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**THE ENVIRONMENT OF AUTOMATED TRAINING WITH PROPERTIES  
OF ADAPTATION BASED ON COGNITIVE MODELS**

Specialty 05.13.01 – “The system analysis, control and information  
processing” (technical systems)

**AUTOABSTRACT**  
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Work was performed at “The Saint-Petersburg state electrotechnical university "LETI" named after V.I. Ulyanov (Lenin)” (“The SPbSETU "LETI"”) in 2005 y.

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## GENERAL CHARACTERISTIC OF WORK

**The relevance of a theme of research** is explaining by the evolution of priorities from outside of the state and international bodies regulating the policy of development of an system of education and informatization of educational sphere, the extension of requirements to the synthesis of information environments of educational establishments, the imperfection of scientific-methodical and technological device for the analysis and assessment of efficiency of information exchange between subjects and means of training in educational process, the absence of universal scientific approach (method and technology) to the assessment of quality of training, developed in the context of applied bases of physiology, psychology, linguistics and etc., and also continuous development and emergence of innovations in the field of the inf. technologies (IT) and environments of programming, the emergence of a set of problems in various spheres of social activity, influencing on consumer preferences of educational services.

The globalization of information environment of post-industrial society and high rates of scientific-technical progress cause the exponential growth of flows of information as cumulative unit of knowledge on various subject areas, that defines the specifics of educational process, covariant to limited time of training and opportunities (physiological, psychological and linguistic) of subjects of training, which consumer preferences in a mediated way also influence on organizational-methodical and technological bases of educational process in the automated information-educational environment (IEE).

There is a need of creation of approaches, methods and technologies for a research of opportunities of the automated IEE and assessment of quality of functioning of the adaptive training means developed in its, allowing to generate information-educational influences based on the individual features of the person of subjects of training (IFPST).

**The theoretical-methodological basis of research** is reflecting in scientific works of the russian and foreign scientists: questions of organization, technical and methodical supply of the automated training in the sphere of the higher education (Yershov A.P., Kashitsin V.N., Sovetov B.Ya. and others); programmed training and development of training systems (Briggs L., Harrison N. and others); technologies of distance training (Knowles M.S., Moore M.G. and others); perception of electronical inf. (Dillon A., Salomon G. and others); mathematical methods and models of the analysis and synthesis of automatic control systems (Yzerman M.A., Besekersky V.A. and others); theory of open systems (Moiseyev N.N., Haken G. and others); theory of modeling of training process (Bespalko V. P., Mashbits E.I. and others); theory of intellectual systems and lang. of representation of knowledge (Ivashchenko K.I., Pospelov D.A. and others), theory of algorithms (Gurevich I.B., Zhuravlev U.I. and others), object-oriented paradigm in integrated environments of programming (Zikhert K., Davies S.R. and others).

*The problem of synthesis* of IEE of “adaptive” training based on new IT was not rather widely solved, though many its aspects, including and not related with it directly, but extremely important owing to their fundamental nature, *were developed* by teachers, physiologists, psychologists, linguists, experts in the field of IT: systems of training and innovative processes in education (Galperin P.Y., Zagvyazinsky V.I., Makhmutov M.I. and others); personal-oriented education (Amonashvili Sh.A., Bondarevskaya E.V., Yakimanskaya I.S. and others); modeling and programmed training (Bespalko V.P., Gershunsky B.S., Talyzina N.F. and others); psychophysiology of perception (Izmaylov Ch.A., Croll V.M., Smirnov V.M. and others); cognitive psychology (Druzhinin V.N., Zinchenko T.P., Holodnaya M.A. and others); applied linguistics (Geek M. L., Kobrina N.A., Potapova R.K. and others).

The analysis of the modern stage of development of technologies (automated) training has allowed to reveal **the most essential various contradictions**:

- the existing technologies *of creation* of the automated means of training and training-methodical complexes (TMC) practically did not consider the features of information processing by the trainee as the subject of process of training;
- the improvement of organization and technology of the process of automated training causes need *of the analysis* of efficiency of functioning of the information-educational environment with taking into account of individual features of subjects (physiological, psychological, linguistical and etc.);
- the requirements to modern IEE initiate *the realization* of accumulation and expeditious data processing, characterizing individual dynamics of change of indicators of quality of formation of knowledge of trainees.

**As object of research** is the information-educational environment of system of automated (remote) training (ART) of educational establishment.

**As subject of research** performs the automated training system with properties of adaptation based on parametrical cognitive models block.

**The hypothesis of research** is based on the assumptions about continuity of development of new IT and expansion of the sphere of their use in education, providing a possibility *of realization* of means of adaptive training in the automated IEE, considering physiological, psychological, linguistical and others features of subjects of educational process, allowing to increase efficiency of formation of knowledge of the trainee with the minimum loadings, transaction and temporary expenses, and also to sustain the required level of his preparation.

**As purpose of research** is increase of efficiency of functioning of IEE ART due to realization of individually-oriented formation of knowledge of the trainee with use of adaptive generation of educational influences based on block of parametrical cognitive models (CM).

According to the hypothesis and purpose the following **research tasks** were solved:

1. *The analysis* of theoretical bases of construction of the automated IEE of adaptive training with model of subject of training at base of the theory of automatic control, organizational models and technologies of interaction of subjects with educational means, and also the main actions at the organization of individually-oriented formation of knowledge: models of representation of information-educational influences, algorithms of training, specifics of realization of monitoring of progress and assessment of level of residual knowledge of the trainee.
2. *The synthesis* of structure of IEE of the ART system with properties of adaptation based on block of parametrical CM: features of channels of information interaction of subjects and means of training; specifics of organization, main technological stages of training as the operated process and components of the ART system.
3. *The creation* of cognitive modeling technology (CMT) for the analysis and increase of efficiency of functioning of the automated IEE.
4. *The formation* of CM of subject and CM of means of training at the base of IEE of ART.
5. *The development* of software for automation of research tasks.

