, for example, classical Japanese haiku) it is possible to find the S-shaped curve (probably, not smooth, but “broken”). We take, for example, haiku of the Japanese poet Issa (1763 – 1827): “The moon here has come up, and the smallest bush is invited to a holiday”. “The moon here has come up” is 1st stage of a S-shaped curve (exposition). “And the smallest bush” is an unfinished sentence, but in essence it is the 2nd stage (rising action) with transition to the 3rd stage (culmination) as describes process of illumination by the moon of all nature, finishing the smallest bush. “Is invited to a holiday” is a transition to the new S-shaped curve (outcome).

There is a variety of arts in which the image does not change with time (plastic arts): fine arts, sculpture, architecture, etc. However, there are laws of images perception known in psychology according to which the image both is visually perceived, and is analyzed by a brain consistently. The S-shaped curve of development at perception plastic arts pieces is passed by each spectator individually. It still exists, but it "is taken out" from work of art into a brain of the spectator (the "Taking Out" principle).

From the aforesaid it follows that in engineering education it is possible to learn to solve problems and to generate ideas even when studying natural-science and humanitarian disciplines. It is especially important in connection with transition to a new paradigm of engineering education "cooperation with the nature".

On Fig. 2 the graphic scheme of the invention of knowledge is shown. On the basis of this scheme a number of examples will be given below. The scheme looks like a table. Columns on the left and on the right coincide with left (Past) and central (Present) columns of the System Operator (the 9-screen scheme of talented thinking created by G.S. Altshuller). In sequence from the top to the bottom supersystems, systems and their subsystems being studied are shown. In the central ovals the laws now known in TRIZ are specified according to which contradictions in systems-predecessors have been overcome.

For example, at the lesson of physics devoted to engines, it is possible to "invent" an internal combustion engine. A prototype will be a steam engine where it is necessary to raise the efficiency factor but it is interfered by basic restrictions of thermodynamics. Applying the TRIZ law of expansion-curling, we "turn off" together a fire chamber and cylinders, excluding, as excessive elements, a copper, water and steam. Applying the TRIZ law of transition to microlevel, we replace firm fuel (coal) by liquid or gaseous one. The efficiency factor essentially increases.

![Fig. 2. The graphic scheme of the invention of knowledge](image)

On Fig. 3 the graphic scheme of "reinvention" of internal combustion engine is given.

![Fig. 3. Evolution of engines](image)

Further, deepening curling, excluding cylinders, pistons, a cranked shaft, etc. we receive the turbine.

At the lesson of physics where radio begin studied, it is possible to "invent", for example, a modulation principle (amplitude, frequency, phase, etc.). A prototype is radio telegraph. With its help it was impossible to transmit sounds. To radiate in an aether and to receive waves with the frequencies equal to sound is im-

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**Fig. 2. The graphic scheme of the invention of knowledge**

**Fig. 3. Evolution of engines**
possible too, because aerials of the huge sizes are required for this purpose. Besides, radio stations will disturb each other. Applying TRIZ principles of the intermediary and copying, we come to a determination: the intermediary – high frequency which is easy for radiating and receiving by rather small aerials, and amplitude of fluctuation with this frequency "copies" low sound frequencies. The graphic scheme of "invention" of amplitude modulation is shown in Fig. 4.

**Fig. 4.** Creation of idea of amplitude modulation

Let's see how this can be implemented, for example, in mathematics. We will consider the examples connected with studying of numbers and functions. It is obvious enough that fractional numbers have appeared due to spontaneous application of the principle of Segmentation to integers. Creation of negative numbers is the result of spontaneous application of the principle of "Other Way Around" to positive numbers. Irrational numbers have appeared as the result of applying the principle of Continuity of Useful Action to rational numbers: numbers occupy continuously all numerical axis. Complex numbers are the result of applying the principle of Transition into Other Dimension to real numbers (expansion of a real numerical axis to a complex plane). Variables are the result of applying the law of Increase of Dynamism and Controllability and the Dynamism principle to constants. Function of one variable is a bi-system, and function of many variables is a poly-system.

It is similarly possible to consider an example from physics, but not regarding technical devices, but the fundamental laws of the world – the Einstein theory of relativity. The system is represented by the predecessor of the theory of relativity – Newton laws. The role of Newton laws in machinery development cannot be underestimated even nowadays. But in due course insufficiency of Newton laws for the description of some physical supervision (for example, experimentally proved independence of the velocity of light from the velocity of its source) was found out. The special and general Einstein theories of relativity were results of spontaneous application of the principle of Local Quality (to pass from homogeneous structure to heterogeneous) at first to time (time flows unequally), and then to space (having different curvature), see Fig. 5. The contradiction between the theory and the practice, known, as "crisis in physics" is thus eliminated.

**Fig. 5.** Creation of the theory of relativity

At the lesson of chemistry it is possible to outline, for example, that creation of a periodic table by D.I. Mendeleev has appeared due to spontaneous application of the principle of Periodic Action, and F.A. Kekul'e's guess about cyclic structure of benzene is a result of spontaneous application of the principle of Curvature (Fig. 6).

**Fig. 6.** Creation of idea of molecule cyclic structure

Let's consider the example of "invention" of non anthropogenic system. For example, the theme "arthropods" is studied. It is considered that evolutionary predecessors of arthropods – the annelidas have been living in soil. They could not stay for long at the soil surface in connection with drying effect of air and sunlight on their epithelium. At the same time, according to the principle of expansion of life, in the course of evolution on the soil surface there should be living organisms, and they have appeared, in the form of arthropods, occurred from annelidas. The technical contradiction: "With increase of time of staying at surfaces the epithelium inevitably dries up" was eliminated on the basis of the law corresponding to the standard 1.2.2 "Elimination of harmful communication by introduction of modified substances". On an integumentary fabric of arthropods there is a modification of the epithelium – the cutinous cover which is carrying out protective, and also support function (Fig. 7).

By the knowledge invention method TRIZ is studied contextually, by application examples. Concepts of TRIZ "are built in" (by the Nested Doll principle) in usual educational texts, replacing usual logic connection between concepts with dialectic-logic communications (in understanding of dialectics, as applied, i.e. TRIZ). Thus no more time is required for studying any discipline or a subject, but actually they are studied in integration with TRIZ. Such studying simultaneously helps to understand better the material of studied disciplines or subjects.
The method of the invention of knowledge is described in more details in the books [3, 4] which are published now in Russian, but publishing of the book with the description of this method in English is planned as well.

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