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TRIZformatics: A Metasubject Uniting Computer and Intelligence Technologies of Information Processing (Response to Information Society Challenge)

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The paper describes analysis of requirements for the course of informatics brought by the emerging informatics society. In order to meet these requirements, the authors offer a course of TRIZformatics, a "Perm version" of a propaedeutic course of informatics uniting computer and intelligence technologies of information processing. The course contents and published methodological complex are described.

Transformation of Russia into an information society creates a challenge for educational system as a whole, as well as for informatics teaching technologies. We offer a solution for this set of requirements: a "Perm version" of a propaedeutic course of informatics [1–4] called "TRIZformatics." This name is a neologism combining the words "TRIZ" (standing for "the theory of solving inventive problems" in Russian) and "informatics", similar to the neologism "informatics" that appeared half a century ago by combining "information" and "automatics". The course is developed by M.A. Plaksin, N.I. Ivanova, and O.L. Rusakova. The paper presents the authors' point of view on the role of informatics at school and realization of this point of view in a series of text books and supporting methodological materials.

WHAT REQUIREMENTS ARE SET FOR INFORMATICS IN THE COURSE OF TRANSFORMATION INTO INFORMATION SOCIETY?

Russia is on the way to information society. This transfer is accompanied by enormous growth of the volume of information and complexity of the world around us, as well as by the growth of the update speed for knowledge and nomenclature of the problems being solved.

Two significant problems are set for education by this transfer. These are (1) the problem of student overload and (2) the problem of lack of correspondence between education requirements formed by demands of the present industrial society and requirements of the growing information society.

Both problems have objective reasons.

The first one follows from the contradiction between an avalanche-like growth of the volume of knowledge required to be mastered by students and the constraints of the abilities. The fast growth of the volume of knowledge is objective reality, the result of development of science and the growing complexity of the surrounding world.

The main solution of this problem suggested today is extensive: increase of education period or resolute cut of education programs. It is obvious that this way is a deadlock. We would either need to permanently increase education period or agree with a growing gap between school education and science achievements.

The second problem, lack of correspondence between orientation of school education and requirements of the modern society, has historical roots. Modern school appeared due to mechanized production that required that a worker could manage machinery. Industrial society needed an employee, who was able, first of all, to follow strict technological discipline. Information society needs a "problem solver" (including problems that are not yet known).

Transformation into information society is linked with acceleration of technology development. In agrarian and industrial societies, a "life" of "technological generation" was longer than a "life" of biological generation. Once having mastered some occupation, a person used this knowledge during his/her whole life. Experience added nothing but value to an employee. In information society, change of "technological generations" is many times faster than the change of biological generations. During the life, an employee has to constantly update knowledge store, has to "run as fast as one can in order to stay in one place."

During a long period of time, information-communication technologies (ICT) were considered to be the main tool for solving the problems mentioned above. But practice showed that even the most powerful computers are helpless when the users lack intellectual capabilities. In information processing, computer can strengthen human abilities, but it cannot replace them. Computer serves as a scaling factor rather than as a summand. If a human is able to organize information storage and processing, then computer will strengthen these abilities manifold. But if a human cannot do this, no computer will help (zero may be multiplied by any number).

To solve the problems mentioned above, it is required

(1) to intensify education (without increasing education period, give more knowledge during the same period of time),

(2) to re-orientate educational system from reproduction to problem research (to teach a "problem solver" capable of finding and formulating a problem that does not yet exist and solving it efficiently rather than a reproducer of the acquired knowledge), and

(3) to learn to study (educate a person capable of permanent independent professional and cultural self-development).

The achievement of these goals will become possible if school program includes the courses of logic, system analysis and TRIZ/RTV (standing for "development of creative imagination" in Russian). Since it is impossible to do this in the form of separate subjects, these courses need to be integrated in the existing program. Informatics is the most appropriate school subject for this, as it is the most flexible and the closest to the disciplines mentioned above.

Integration of informatics, logic, system analysis, and TRIZ/RTV will turn informatics into a course of "strong reasoning," which is aimed to provide students with instruments for mastering all other school disciplines, including both technological and intellectual instruments.