It is necessary to carry to **the main methods of research**:

- theoretical – the theory of systems, the system analysis and modeling, structuring and representation of knowledge, engineering psychology and pedagogics;
- experimental – applied methods of physiology of analyzers, cognitive psychology and applied linguistics.

**The main scientific results, submitted on protection** and their novelty:

1. The structure of IEE and principles of functioning of components of the ART system with properties of adaptation based on block of parametrical CM – differ in a possibility *of realization* of an additional contour of adaptation on the basis of IFPST, allowing to increase efficiency of functioning of IEE of the ART system.
2. The CMT, including the technique of its use, the algorithm of formation of structure of CM, the technique of research of CM parameters, the algorithm of processing of a posteriori results of testing – allows *to respectively formalize* the sequence *of use* of technology, *to receive* structure of CM, *to provide* statement of an experiment and diagnostics of parameters of CM of subject of training, *to form* function of estimation and to calculate the indicators of quality of test on the basis of results of testing and in general *to carry out the complex analysis* of efficiency of functioning of IEE of the ART system in the context of a series of the chosen scientific aspects.
3. The structures of CM of subject of training and CM of educational means – accumulate respectively the parameters, characterizing IFPST and technical opportunities of means of training, *providing* adaptive generation of educational influences.
4. The complex of programs, including the adaptive means of training, the basic and applied diagnostical modules – provide an opportunity according to the automated individually-oriented generation of informational fragments, assessment of level of residual knowledge and diagnostics of parameters of CM of the trainee.

**The theoretical and practical importance of research** consists:

1. The bases of reorganization of IEE with taking into account realization of adaptation to individual features (parameters) of subjects of training were offered: structure of the ART system with properties of adaptation; specifics of training as operated process; features of structure of components of the ART system; bases of extraction of subject knowledge for purposes of construction of theoretical-reference modules of electronic textbooks and parameters of their assessment; specifics of use of means of multimedia in IEE of ART.
2. The organizational and technological modifications of IEE, and also the principles of functioning of components of the ART system at realization of a contour of adaptation based on block of parametrical CM were allocated.
3. The channels of information exchange of subjects and means of training in the ART system with properties of adaptation based on block of CM were considered, the key parameters, influencing on efficiency of formation of knowledge of the trainee in IEE were allocated.
4. The developed cognitive modeling technology provides the analysis of IEE.
5. The received structures of CM of subject and CM of means of training by means of the algorithm of formation of structure of CM allow to provide generation of informational fragments adequately of IFPST.
6. The developed technique of research of parameters of CM and algorithm of processing of a posteriori data of testing formalize according to the sequence of statement of an experiment and processing of a posteriori data.
7. The complex of programs provides automation of adaptive generation of informational fragments on discipline on the basis of previously diagnosed parameters of CM and the subsequent assessment of level of residual knowledge of the trainee.

**The reliability of scientific results** was provided by the system approach to the description of an object of research, correct use of fundamental provisions of computer science, engineering psychology and ergonomics, approbation of basic provisions of the dissertation on seminars and conferences of various level, results of statistical processing of a posteriori data of a series of experiments.

**The introduction of results of research** was carried out in "The Saint-Petersburg state electrotechnical university "LETI"" ("The SPbSETU "LETI"") and "The International banking institute" ("The IBI"), that was confirmed by the relevant acts about practical use.

**Publications.** On the theme of dissertation were publ. 43 on 2007 y. (80 on 2012 y.) scientific works: 01 textbook and 03 methodical instructions to lab. works on discipline "Computer science"; 02 units in 01 coll. scientific monography of "The IHEAS" (with forms. coauthors-teachers); 08 (16) training manuals and scientific monographies (without coauthors); 01 (02) report(s) on individual initiative SRW; 05 (12) scientific articles in scientific journals recommended by "The HSAC of The RF", from them 00 (05) scientific articles were deposited in "The VINITI" of "The RAS"; 22 (43) scientific reports in materials of 11 (24) international scientific conferences, and also 04 copyright certificates about deposition and registration of works – objects of intellectual property in "The RAS" (The RF, Moscow city).

**The structure and volume of dissertation.** The manuscript on the rights of monography consists of the introduction, seven chapters, conclusion, bibliographical list, including 68 nomens (without appendixes). The main part of work was stated on 262 pages of the typewritten text and contains 77 pictures and 29 tables.

## MAIN CONTENTS OF DISSERTATION

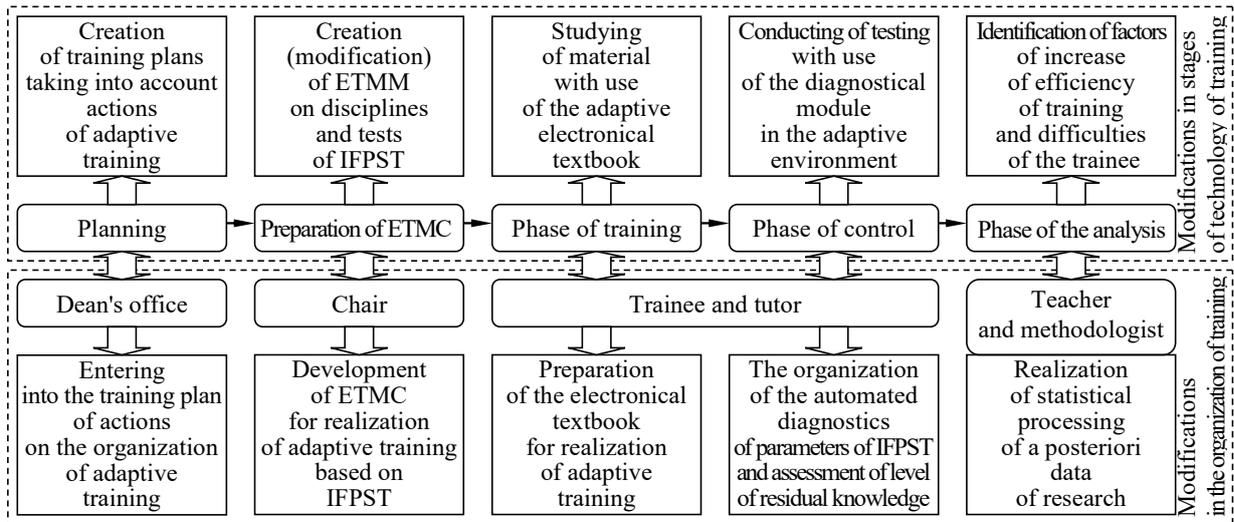
**In introduction** informatization of establishments of an system of education acts as the complex scientific problem initiating consideration of a wide range of scientific areas, and also creation of innovative approaches, methods, technologies and algorithms at realization of the automation means at the base of IEE, which provide a possibility of the analysis and increase of efficiency of functioning of the ART system.

