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A model of information interaction between the components of an intelligent learning system

Un modelo de interacción de información entre los componentes de un sistema de aprendizaje inteligente

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Contents

ABSTRACT:
The article presents a model of information interaction between the subject of training and an intelligent learning system that helps to create the conditions for the formation of the competencies required for the future professional activity of students. The article examines the theoretical background for the technology of the instructional design of an intelligent learning system that can generate an educational environment that adapts to students' capabilities in terms of the learning style and rate new educational material and that takes into account the students' chosen type of professional activity.
Keywords: intelligent learning system, information technology, instructional design, tailored education, learner-centered education

RESUMEN:
El artículo presenta un modelo de interacción de información entre el tema de capacitación y un sistema de aprendizaje inteligente que ayuda a crear las condiciones para la formación de las competencias requeridas para la futura actividad profesional de los estudiantes. El artículo examina los antecedentes teóricos para la tecnología del diseño instruccional de un sistema de aprendizaje inteligente que puede generar un ambiente educativo que se adapte a las capacidades de los estudiantes en términos del estilo de aprendizaje y califique el nuevo material educativo y que tenga en cuenta los estudiantes elegidos. tipo de actividad profesional.
Palabras clave: sistema de aprendizaje inteligente, tecnología de la información, diseño instruccional, educación personalizada, educación centrada en el alumno

1. Introduction

The Law on Education in the Russian Federation prescribes general rules for the education system operation, aimed at "creating conditions for self-fulfillment of each individual" and "freedom of choice to receive an education according to the aptitudes and needs of everyone" (Federal Law No. 273, 2012). In this regard, the higher education standards specify requirements for a learning environment for students with the purpose to execute the government order for university graduates (Federal Standard, 2018). So far, there has been a lot of research in the use of intelligent learning systems. The problems of student adaptation to the use of information and computer technologies were addressed many works (Bespalko, 1995; Krechetnikov, 2002; Okolelov, 1999; Selevko, 1998; Khutorskoy, 2001); the principles of learner-centered and competency-based approach, also applicable in information systems, were considered by Verbitsky and Kruglikov (1998), Shiyanov and Kotova (1999), and other researchers; the conceptual basis for new information technology development was dealt with by Mashbits (1988) and Tikhomirov (1977). Therefore, our first priority is to give a theoretical description of the fundamentals for using intelligent learning systems in the educational process.

The research and practical experience have allowed us to identify the fact that educational institutions do not fully use the whole potential of computer technology in the modern context, despite the fact that intelligent learning systems (ILSs), as one of the stages of software application in training, are adaptable. In the course of the study, it was necessary to theoretically and methodologically substantiate the instructional design of an intelligent teaching system that would generate an adaptive educational environment aiming to enhance common cultural and professional competencies in undergraduate students. The goal of the present study is to theoretically and methodologically substantiate the instructional design of intelligent learning systems aimed at forming undergraduate student competencies.

Most literature sources view e-learning systems as the possibility to use online materials outside the school. Cemile, Nur, and Lakhmi (2008) present an adaptive intellectual learning system that monitors students' learning process in accordance with their profile, and describe a case study of using this system (Xu, Wang, and Wang, 2005).

Xu, Wang, and Wang (2005) describe a conceptual model of personalized virtual learning environments, which is one of the rapidly evolving areas of educational technology research and development. Mona and Sanaa (2016) describe an intelligent learning system for teaching Arabic grammar, which consists of a training module, a module for selecting questions, an expert module, a student model, and a graphical user interface (Mona et al., 2016). Stellan Ohlsson (1993) describes the possibility of using various gadgets in training. His research shows the extended use of learning programs as mobile applications, which improves student performance.

2. Materials and methods

The methodological framework of the study was composed of the theoretical background and conclusions contained in the fundamental and applied studies of domestic and foreign authors on the data systems engineering (Mashbits, 1988; Tikhomirov, 1977), as well as on the problems of forming professional competencies in students, social design of instructional systems and educational parks management (Verbitsky and Bakshaev, 1988; K.G. Krechetnikov, 2002; Okolelov, 1999; Selevko, 1998; Khutorskoy, 2001). The research is based on the concepts of vocational pedagogy, computer science, and instructional systems design.