So far, the main school subject aimed to develop thinking abilities was mathematics. However, it is not enough today. One needs to know basic notions and methods of classical system analysis and its modern extensions: TRIZ; addition to mathematical logic with elements of classical Aristotle logic, on one hand, and with contradiction-based dialectical logic, on the other hand; skills of structuring large amount of information; transfer from purely syntax (formal) information processing to semantics- and pragmatics-based processing; skills of assessing information usefulness and validity.

When combining studying of ICT and modern reasoning technologies, informatics will provide a possibility to intensify education and will become a basic discipline for school in information society.

ALGORITHMICS–COMPUTERICS–INFORMATIONOLOGY–SYSTEMOLOGY–TRIZFORMATICS

If we look at the development of school informatics from the point of view of the main tasks put for the course at each moment of time, we can see 5 stages (each of them, rising by a dialectical spiral, includes achievements of the previous stage):

1. *Informatics–algorithmics.* In 1985, school informatics was born under the motto "Programming is the second literacy" and was concentrated on acquaintance with computer, developing algorithmic thinking, and acquaintance with programming foundations. Huge effort was made to teach everyone to use primitive Basic and, later, Pascal.

2. *Informatics–computerics.* Transfer to this stage took place at the beginning of the 1990s. The questions of preparing a qualified user and use of computer in everyday life were moved to the front place. The triad "Lexicon–SuperCalc–dBase" became the symbol of computer literacy.

3. *Informatics–informationology.* This ideology dominated in late 1990s and early 2000s. The main direction of this stage is fundamentation. "Information" becomes the basic notion of the course. Everything else is regarded as derivatives (algorithm is control information, computer is a device for information processing, etc.). This ideology is clearly expressed in the "Perm version" of the base course of informatics developed by the team of authors directed by I.G. Semakin.

4. *Informatics–systemology.* The present day stage. The main feature of this stage is extension of the course by including elements of system analysis. The necessity of studying the basis of systemology at school became evident some time ago, but it could not be included in the school course. School education is built on the disciplinary principle; system is an interdisciplinary notion. It can be interesting and useful for any school subject but does not belong to any of them. The new state educational standards now include the notion of interdisciplinary knowledge.

Inclusion of system analysis into the course of informatics turned out to be the most natural, because studying of any system is construction of some form of its information model. This is what informatics deals with.

The idea of necessity of introducing the basics of system analysis into school course was first mentioned by the author of the present paper as early as 16 years ago [5–7]. Systemology methodological materials were first offered to "broad pedagogical masses" in two-volume "Book of practical problems" developed by a group of Perm authors and published in 1999 [8]. After this, different textbooks began to include chapters devoted to tables, systems, etc. Today, the basics of systemology go "down" to primary school [1–4].

5. *Informatics–TRIZformatics, informatics–strong reasoning.* What is the next step of informatics development? Information society requires development in the direction of solving inventive problems and development of dialectical reasoning.

Systemology gives tools for situation analysis, for choosing the best solutions. This implies an inevitable question: where are these alternatives taken from, how can one learn to generate possible variants of solving a specific problem?

Talking about information, three aspects can be named: syntax, semantics, and pragmatics. Modern informatics is almost entirely concentrated on the syntax aspect. We accumulate large volumes of information without taking an interest in how meaningful or useful it is. We say that informatics is a science studying information representation, storage, transfer, and processing. But today, we do not even try to raise a question about *purposeful* generation of *required useful* information.

Fortunately, we have a good base for transfer to "semantics–pragmatics" approach to information, the theory of solving inventive problems (TRIZ). TRIZ was created in the second half of the XXth century by the Soviet scientist G.S. Al'tshuller and his students. The basic TRIZ points are as follows: there exist objective laws of system development; these laws are cognoscible; these laws can be consciously used for purposeful system development in the required direction; development happens through solution of contradictions.

Today, TRIZ is actively implemented in different areas of human activities. The so-called general theory of strong thinking is built on the basis of TRIZ.

