Models and Applied Tools for Prediction of Student Ability to Effective Learning

Oleg Spirin[1] and Oleksandr Burov[2]

[1]Institute of Education Content Modernization, Kyiv, Ukraine
Oleg.Spirin@gmail.com
[2]Institute of Information Technologies and Learning Tools
ayb@iitlt.gov.ua

Abstract. Models of the system "Learner-techno-tools-environment" (SLTE) from viewpoints of psychophysiology, stages of learning and appropriate ICT tools were developed and their constructions were discussed. Functional system of cognitive activity (FSCA) in digital environment has been developed as a refinement of the previous general functional system of activity by K.Anokhin. In general case, the conceptual model can be considered as an information stratum of professional activity, and physiological chain „afferent inputs – activity acceptor – physiological control – effectors - act" is an energetic stratum in this context. The goal of professional training is forming the conceptual model of activity of the particular type, carrying out particular tasks. The FSCA was proposed as a structural functional system representing psychophysiological model of cognitive activity, and as a hyper-complex dynamic (HCD) system. Considering student's ability to lear (SAS) as a three-level closed hyper-complex dynamic system, in which factors of influence on the efficiency of SLTE are the elements of the HCD that interact with each other, the general suitability for the profession can be represented as the first level HCD, micro-age - as the second level HCD, current - as HCD of the third level. Theoretical models can be used in ICT for students' abilities assessment, monitoring of the intellect development on micro-age intervals, as well as for studying cognitive stability in over week's intervals.

Keywords: human abilities, model, functional system of activity, hyper-complex dynamic system.

1 Introduction

Nowadays' general requirements to the higher education worldwide are based on modern possibilities and tendencies [4] to use electronic forms of education and, first of all, online learning [16]. But more and more experts pay attention to "another site" of this tendency, first of all, its efficiency [17] and strategy [9]. Especially, because electronic education gives new opportunities such as [3]:

- Flexibility of education programs – a student can choose courses, teachers, time of active work, etc.

adfa, p. 1, 2011.

- Individualization of education process – re-allocate time and education resources in dependence on a student's individual psychophysiological possibilities (features) to make this process more intensive and to give equal opportunities for both common people and people with disabilities.

In this light it is important to give students and teachers' knowledge in what way they can adapt the education process to an individual and individual's potential to the learning process [2].

It is known up to date a lot of methods, techniques and units patented and published that are used for human performance reliability assessment and prediction in the synthetic environment [14], social systems [11] or in operator occupations in general [19]. But their efficiency can be evaluated really only from viewpoint of prediction of efficiency related to a human education [8] as a specific type of mental work [15] and needs in lifelong learning [5].

It is necessary to highlight that learning performance becomes more and more close to the operator work, because the human product (knowledge and skills) are obtained via technical tools (gadgets, networks etc.), human activity can be described as information search and processing, project activities that involve people (teachers/mentors and learners) etc. In general, the human-learner interacts and collaborates with other humans, tools, and environment. Together they form a system of activity that can be described in terms of main features, goals and tasks of ergonomics as the scientific discipline with its new features [20]. Accordingly, ergonomics findings could be applied to education system accounting its specific impact on learners [7] and their safety [6], as well as problems arising in cognitive activity which is most characteristic for the learning process, especially in future adaptive automation of industrial and educational fields [13].

The purpose of the article is to describe model(s) of the system "Learner-techno-tools-environment" (SLTE) from viewpoints of psychophysiology, stages of learning and appropriate ICT tools.

2 Results and Discussion

The method used is based on the model proposed and generally discussed earlier [5] . This model is a development of the basic idea of P.Anokhin regards formation and functioning of the "functional system of cognitive activity" (FSCA) [1].

2.1 Methodology

The learning activity could be analyzed as an operator work, because learners have to do with the objects (information, facts, knowledge) indirectly, especially in digital education, through the information model of the learning process [5]. Work (activity) of such a type has some specifics. The reason is that the conceptual model of activity (as result of a human psychological adaptation to the work) is expanded in the time independently on external process and an activity consists in discrete comparison of the information obtained from outside with the model formed and corrected permanently. In general case, the conceptual model can be considered as an information stratum of professional activity, and physiological chain „afferent inputs – activity acceptor – physiological control – effectors - act" is an energetic stratum in this context. The goal of professional training is forming the conceptual model of activity of particular type, carrying out particular tasks. It means creation of „information contour" that exists and is maintained in activated state in carrying out process for purposeful activity and embraces afferent inputs, decision making block, activity acceptor and act program, as well as the object of activity (is represented as information model in case of operator-watcher that creates the information contour together with the imagine-conceptual model).