The paper uses such research methods as analysis of literature on the problems of vocational education, the use of information technologies in the educational process, analysis and generalization of theoretical principles and conclusions, analysis of documents governing the formation of undergraduate student competencies, questionnaires, testing, etc.

A preliminary experiment was conducted among students majoring in Mathematical Methods in Economics, Applied Information Science in Economics, and Computer Science. The intelligent learning system developed in accordance with theoretical principles and conclusions was used to organize students' self-directed leaning with a subsequent knowledge assessment. Their knowledge was assessed using the learning system tests.

An intelligent learning system is a computer program consisting of a certain action rule set in this program and rules for educational and assessment content supply (Ding *et al.*, 2016). These rules are subject to requirements for the learning system and take into account the learner's behavior, their level of earlier and newly acquired competence, and their aptitude to the selected type of professional activity. The actions carried out by the ILS occur according to the rules of expert systems capable of resolving problem situations. Their key feature is the ability to find the optimal solution under given conditions to achieve the best result (Yakhneeva *et al.,* 2020). Thus, ILSs operate according to the principles of expert systems that implement expert action models within a certain knowledge domain, in this case impersonating the teacher, using inference and decision-making procedures and a database comprising information required for forming student competencies and a collection of rules for its inference and updating.

When using the ILS, an individual modular educational path is generated for each student, with specific goals and objectives for the current and subsequent periods. Competencies are formed in accordance with the identified degree of students' propensity for the chosen type of professional activity (general abilities, elementary special abilities, and vocational abilities), as well as the level of competence available at the time of using the ILS. Each ILS user can opt for a path to study the proposed learning content required to form the selected competencies. The user environment where they carry out their educational activities should provide comfortable conditions, take into account the requirements of engineering psychology and ergonomics, and be easily navigable (Salih, 2019).

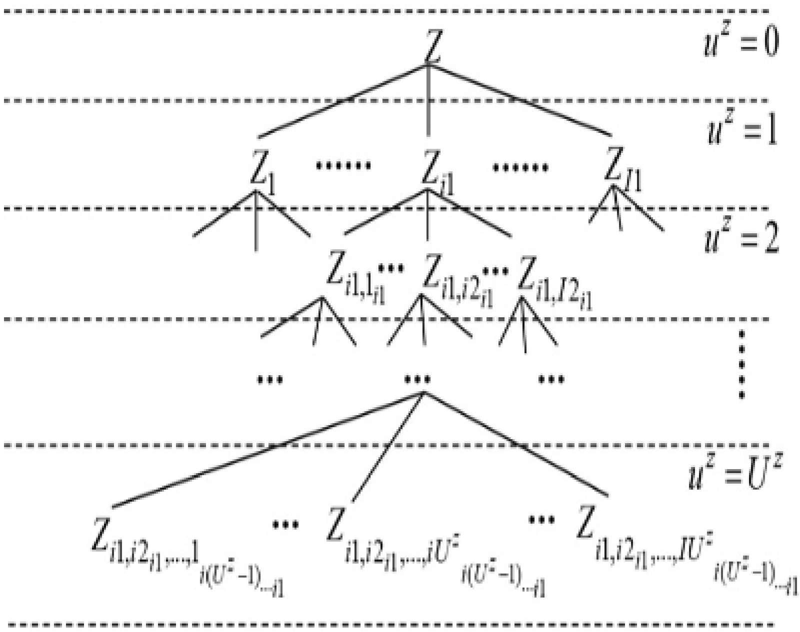
Let us consider a model of information between the intelligent learning system components. Let Z be a global-level task set before the intelligent instructional components, which determines the global goal and purpose of the ILS as a whole. Z is the root of the tree of tasks D^z that are being solved in the ILS and is at the highest level of the hierarchy. When considering the hierarchy level decomposition, number u^z of the level under consideration indicates a random task location in the task tree whose value may vary in the range $[0, U^z]$, that is, $u^z = \overline{0, K^z}$. Decomposition level $u^z = 0$ corresponds to global task Z. The next decomposition level $u^z = 1$ describes a number of specific tasks that ensure achievement of the goal to form the optimal learning path during the interaction between the student and the ILS. The global task and the first-level task can be represented it in the form:

$$Z = \{Z_{i1}, i1 = \overline{1, I1}\}; \quad (1)$$

$$Z_{i1} = \{Z_{i1,i2_{i1}}, i1 = \overline{1, I1},\ i2_{i1} = \overline{1, I2_{i1}}\}. \quad (2)$$

Figure 1 describes the general form of tree D^z of the tasks solved in the ILS. When analyzing it, one can see the dependency relation of functional components aimed at solving the tasks set before the system. Circuit mathematical description of the information interaction between the components allows one to specify the connectivity of the subordinate tree nodes.