Synthesis of the formal (syntax) informatics approach with the TRIZ semantics–pragmatics approach and uniting of informatics and TRIZ into a new discipline, TRIZformatics will be extremely useful.

CONTENTS OF TRIZFORMATICS COURSE

In what way the ideas described above are implemented in the "Perm version" of propaedeutic course?

The course is built on the basis of four interconnected notions: information, system, algorithm, and computer and includes both traditional informatics issues (information, algorithmics, ICT) and a number of innovations.

The main innovations in the course contents are as follows:

1. Systematical usage of basic system analysis notions: system, system effect, system functions, universal system character of world (including analysis of cause–effect relations and consequences of real and hypothetical actions).

2. Mastering and usage of TRIZ notions and methods: dialectical contradictions and methods to solve them; concept of an ideal system; formula for estimating the degree of the system "idealness" and its application to determine the ways of system improvement; resource mobilization.

3. Teaching information structuring [9], including

– use and development of dictionaries, directories, and catalogues;

– construction of tables of different types (from the simplest tables to complex computational ones);

– construction of diagrams of different types; and

– hierarchical organization of computer storage of information.

Large volumes of data are considered as systems with system effect consisting in the fast access to information and fast information processing.

4. Studying the basics of logic: simple and complex predicates, logic operations, deductions, and quantifiers. Teaching logic includes nontraditional tools: packs of playing cards with edge perforation, solution tables, and characteristic tables [10].

5. Mastering of the notions of classification (including multilevel classification) and generic definitions.

6. Mastering the technique of experimental investigation of the world.

7. Systematic application of "open problems" in the educational course.

8. In the "Algorithmics" section, considerable attention is devoted to the descending techniques of algorithm development, its testing and verification.

The course has a spiral structure: the same topic is studied in several grades, with the material studied in each next grade becoming deeper and wider.

This course can be read by an informatics teacher or by a primary school teacher. The latter is preferable from the point of view of flexibility of educational process organization and interdisciplinary integration (using knowledge and skills acquired at informatics lessons for studying other subjects). This provides realization of the activity approach for knowledge acquiring, increases course efficiency, and provides mutual enrichment of all subjects.

SCHOOL METHODOLOGICAL COMPLEX FOR THE COURSE OF TRIZFORMATICS

In 2011, BINOM publishing house issued "Informatics and ICT: 3–4 Grades" series included in the Federal list of textbooks for 2011–2012 academic year [1, 2]. In summer of 2011, the textbooks were presented for official approbation according to the new state educational standard. The series will be continued up to the link with the basic course.

The school methodological complex for the 3d–4th grades includes

– textbooks for the 3d and 4th grades;

– computer practice;

– intellectual practice (book of problems);

– a set of comics “Informatics in pictures”;
– “Self-training”;
– a set of qualifying materials;
– teacher’s book;
– digital materials for teacher and students on CD;
– a set of option controls turning standard office programs into educational software.

An additional instrument of course support is an interregional Internet contest “TRIZstudent” for students of the 1st–11th grades, which is held every spring and attracts several hundred of participants from all over Russia [11] (details can be found on the websites www.trizformashka.ru and www.trizformashka.land.ru).

Let us consider the school methodological complex in more detail.

Textbooks do not need any comments.

Computer and intellectual practice. These are workbooks for practical activities.

Computer practice is devoted to studying ICT. It includes theoretical information based on textbook material and practical exercises. Publishing practice as a separate book has two goals. Firstly, this is a workbook for computer part of the course. Secondly, practice is aimed to protect the textbook from the fast change of software and hardware. Due to this, presentation of material in the textbook is more fundamental and invariant with respect to software–hardware resources used.

Intellectual practice contains problems that are solved without a computer.

Intellectual and computer practices are published in separate books, because the course can be taught both in a computer variant and a “without a computer” variant. There are several reasons for presenting the “without a computer” variant. First of all, not all schools have a sufficient number of computer classes that can be granted to primary school. Secondly, the course can be taught by a teacher of informatics or by a primary school teacher. For the present moment, for many primary school teachers, “without a computer” course of informatics will be much simpler than a computer one. Thirdly, computer lessons imply division of the class into halves, which makes the schedule more complicated. Finally, on the conceptual level, we believe that the “without a computer” part of the course is more important than the computer part. Modern children will master computer without the help from school. On the other hand, it is only at school where they can learn the basics of system analysis and dialectics.