**In the first chapter** “The condition of a problem of creation of adaptive intellectual environments of training” were proved the relevance of creation of adaptive intellectual means and environments of automated training, the analysis of a condition of problem and the existing contradictions, degree of readiness of a problem of creation of adaptive intellectual technologies and means of training, the purpose and tasks of creation of adaptive IEE of the ART system based on CM, stages of creation and the analysis of the environment of automated training based on cognitive models and the list of scientific results, submitted on protection.

**In the second chapter** “The analysis of information technologies and theoretical bases of creation of information-educational environments and automated means of training” were given the standards in the field of quality IEE, the priority aspects and directions of informatization, the basic principles of ART, the stages of development of automated means and environments of training, the features of organization of the IEE of ART (in distance), the characteristic of opportunities of the ART systems, the key parameters of assessment of modern means of training and development of their functional possibilities, the features of information exchange of subjects and means of training in the automated IEE, the factors influencing to efficiency of formation of knowledge of trainees in the automated IEE, the influence of components of the ART system on health of consumers (subjects of IEE).

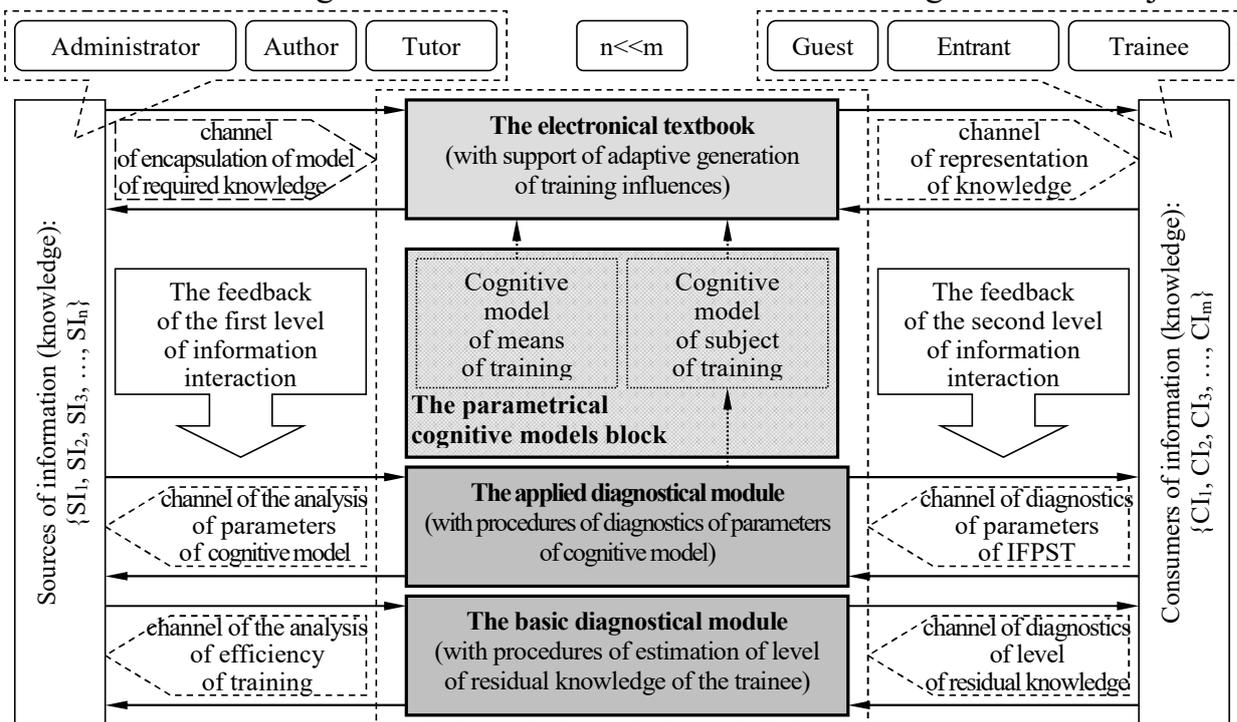
**In the third chapter** “The environment of automated training with properties of adaptation based on cognitive models” were considered the essence of approach to the complex solution of problem and statement of research tasks, the modifications in organization of IEE for realization of accounting of individual features of the contingent of trainees, the modifications in technology of ART for realization of a contour of adaptation based on CM, the structure of environment of ART with properties of adaptation based on CM (appointment and functions of the adaptive electronical textbook (ET), the basic and applied diagnostical modules (DM), structure of the block of parametrical CM), the processing and extraction of information, structuring of data and representation of knowledge for filling of ET (classification of sources of information, methods of knowledge acquisition on subject area, the main models of representation of knowledge, information structure of ET, sequence of filling by the structured information of content of ET), the formal description of adaptive IEE on the basis of the theory of control.

The realization of IEE of ART based on block of CM causes the organizational and technological modifications at various stages of educational process (pic. 1).