Figure 1
Tree of tasks solved in ILS



Source: compiled by the authors

If we consider random target task $Z_{i1,i2_{i1},...,iu^z_{...i2_{i1}}}$, its solution can be represented in the form of abstract system $R^z_{i1,i2_{i1},...,iu^z_{...i2_{i1}}}$ described by relation (2) in the space of inputs $X^z_{i1,i2_{i1},...,iu^z_{...i2_{i1}}}$ and outputs $Y^z_{i1,i2_{i1},...,iu^z_{...i2_{i1}}}$ of the task in question $Z_{i1,i2_{i1},...,iu^z_{...i2_{i1}}}$ (Pospelov, 1986; Korolev, 1989). Subscripts $i1,i2_{i1},...,iu^z_{...i2_{i1}}$ can be omitted for formalization convenience and then the target task may be designated as Z_k and expressions (2) and (3) can be written as:

$$Z=\{Z_k, k=\overline{1,K}\}; \qquad (4)$$

$$R^z \subset X^z \times Y^z;\ R^z_k \subset X^z_k \times Y^z_k, \qquad (5)$$

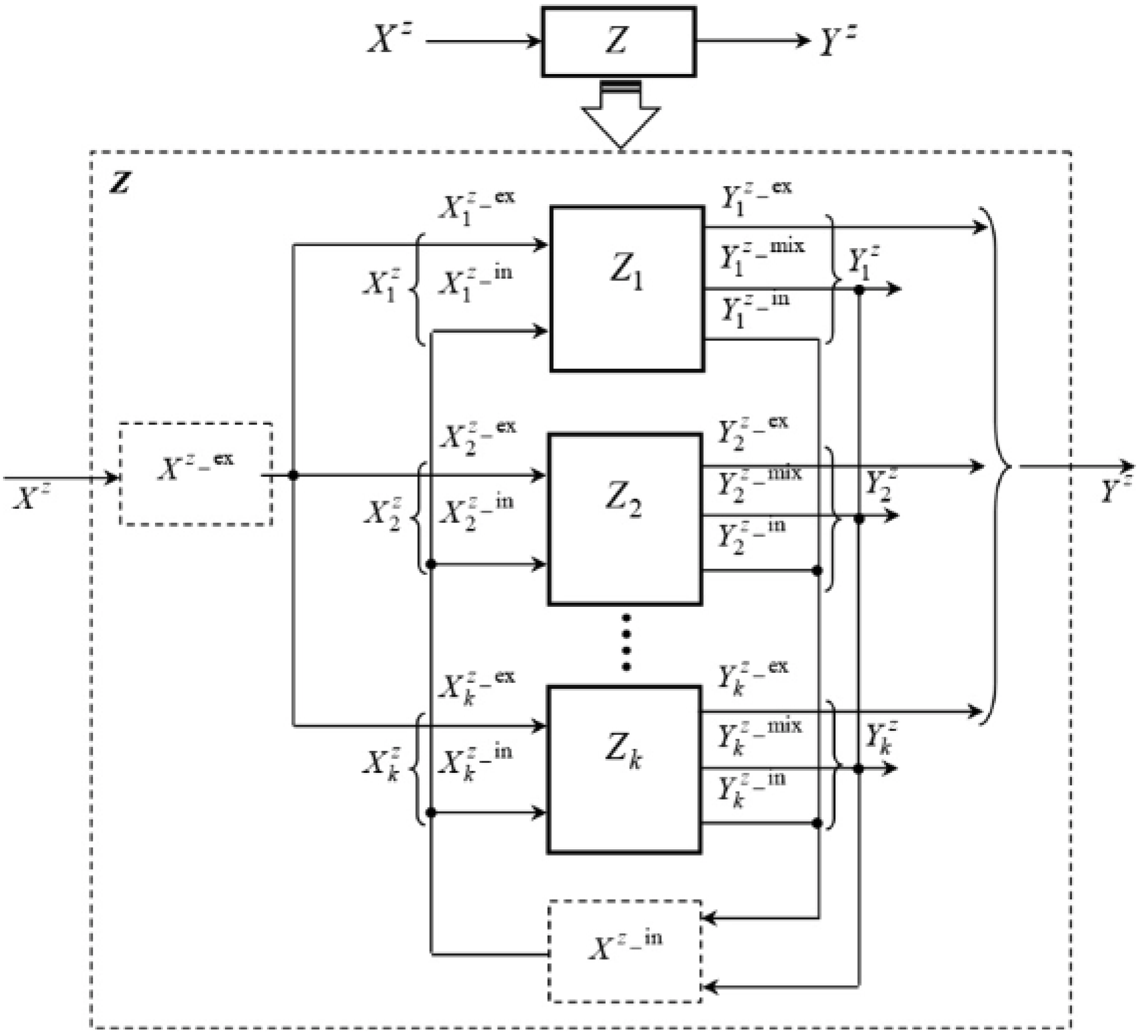
where:

$$X^z=\{x^z_i,\ i=\overline{1,I}\};\ X^z_k=\{x^z_{k,i_k},\ i_k=\overline{1,I_k}\};$$

$$Y^z=\{y^z_j,\ j=\overline{1,J}\};\ Y^z_k=\{y^z_{k,j_k},\ j_k=\overline{1,J_k}\}.$$

Figure 2 shows the information interaction pattern of subordinate functional components.

Figure 2
Information interaction pattern of subordinate functional components in task solving



Source: compiled by the authors

Let us provide a mathematical description of connections between the subordinate components, implemented in solving the task to form student competencies Z. To do this, we will sequentially consider the structures of input and output sets and their connection with the global learning task.

Let us represent input sets X_k^z as two disjoint subsets of "external" $X_k^{z\_\mathrm{ex}}$ and "internal" $X_k^{z\_\mathrm{in}}$ inputs. After this, in a general way, it can be written in the form (Korolev, 1989):

$$X_k^z = \{X_k^{z\_\mathrm{ex}}, X_k^{z\_\mathrm{in}}\};\; X_k^{z\_\mathrm{ex}} \subseteq X^z;\; X_k^{z\_\mathrm{in}} \not\subset X^z;\; \bigcup_{k=1}^{K} X_k^{z\_\mathrm{ex}} = X^z;\; \bigcup_{k=1}^{K} X_k^{z\_\mathrm{in}} = X_k^{z\_\mathrm{in}},$$
$$X_k^{z\_\mathrm{ex}} \bigcup X_k^{z\_\mathrm{in}} = X_k^z;\quad X_k^{z\_\mathrm{ex}} \bigcap X_k^{z\_\mathrm{in}} = \varnothing; \qquad (6)$$

where

$$X_k^{z\_\mathrm{ex}} = \{x^{z\_\mathrm{ex}}_{k, i_k^{z\_\mathrm{ex}}},\, k = \overline{1, K},\, i_k^{z\_\mathrm{ex}} = \overline{1, I_k^{z\_\mathrm{ex}}}\};$$
$$X_k^{z\_\mathrm{in}} = \{x^{z\_\mathrm{in}}_{k, i_k^{z\_\mathrm{in}}},\, k = \overline{1, K},\, i_k^{z\_\mathrm{in}} = \overline{1, I_k^{z\_\mathrm{in}}}\}. \qquad (7)$$