As it was stated, the energetic and information stratums can be represented as two contours which partly coincide at the level of morphological structures and functions, but partly differ because of including into the information contour an activity object that does not participated in the energetic contour of the organism regulation, but is an inalienable part of the information contour. Human activity is a *mediator between internal and external environment of organism*, projection of structural-function specific of professional homeostasis on the operator work. Output parameters of the activity program (activity effectors) stand in the information contour as parameters of capability. In such a context, operator's activity is an activity program realized as physical and/or mental acts in external environment.

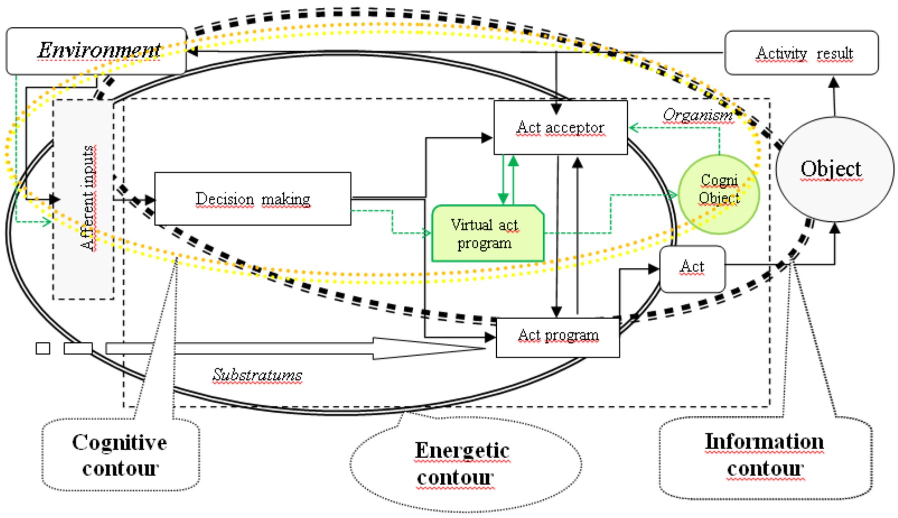

Fig. 1. Theoretical scheme of the functional system of learning activity, where regulation (Anokhin, 1973, [1]) was divided into two contours – information and energetic ones. The third (cognitive) contour is associated with the "internal" activity

In the digital world and synthetic learning the external object may not exist. Instead of it, the virtual object can appear ("cogni object") that is produced by the virtual act program and can be not a result of training and experience, existing in time of the particular activity (f.e., during the game). This object and interaction with it can be created by sensors (information for them is produced by artificial system, virtual one, simulating real world) and the act acceptor compares virtual result with virtual sensors signals, creating the cognitive model of the synthetic object. In such a case, an illusion of the object as well as knowledge regards it appears.

This model can explain the phenomenon of not expectedly low effective performance after watching others acts [10]. As authors revealed, “extensive viewing allows people to track what steps to take … but not how those steps feel when taking them. Accordingly, experiencing a “taste” of performing attenuates the illusion: Watching others juggle but then holding the pins oneself tempers perceived change in one’s own ability”. From our point of view, watching (in that experiment, in YouTube) or imaging (in virtual world) some even real others work can create only virtual act program, that does not coincide, in whole or in part, with real world and does not allow to form practical act program (at least, at the sensory-motor level).

2.2 FSA as a hyper-complex dynamic system

The phenomenon described above, has pointed to another challenge of education efficiency, dealt with conformity of the person abilities to requirements of the particular kind of action.

Taking into account the multilevel character of psychophysiological indicators involved in the formation of a student's working condition and the heterogeneity of the parameters influencing the functioning of the FSA, as well as the importance of taking into account the dynamic nature of the FSA, there is a need for the choice of adequate tools for solving the problems of invariant modeling with the aim of studying, developing and applying the most common patterns and principles of simulation of complex multi-quality systems, which are the systems for assessing the student's ability to study (SAS) at different levels, regardless of the nature of their application. As a tool for general description of the system, the theory of hyper-complex dynamic systems (HCD) was chosen. It was developed by O.N. Malyuta [12] where hyper-complexity is understood as the variability of data, and the set of close-to-quality components that forms 1 element of the HCD. Accordingly, the number of elements determines the order of the HCD. An important feature is the mandatory presence of interaction between the elements. The analysis of the HCD as an isolated object requires that the interaction of the elements should be realized through the internal resources of the system, for example, as a result of the dynamics of at least one element.

Considering SAS as a three-level closed hyper-complex dynamic system, in which factors of influence on the efficiency of SLTE are the elements of the HCD that interact with each other, the general suitability for the profession can be represented as the first level HCD, micro-age - as the second level HCD, current - as HCD of the third level.