The possibility of the “without a computer” teaching is provided by a redundantly large number of problems in the intellectual practice.

The following components of the methodological complex are not traditional. “Informatics in pictures” is a series of comics devoted to a number of complicated topics, such as search of words in a dictionary, study of a black box, and the like. “Self-training” is a manual presenting material of the course in the form of questions and answers. They are located in such a way that a child can revise the material studied in class by himself and control his knowledge. The manual is also useful for teachers (as a source of questions and answers for oral and written tests) and for parents (as an instrument for controlling their children’s knowledge).

Teacher’s book is a traditional component. It presents a special interest for us, since the course is innovative. The book includes description of all theoretical questions, analysis of practical problems, lesson-wise planning, and detailed lesson scenarios (up to the times recommended for studying one or another question). The latter can be redundant for an experienced teacher but can turn out to be useful for a beginner.

The set of qualifying materials includes variants of control tests of different levels with solutions.

The set of option controls turning standard office programs into educational software is another “know-how” of our methodological complex. Special programs re-customize interface of MS Office 2003 and OpenOffice packages, so that children do not have access to the whole variety of program options but only have access to the functions that are necessary for studying a current topic. Other functions are hidden.

REASONING DEVELOPMENT IN THE COURSE OF TRIZFORMATICS

The main instrument of information processing is human’s head! One needs to know ICT. But we think that it is more important to teach a child to think.

What should thinking of the future information society citizens be like? To our mind, it should be systematic, dialectical critical, logically correct, open, responsible, and investigative. How does the “Perm version” form these qualities?

Forming of *systematic* and *logical* thinking has been mentioned above, when the course contents was described.

Dialectical thinking. From the first school year, children are taught to apprehend contradictoriness of the world. Apprehension of the “contradictoriness” notion occurs in four stages: contradictoriness in comparing two systems (one is better in some way, another is better in another way), contradictoriness in the properties of one system (there is something good and something bad in any system), contradictoriness of one property (any property can be either good or bad depending on situation), contradictoriness of the system as a source of its development (system improvement is aimed to eliminate its drawbacks; during this process new drawbacks appear, which should be eliminated in turn). Investigating contradictions makes it possible to enhance understanding of the systems under consideration; to acquire experience of reasoning as a method of acquiring knowledge; to develop critical mind; and to compare different methods of information representation.

Critical thinking is a direct consequence of dialectical thinking directly. A child knows that any system has drawbacks and that getting rid of these drawbacks generates new ones. One should to be able to compare importance of the drawbacks and choose a variant with less important ones.

Openness. We aim consciously and purposefully to lead a child out of the world of well-formalized "closed" problems (with accurately defined conditions, input data and results, and solution algorithm) to "open" problems (with fuzzy conditions, multiple ways of solution, a number of possible results with different degrees of admissibility), i.e. the problems he/she will meet in real life. The students acquire extremely useful skills: an ability to fully analyze problem conditions, to define what is a problem solution, what necessary data is missing; to determine possible sources of the missing information; to find necessary data in different sources or to deduce them from the known facts; to be able to use approximate data; to be able to assess results critically. Open problems make students to attract knowledge and skills from different subject areas.

Responsibility. When studying the "System character of the world" topic, children learn to construct cause-and-effect relation chains and analyze consequences of their own (real or hypothetical) actions.

Investigative character. Traditional school teaches the child to apprehend knowledge from the grown-ups dogmatically. Any idea can be either correct or incorrect. Correctness is determined by opinion (of parents, teachers, books). We give a mechanism of acquiring new knowledge by representing an unknown event or object as a black box. A child will learn that knowledge is derived from experience, that practice is a criterion of validity, and that the main advantage of any theory is its ability to predict future.

The course of TRIZformatics is aimed to prepare a child to the life in the world that can be different from today's world in terms of most different and unexpected parameters, which will change rapidly and significantly all the time.

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