What is more, non-empty subsets can also be results of intersections $\bigcap_{k=1}^{K} X_k^{z\_\mathrm{ex}}$ and $\bigcap_{k=1}^{K} X_k^{z\_\mathrm{in}}$, since some elements of the "external" and "internal" input sets of some subtasks may coincide. Let us represent the structure of output set Y_k^z of subtask Z_k in the form of three pairwise disjoint subsets: "external output" subset $Y_k^{z\_\mathrm{ex}}$ whose elements are the outputs of global task Z but are not the inputs of other subtasks, "internal output" subsets $Y_k^{z\_\mathrm{in}}$ whose elements are presented as the inputs of other subtasks that are not the outputs of global tasks Z , and "mixed output" subsets $Y_k^{z\_\mathrm{mix}}$ that are elements being both the inputs of other subtasks and the outputs of global task Z. Mathematically, this structure can be represented as follows:

$$Y_k^{z\_\mathrm{ex}} \bigcap Y_k^{z\_\mathrm{in}} = \varnothing;\; Y_k^{z\_\mathrm{ex}} \bigcap Y_k^{z\_\mathrm{mix}} = \varnothing;\; Y_k^{z\_\mathrm{mix}} \bigcap Y_k^{z\_\mathrm{in}} = \varnothing;$$
$$Y_k^{z\_\mathrm{ex}} \bigcup Y_k^{z\_\mathrm{mix}} \bigcup Y_k^{z\_\mathrm{in}} = \{Y_k^{z\_\mathrm{ex}}, Y_k^{z\_\mathrm{mix}}, Y_k^{z\_\mathrm{in}}\} = Y_k^z;$$
$$\bigcup_{k=1}^{K} (Y_k^{z\_\mathrm{in}} \times Y_k^{z\_\mathrm{mix}}) = X_k^{z\_\mathrm{in}};\; \bigcup_{k=1}^{K} (Y_k^{z\_\mathrm{ex}} \times Y_k^{z\_\mathrm{mix}}) = Y^z, \qquad (8)$$

where:

$$Y_k^{z\_\mathrm{ex}} = \{y^{z\_\mathrm{ex}}_{k, j_k^{z\_\mathrm{ex}}}, k = \overline{1, K},\; j_k^{z\_\mathrm{ex}} = \overline{1, J_k^{z\_\mathrm{ex}}}\} \subseteq Y^z;$$
$$Y_k^{z\_\mathrm{mix}} = \{y^{z\_\mathrm{mix}}_{k, j_k^{z\_\mathrm{mix}}}, k = \overline{1, K},\; j_k^{z\_\mathrm{mix}} = \overline{1, J_k^{z\_\mathrm{mix}}}\} \subseteq Y^z;$$
$$Y_k^{z\_\mathrm{in}} = \{y^{z\_\mathrm{in}}_{k, j_k^{z\_\mathrm{in}}}, k = \overline{1, K},\; j_k^{z\_\mathrm{in}} = \overline{1, J_k^{z\_\mathrm{in}}}\} \not\subset Y^z. \qquad (9)$$

Equation (8) shows that "internal output" subsets $Y_k^{z\_\mathrm{in}}$ and "mixed output" subsets $Y_k^{z\_\mathrm{mix}}$ represent "internal input" subsets $X_k^{z\_\mathrm{in}}$. To form elements of set $X_k^{z\_\mathrm{ex}}$, a selection is made from set X^z of such elements $x^z_{i^z}$ that are input actions $x^{z\_\mathrm{ex}}_{k, i_k^{z\_\mathrm{ex}}} \in X_k^{z\_\mathrm{ex}}$ for subtask Z_k. It should be noted that for $Q_k^{z\_\mathrm{ex}} = \left\| q_{i^z, i_k^{z\_\mathrm{ex}}} \right\|$, which is visualization of the formation of "external inputs" of the k-th subtask and for each pair of tasks $(x^z_{i^z} \in X^z, x^{z\_\mathrm{ex}}_{k, i_k^{z\_\mathrm{ex}}} \in X_k^{z\_\mathrm{ex}})$, the following equation is true:

$$q_{i^z, i_k^{z\_\mathrm{ex}}} = \begin{cases} 1, \; if \;\; x_i^z = x^{z\_\mathrm{ex}}_{k, i_k^{z\_\mathrm{ex}}}; \\ 0, \; if \;\; x_i^z \neq x^{z\_\mathrm{ex}}_{k, i_k^{z\_\mathrm{ex}}}, \end{cases} \qquad (10)$$