In general, the use of the system analysis, difficulties arise, as a rule, when describing the hierarchical properties of the system. In order to solve this difficulty, we propose to use a description of the system in the form of hyper-complex matrices:

$Y =$

<table>
<tr><td>$Y_{(1.1)(1.1)}$</td><td>$Y_{(1.1)(1.2)}$</td><td></td><td rowspan="3">$Y_{1.2}$</td><td rowspan="3" colspan="2"></td></tr>
<tr><td></td><td>$Y_{(1.2)(1.2)}$</td><td></td></tr>
<tr><td></td><td>$Y_{(1.3)(1.2)}$</td><td>$Y_{(1.3)(1.3)}$</td></tr>
<tr><td colspan="3"></td><td>$Y_{2.2}$</td><td colspan="2">$Y_{2.3}$</td></tr>
<tr><td colspan="3" rowspan="2"></td><td rowspan="2"></td><td>$Y_{(3.1)(3.1)}$</td><td>$Y_{(3.1)(3.2)}$</td></tr>
<tr><td>$Y_{(3.2)(3.1)}$</td><td>$Y_{(3.2)(3.2)}$</td></tr>
</table>

(1)

The use of hyper-complex matrices allows us to eliminate these defects and formally make links between elements of different levels and between elements of the same level.

The physical meaning of the matrix elements is as follows:

sub-matrix Y1.1 - indicators of general SAS (professional suitability), which include:

Y (1.1) (1.1) - parameters of intelligence,

Y (1.2) (1.2) - cognitive parameters,

Y (1.3) (1.3) - parameters of the mobility of the nerve processes;

sub-matrix Y2.2 - indicators of micro-level abilities (professional formation);

sub-matrix Y3.3 - indicators of current abilities, which consist of:

Y (3.1) (3.1) - physiological parameters of SAS,

Y (3.2) (3.2) - parameters of cognitive activity.

The non-zero element of the matrix corresponds to the presence of a connection between the elements; the absence of an element means the absence of a connection between the corresponding elements of the matrix. For example, Y (1.1) (1.2) means that the intellect affects the student's cognitive abilities as well as the mobility of the neural processes Y (1.3) (1.2). In the sub-matrix Y3.3 there is a mutual influence of parameters of cognitive activity (for example, speed) and physiological maintenance of efficiency.

The formalization of the interaction mechanism of the HCD elements can be described using hyper-complex matrices in expanded form. For the general case of describing the interaction of elements of the structure of professional suitability, formalization is carried out in this way.

Model of the "reference student" is a HCD-model of three different-quality structures: personal characteristics (socio-psychological), intelligence (individual-"logical"), psychodynamic (neuro-dynamic). The identification process consists in creating (constructing) a system model that summarizes the psychophysiological structures given for a specific type of activity (training profile). Then the HCD-model of each particular student is constructed on the basis of the results of the study of his individual qualities and the degree of mismatch between the two models is checked by the degree of conformity of the student of the chosen profession.

If we consider each structure as an element of open-loop HCD exposed to external actions of I_i and undergo changes $d\varphi_i$ under the influence of these actions, as well as accounting the specific intensity of the interaction of elements among themselves in the course of the implementation of educational activity y_{ij}, then we can write the equation for the first element:

$$d\varphi 1 + i1 = d\varphi_2\, y_{12} \oplus d\varphi_3\, y_{13}, \qquad (2)$$

where $\oplus$ is the HCD interaction, $d\varphi_i y_{ij}$ is the symbol of element *i* while taking into account its quantitative and qualitative aspects. In the general case, by simplifying the recording of a hyper-complex interaction sign by replacing it the sign of a normal addition, we obtain a complete system of equations:

$$\begin{aligned} d\varphi 1 + d\varphi 2\ y12 + d\varphi 3\ y13 &= I1, \\ d\varphi 1\ y21 + d\varphi 2 + d\varphi 3\ y23 &= I2, \\ d\varphi 1\ y31 + d\varphi 2\ y32 + d\varphi 3 &= I3. \end{aligned} \qquad (3)$$

In the matrix short form:

$$Y\Phi = I \qquad (4)$$

2.3 ICT for learner assessment

Described theoretical models correspond to real ICT used for high school children assessment. At present, we provide service in assessment of adolescents' ability level and giftedness. The tool of the second level allowed to realize monitoring of the abilities on micro-age intervals and to study dynamics of student intellect from grades 8 to 11. The tool of 3[d] level is used for studying cognitive abilities changes over one month period under influence of learning workload and external factors, as well as balancing between cognitive productivity and physiological maintenance of particular high school students (experimental groups).

The statistical models (multiple regression equations) were used for practical reasons in all tools.

3 Conclusions and outlooks

Models of the system "Learner-techno-tools-environment" (SLTE) from viewpoints of psychophysiology, stages of learning and appropriate ICT tools were developed and their constructions were discussed.

Functional system of cognitive activity (FSCA) in digital environment has been developed as a refinement of the previous general functional system of activity by K.Anokhin.

The FSCA was proposed as a structural functional system representing psychophysiological model of cognitive activity, and as a hyper-complex dynamic system.

Theoretical models can be used in ICT for students' abilities assessment, monitoring of the intellect development on micro-age intervals, as well as for studying cognitive stability in over week's intervals.

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