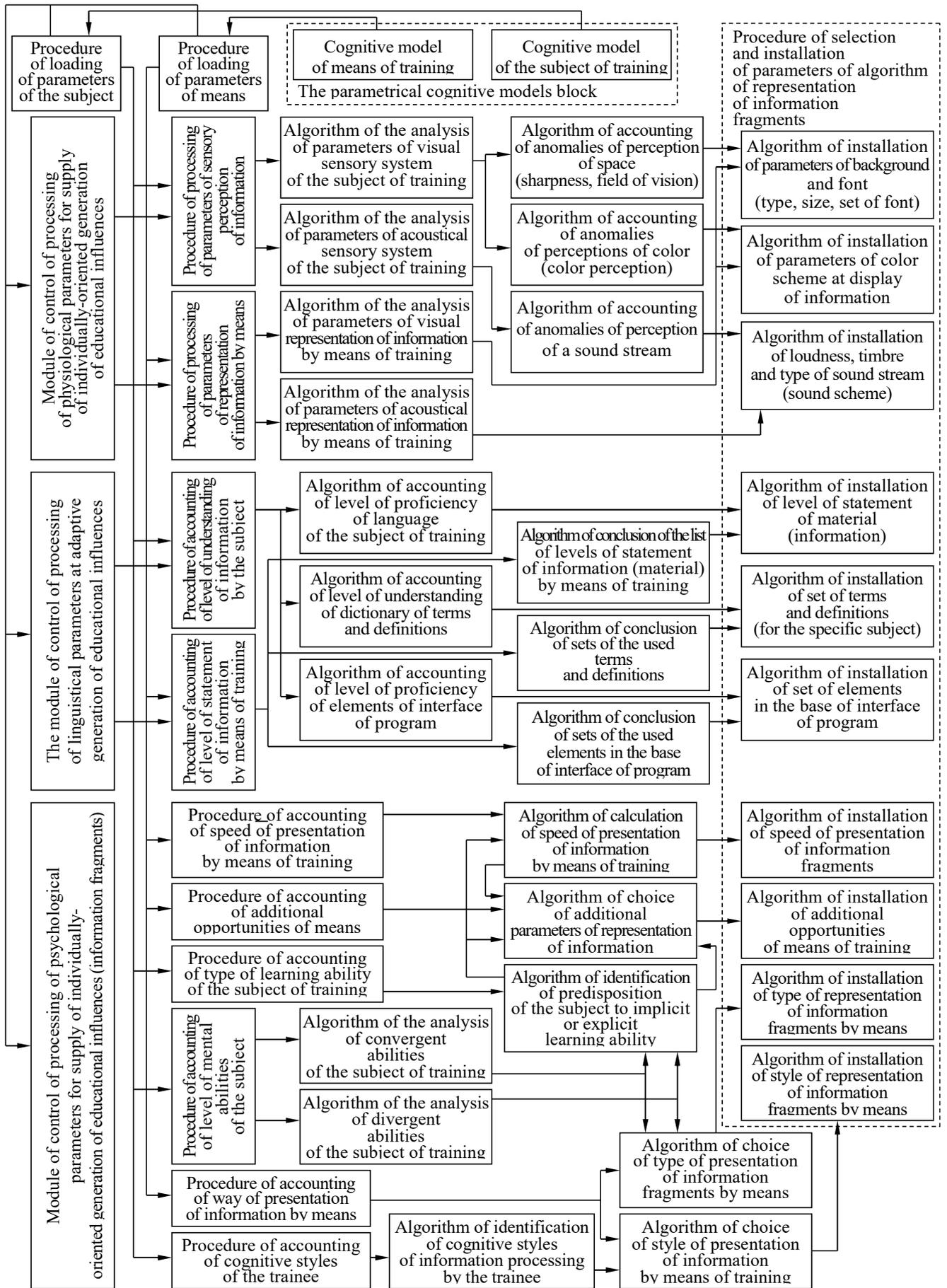
Pic. 1. Modifications in the organization and technology of formation of knowledge at realization of adaptive training based on parametrical cognitive models block

The general structure of the ART system with elements of adaptation based on block of parametrical cognitive models (pic. 2) represents the closed contour, including two levels of information interaction and several channels of exchange of information between two categories of subjects.



Pic. 2. The automated (remote) training system with properties of adaptation based on block of parametrical cognitive models

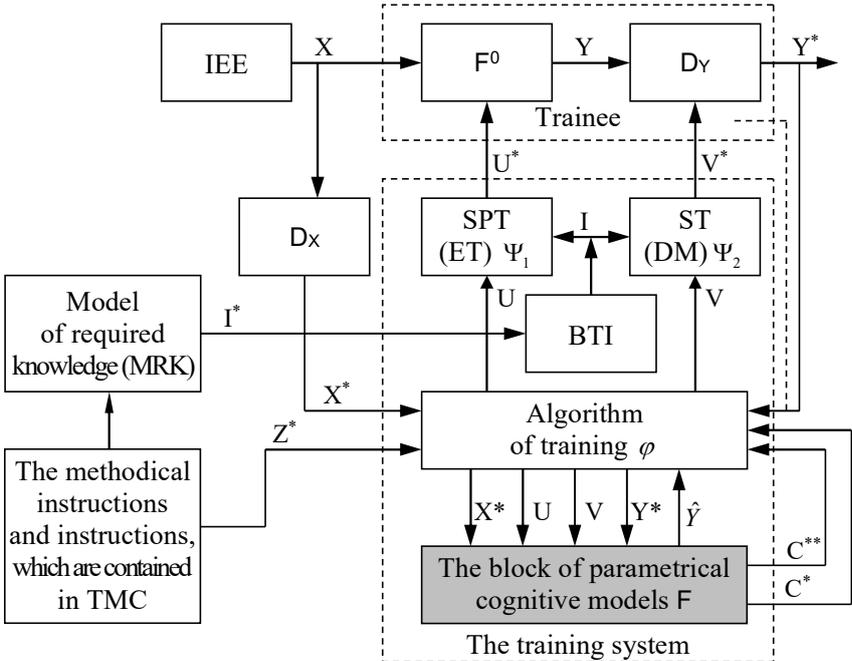
Training represents process of the operated formation of knowledge of the trainee and includes the sequence of stages of information processing: visual representation, perception, understanding, formation of skills, aggregation of the obtained information in knowledge. Level of residual knowledge of the trainee depends on quality of perception and understanding of informational fragments, which display provides the processor of adaptive representation in the base of ET (pic. 3).