where an expression of the form $x_i^z = x^{z\_\mathrm{ex}}_{k, i_k^{z\_\mathrm{ex}}}$ may mean the i-th input of global task Z and be the $i_k^{z\_\mathrm{ex}}$-th input of subtask Z_k, whereas an expression of the form $x_i^z \neq x^{z\_\mathrm{ex}}_{k, i_k^{z\_\mathrm{ex}}}$ is the opposite case. For sets $X_k^{z\_\mathrm{ex}}$ and X^z that are dimension column vectors of $I_k^{z\_\mathrm{ex}}$ and I^z, respectively, it can be written as follows (Korolev, 1989):

$$X_k^{z\_\mathrm{ex}} = Q_k^{z\_\mathrm{ex}} \cdot X^z, \qquad (11)$$

where: $Q_k^{z\_\mathrm{ex}}$ is a matrix with dimension $I_k^{z\_\mathrm{ex}} \times I^z$.

Similarly, elements $X_k^{z\_in}$ are formed. Using family $Q_k^{z\_in} = \left\| q_{i^z, i_k^{z\_in}} \right\|$, combinations of "internal inputs" (Figure 2) are selected from elements $y^z_{j^{z\_in}}$ and $y^z_{j^{z\_mix}}$, which will be input actions $x^{z\_in}_{k, i_k^{z\_in}} \in X_k^{z\_in}$ of subtask Z_k (Korolev, 1989):

$$\forall (y_{j^{z\_in}} \in Y^{z\_in}, y_{j^{z\_mix}} \in Y^{z\_mix}) \exists q_{j^{z\_in}, j_k^{z\_in}} =$$

$$= \begin{cases} 1, \; if \;\; y_{j^{z\_in(mix)}} = y^{z\_in(mix)}_{k, j_k^{z\_in(mix)}}; \\ 0, \; if \;\; y_{j^{z\_in(mix)}} \neq y^{z\_in(mix)}_{k, j_k^{z\_in(mix)}}; \end{cases} \quad (12)$$

$$X_k^{z\_in} = Q_k^{z\_in} \cdot (Y^{z\_in} \times Y^{z\_mix}). \quad (13)$$

When analyzing relations (6)–(9), one can see that solving the target task to form student competencies Z is facilitated by the structures of input X_k^z and output Y_k^z sets of slave tasks Z_k. Relations (10)–(13) describe the information interaction between slave tasks Z_k in the process of solving target task Z using the rules for forming the components of input X_k^z and output Y_k^z sets.

According to D.A. Pospelov and L.N. Korolyov, on whose work we relied for the calculations, a description of the morphology of solving the target task to form student competencies (6)–(13) can be presented in the form of composition (Pospelov, 1986; Korolev, 1989):

$$R^z = \mathop{\circ}_{k=1}^{K} R_k^z, \quad (14)$$

where the connective operation " $\circ$ " is described by relations (3)–(13).

Turning to the original notation (3) in this case, we obtain:

$$R^z_{i1, i2_{i1}, \ldots, iu^z_{\ldots i2_{i1}}} = \mathop{\circ}_{i(u^z+1)_{\ldots i2_{i1}}=1}^{I(u^z+1)_{\ldots i2_{i1}}} R^z_{i1, i2_{i1}, \ldots, i(u^z+1)_{\ldots i2_{i1}}} \quad (15)$$

To obtain a generalized model R^z for solving the entire set of tasks performed during the interaction between students and the ILS, expression (4) is applied sequentially to all the nodes of task tree D^z. The constructed task tree D^z and the process of analyzing and processing it form a structural morphological task model solved in the ILS (Pospelov, 1986):

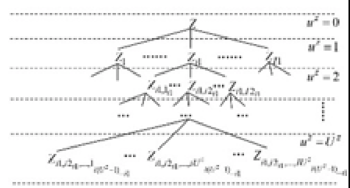
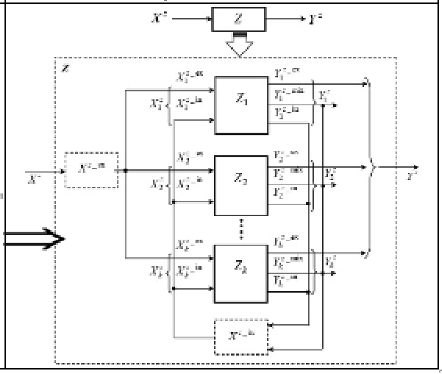
$$M^z = \langle D^z, R^z \rangle, \quad (16)$$

where D^z is the structure of student competencies formation process management tasks and R^z is the morphology of the tasks.