Pic. 3. Structure of the adaptive representation of informational fragments processor

The limitation of communicative duplexity of (virtual) information interaction of subjects of different categories was caused by an betweenness of representation of educational influences by means of means of IEE (ET and DM). This shortcoming is inherent in the ART systems and influences on process of formation of knowledge, therefore its needs to be researched and technologically eliminated.

The process of training in the IEE of ART can be to structurally decompose (Semyonov V.V., Rastrigin L.A., Ehrenstein M.H. and others) and to describe in the context of the formal device of the classical theory of automatic control (pic. 4).



Pic. 4. The block diagram of the ART system with elements of adaptation based on block of parametrical cognitive models

In the offered scheme the ART system includes a set of components:

*The cognitive model* – describes assessment  $\hat{Y}$  of a vector of condition  $Y$  of subject as a function of condition of environment  $X$  and information influence  $U$ :  $\hat{Y} = F(X^*, U)$ , and the condition  $Y$  of subject is defined by its operator  $F^0$ :  $Y = F^0(X, U)$ , where the operator  $F$  of model of subject is to be definition and adaptation in the process of training.

*The algorithm of formation of portions of information* has dual appointment: at-first, it defines the training influence:  $U = \varphi(X^*, \hat{Y}, Z^*, R)$ , where –  $\varphi$  algorithm of training;  $\hat{Y}$  – assessment of a condition of knowledge of subject, received by means of (cognitive) model  $F$ ;  $Z^*$  – purpose of training;  $C$  – resource of training, consisting of two components:  $C = (C^*, C^{**})$ , where  $C^*$  – external resource, determined by opportunities of system of training,  $C^{**}$  – internal resource, allocated by subject  $F^0$  on training (for example, time on training); at-second, algorithm of training defines tests  $V$ , answers on which bear information about cognitive model  $F$  of subject:  $V = \Psi(X^*, \hat{Y})$ , where  $\Psi$  – algorithm of synthesis of test  $V$ .

*The bank of training information (BTI)* contains a set of the data  $I$ , necessary for assimilation by subject in the process of training.

*The shaper of a portion of training (SPT)* defines the portion of information, transferred to subject for studying at this stage of training:  $U^* = \Psi_1(U, I)$ , where  $\Psi_1$  – algorithm of formation of a portion. We will notice, that a difference between  $U$  and  $U^*$  same as, for example, between the reference to some page of text, i.e. its number, and text of this page. In other words,  $U$  – addresses in BTI, and  $U^*$  – their content.

*The shaper of tests (ST)* works similarly:  $V^* = \Psi_2(V, I)$ . The subject in the training system represents “converter” of the condition of environment  $X$  and portion of training information  $U^*$  in the state  $Y$ . Information about this state can be obtained only by means of test questions  $V^*$ :  $Y^* = D_Y(Y, V^*)$ , where  $D_Y$  – operator of transformation of test task  $V^*$  and condition  $Y$  of subject to his answer  $Y^*$ . We will notice, that in that specific case, it is possible  $U = V$ , that considerably simplifies the training system.

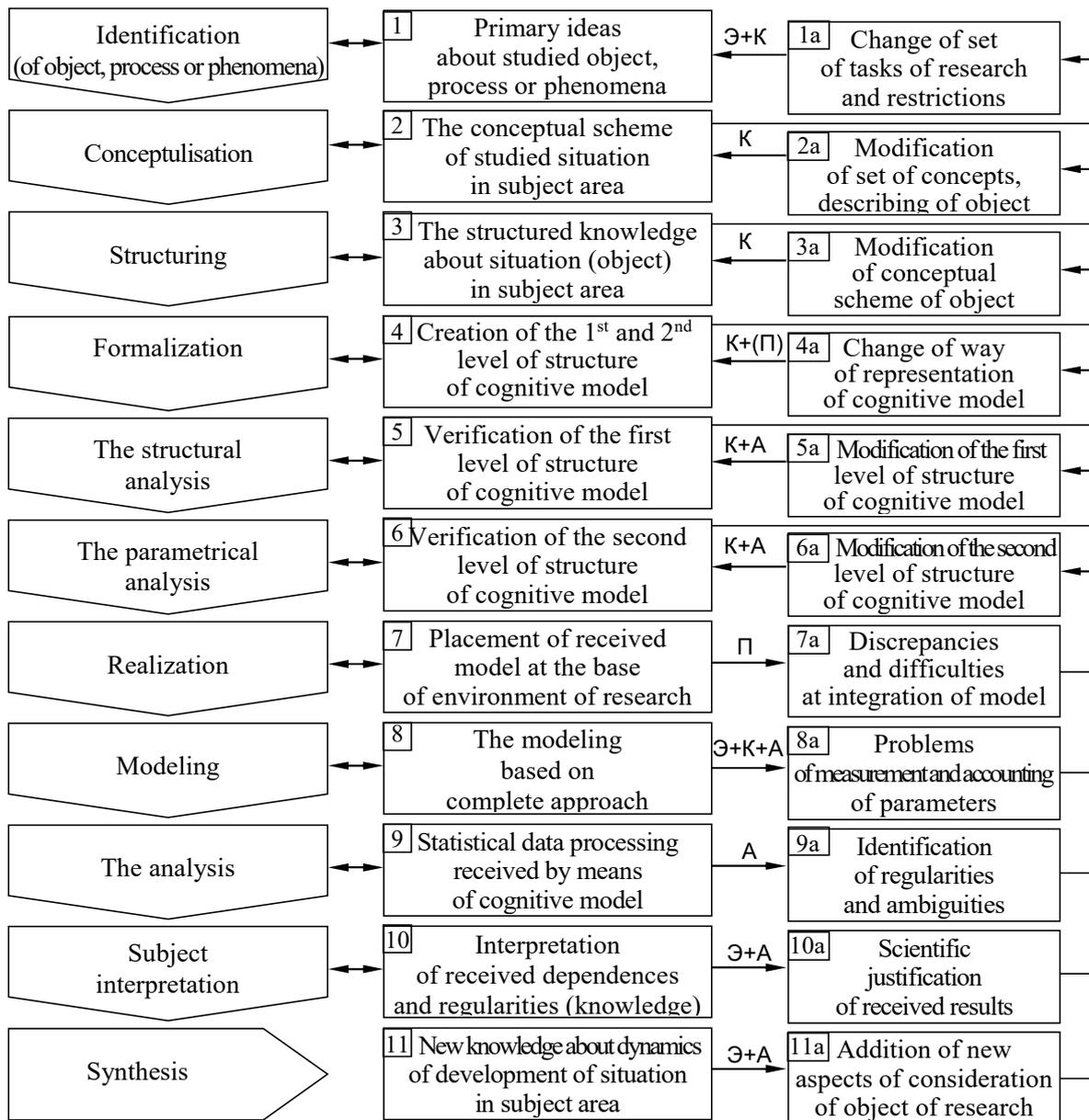
It is obvious, that quality indicators of process of training depend on parameters of CM of subject of training  $F$  and algorithm of formation of portions of information-educational influences  $\varphi$ , which considers parameters of CM of means of training.

**In the forth chapter** “The cognitive modeling technology...” were presented the iterative cycle of CMT, the technique of use of CMT, the ways of representation of structure of CM, the algorithm of formation of structure of CM, the techniques of a research of parameters of CM of subject and means of training, the algorithm of the analysis of a posteriori results of testing.

CMT provides construction of structure of CM and its subsequent parametrical filling. The generalized iterative cycle of CMT provides return on the previous stages of research: if the purposes and tasks have been corrected, the mistakes made on previous or current stages of the analysis of IEE of ART were revealed (pic. 5).

For difficult IEE of ART CMT provides attraction of a set of consultants, who are designated by letters: methodologist (E) – the expert in the field of pedagogics; cognitologist (C) – the expert in the field of engineering of knowledge, providing correctness of the received structure of CM; system analyst (A) – the expert in the field of the system analysis and modeling of the (automated) IEE of ART; programmer (P) – the qualified specialist, owning methods and approaches of realization of hi-technological means of IEE by means of modern integrated environments of programming.

The CM reflects the most important aspects of information interaction of subjects and means of training in the IEE of ART, allows to qualitatively explain the reasons of difficulties in the process of formation of knowledge. Coherence of generation of information influences and IFPST was reached by means of CM of subject and CM of means of training in the IEE of ART.

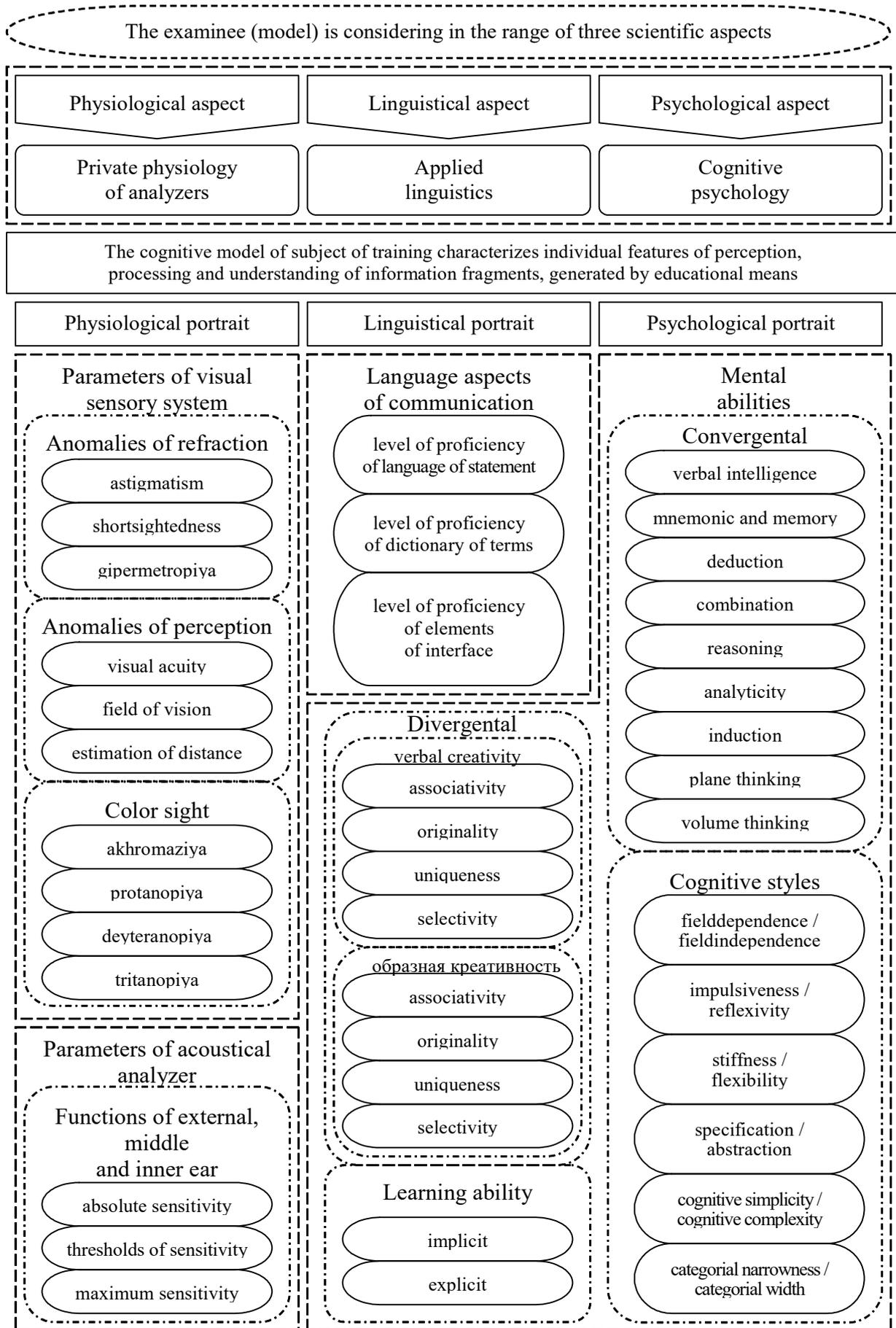


Pic. 5. The iterative cycle of cognitive modeling technology

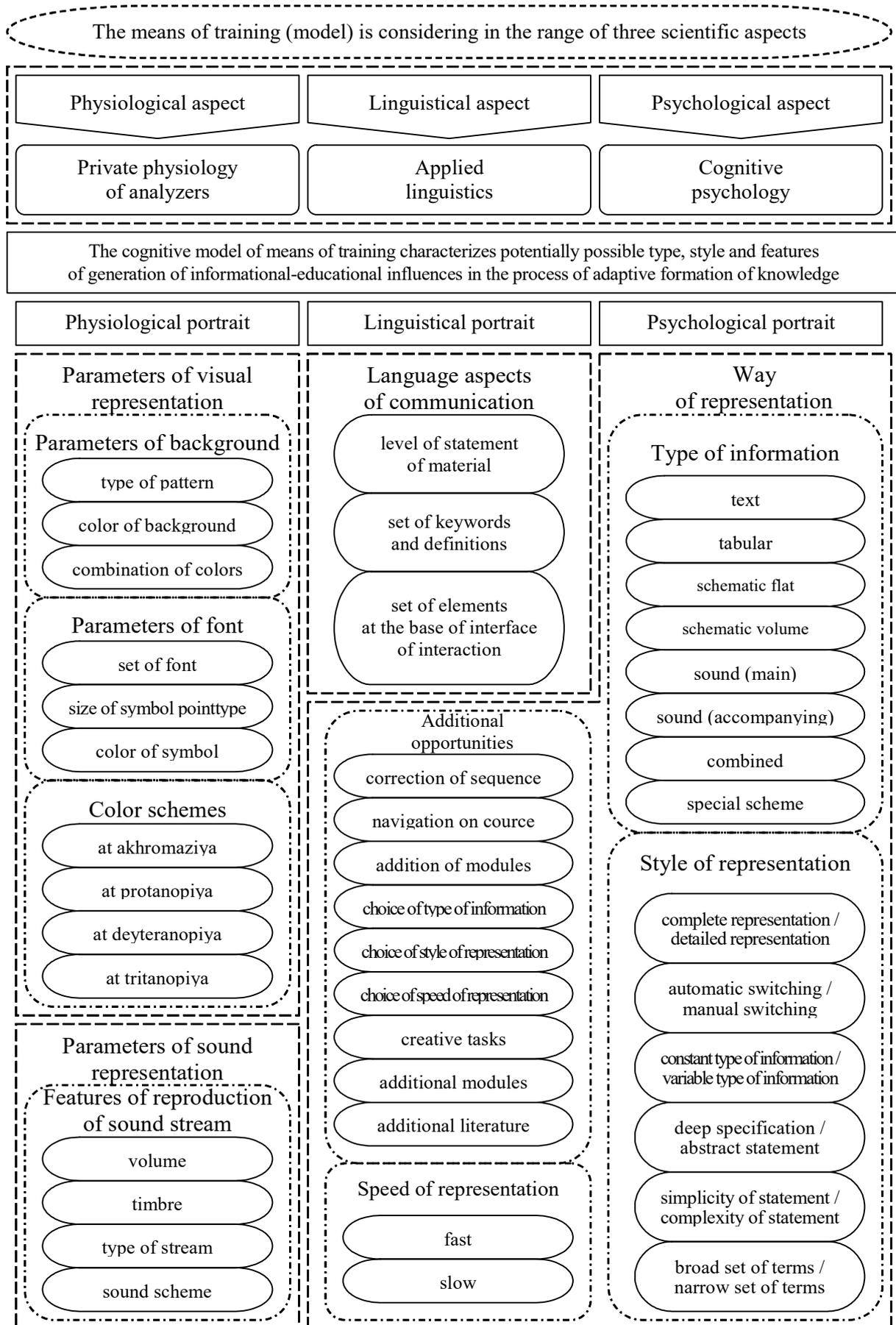
**In the fifth chapter** “The parametrical cognitive models block for the analysis and increase of efficiency of functioning of automated educational environment” the innovative structures of CM of subject and means of training were formed.

The CM of subject of training (pic. 6) represents the parametrized repertoire, echeloned on a set of portraits: physiological (features of sensory perception of information by the visual and acoustical analyzers), psychological (convergent and divergent intellectual abilities, learning ability and cognitive styles of subject), linguistical (natural-language aspects of virtual communication), in general allow to analyze the efficiency of process of formation of knowledge of the trainee, arriving from the informational fragments generated by means of training.

The CM of means of training (pic. 7) is differentiated on a set of portraits: physiological (features of visual representation: parameters of background, font, color schemes of display of content), psychological (way of representation of information-educational influences: type of displayed information, style of representation of informational fragments), linguistical (language aspects of communication).



Pic. 6. The structure of cognitive model of subject of training



Pic. 7. The structure of cognitive model of means of training

The CM of subject of training is technologically applicable in the contour of IEE of ART, if means of training are capable to generate information-educational influences in coordination with CM of means of training.

For purpose of automation of research tasks of the IEE the specially realized complex of programs was used.

**In the sixth chapter** “The complex of software for automation of research tasks” was developed the complex of programs for automation of research tasks, in particular adaptive ET, the basic and applied DM.

**In the seventh chapter** “The statistical substantiation of practical use of the received results” were allocated the factors influencing on efficiency of formation of knowledge of the trainee in the automated IEE, the features of organization and plan of carrying out of experiment, the features of research of parameters of physiological, psychological and linguistical portraits of CM of subject and means of training, the specifics of preliminary processing of a posteriori results of diagnostics, the features of choice of methods of the statistical analysis of formed data sets, the analysis of dynamics of resultativity of training for several years, the results of the regression and discriminant analysis. The technique of research of parameters of CM has provided statement and carrying out of experiment.

At the first stage of research was carried out diagnostics of IFPST – features of perception, processing and understanding of information. The considered technology provides the automated research of parameters of physiological, psychological and linguistical portraits of CM. During diagnostics of parameters of physiological portrait of CM among the contingent of examinees was not revealed the subjects with various anomalies of perception of information by the visual sensory system. The research of linguistical portrait of CM was directed to detection of compliance between level of material statement by educational means and level of proficiency of language of subject.

At the second stage was carried out the automated representation of informational fragments by means of the ET considering parameters of IFPST, which were contained in parametrical CM of subject of training. At representation of a training material as the main information-educational influences of several types were used: `t e x t u a l , t a b u l a r a n d s c h e m a t i c ( p l a n e ) .`

At the third stage was performed the automated diagnostics of level of residual knowledge of trainees with use of the developed software, containing in the basis two scales of assessment (standard and point).

Researches were conducted in “The SPbSETU "LETI"” and “The IBI” on a set of disciplines: “Computer science”, “Intellectual technologies of representation of knowledge”, “ B a n k i n g ” , “ A c c o u n t i n g a n d a u d i t ” , “Taxes and taxation”, “Management accounting” and “Insurance”.

Assessment of efficiency of introduction of results of research was made with use of the standard criteria of efficiency of training:

$$K = \{k_1; k_2; k_3\} = \left\{ Y_i - Y_{i-1}; \frac{Y_i}{Y_{i-1}}; \frac{Y_i - Y_{i-1}}{Y_{i-1}} 100\% \right\}.$$

Coefficients respectively designate absolute, comparative and relative indicators of efficiency. During practical use of CMT the experiment was conducted in the context of a set of groups of examinees. Results of primary statistical data processing of experiment were presented in tabl. 1.

Tabl. 1. Results of statistical data processing of experiment

Name of indicator	The experimental group of examinees							
Number of group	1	2	3	4	5	6	7	8
Quant. of examinees	26	28	22	25	27	23	21	24
Experiment №1 (without use of CMT)								
Average point $Y_1$	3,850	3,414	3,224	3,678	4,036	3,643	3,790	3,645
AQD of av. point	0,867	0,178	1,958	0,879	0,577	0,783	1,679	1,047
Experiment №2 (with use of CMT, personal adaptation)								
Average point $Y_2$	4,041	3,674	3,357	3,786	4,157	3,853	3,821	3,743
AQD of av. point	0,723	0,127	1,743	0,743	0,446	0,654	1,538	0,986
Summary of research								
$k_1$	0,191	0,26	0,133	0,108	0,121	0,21	0,031	0,098
$k_2$	1,049	1,076	1,041	1,029	1,029	1,057	1,008	1,026
$k_3, \%$	0,049	0,076	0,041	0,029	0,029	0,057	0,008	0,027
Change of AQD	-0,144	-0,051	-0,215	-0,136	-0,131	-0,129	-0,141	-0,061

The scientific-methodical researches and experimental check of efficiency of functioning of the IEE of ART based on CMT with use of CM will allow: at-first,- to reveal features of sensory perception (physiological portrait), subsequent processing (psychological portrait) and understanding (linguistical portrait) of the different types of information, presented to the contingent of trainees by means of electronical educational means; at-second,- to develop and integrate in to educational process the adaptive means of training and electronical training-methodical complexes, providing individually-oriented training.

The statistical analysis of a posteriori data and practical use of results of research in training process allow to make the following conclusions:

- effective use of CM in the automated IEE assumes designing of electronical training-methodical manuals;
- extent of influence of the CM parameters on efficiency of training depends on the contingent of trainees and has individual character;
- the efficiency of training with use of CMT is determining by opportunities of means of IEE, the content of ET on a cycle of disciplines and purposes of training, varied according to training plans and working programs.

**In conclusion** of dissertation work were summed up the research results, was given its assessment, were specified the possible directions of use of received results in the IEE. During acquaintance with the manuscript of monography it is possible to notice, that the presented materials are basing on the fundament of IT of training, the theory of automatic control, pedagogics, psychology, physiology and applied linguistics.

### Published works on the theme of dissertation

1. The scientific-educational portal [www.vetrovan.spb.ru](http://www.vetrovan.spb.ru) (from the 01<sup>st</sup> of September 2003 y.).
2. Vetrov A.N. The factors of success in educational activity of modern HEI: Tendencies of development of the information environment of remote education / A.N. Vetrov, N.A. Vetrov // collective monography under ed. of the member-corr. of "The IHEAS" I.N. Zakharov. – SPb.: The publishing house of "The IBI", 2004. – P.54-65 (13 p.).
3. Vetrov A.N. The factors of success in educational activity of modern HEI: The cognitive model for adaptive systems of remote training / A.N. Vetrov, E.E. Kotova // collective monography under ed. of the member-corr. of "The IHEAS" I.N. Zakharov. – SPb.: The publishing house of "The IBI", 2004. – P.65-78 (15 p.).
4. Vetrov A.N. The operational system MS Windows 98/Me/2000: methodical instructions to laboratory works / O.U. Belash, A.N. Vetrov, E.E. Kotova; under ed. of the prof. N.N. Kuzmin. – SPb.: The publishing house of "The SPbSETU "LETI"", 2005. – 72 p.
5. Vetrov A.N. The package of applied programs MS Office 97/2000: Text editor Word: methodical instructions to laboratory works / O.U. Belash, A.N. Vetrov, E.E. Kotova; under ed. of the prof. N.N. Kuzmin. – SPb.: The publishing house of "The SPbSETU "LETI"", 2005. – 64 p.
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