Figure 3 shows a generalized set-theoretic model of the information interaction between the ILS components.

$S = \{U, X, Y, \Re, \Im\}$

Figure 3
A set-theoretic model of information
interaction of ILS components

<table>
<tr><td rowspan="2">Functional part</td><td rowspan="2">Technical part</td><td colspan="2">Information part</td></tr>
<tr><td>Structural component</td><td>Parametric component</td></tr>
<tr><td>Functional part includes the learner and the educator.
Input space:
$U_{\text{jио}} = U^{\text{jво}} \cap U_{\text{иво}}$;
$U_{\text{jто}} = U_{\text{jво}} \cap U_{\text{тво}}$;
$U_{\text{jс}} = U_{\text{jвс}} / (U_{\text{jвс}} \cap U_{\text{jис}} \cap U_{\text{jтс}})$;
$U_{\text{ио}} = U_{\text{иво}} / (U_{\text{иво}} \cap U_{\text{jио}})$;
$U_{\text{то}} = U_{\text{тво}} / (U_{\text{тво}} \cap U_{\text{jто}})$;
$U_{\text{Э}} = U_{\text{jс}} \times U_{\text{эт}} \times U_{\text{jис}}$.
State space:
$X = X_{\text{Э}} \times X_{\text{И}} \times X_{\text{Т}}$.
Output space:
$У_{\text{j}} = У_{\text{jв}} \times У_{\text{jт}} \times У_{\text{jтв}}$.</td>
<td>Technical part includes personal computers and servers.
Input space:
$U_{\text{Т}} = U_{\text{тс}} \times U_{\text{тэ}} \times U_{\text{jтс}}$;
$U_{\text{jт}} = У_{\text{иэ}} \times У_{\text{иЭв}}$;
$U_{\text{тэ}} = У_{\text{jи}} \times У_{\text{jив}}$.
State space:
$У_{\text{т}} = У_{\text{Этв}} \times У_{\text{тв}} \times У_{\text{тЭв}}$.
$У_{\text{т}} = У_{\text{Этв}} \times У_{\text{тв}} \times У_{\text{тЭв}}$
System response: $\Re$ = {R:U×X→Y}</td>
<td>Information part includes a knowledge database, a modeling subsystem, and a learning path selection subsystem.
Input space:
$U_{\text{И}} = U_{\text{ис}} \times U_{\text{иэ}} \times U_{\text{jис}}$.
Output space:
$У_{\text{и}} = У_{\text{ив}} \times У_{\text{иэ}} \times У_{\text{иЭв}}$.
Information function:
$\Im = \{F: X \times Y \rightarrow Y\}$.
Task space:
$Z = \{Z_{i1}, i1 = \overline{1, I1}\}; \quad Z_{i1} = \{Z_{i1, i2_{i1}}, i1 = \overline{1, I1},\ i2_{i1} = \overline{1, I2_{i1}}\}$</td>
<td>Execution of task Z_i through information function
F_i^z :
$Z_{i1, i2_{i1}, \dots, iu^z_{\dots i2_{i1}}} \Rightarrow F^z_{i1, i2_{i1}, \dots, iu^z_{\dots i2_{i1}}} \subseteq X^z_{i1, i2_{i1}, \dots, iu^z_{\dots i2_{i1}}} \times Y^z_{i1, i2_{i1}, \dots, iu^z_{\dots i2_{i1}}}$
Input and output space:
$X_k^z = \{X_k^{z-\text{ex}}, X_k^{z-\text{in}}\};\ X_k^{z-\text{ex}} \subseteq X^z;\ X_k^{z-\text{in}} \not\subset X^z$;
$X_k^{z-\text{ex}} \bigcup X_k^{z-\text{in}} = X_k^z; \quad X_k^{z-\text{ex}} \bigcap X_k^{z-\text{in}} = \varnothing$;
$X_k^{z-\text{ex}} = \{x^{z-\text{ex}}_{k, i_k^{z-\text{ex}}},\ k = \overline{1, K},\ i_k^{z-\text{ex}} = \overline{1, I_k^{z-\text{ex}}}\}$;
$X_k^{z-\text{in}} = \{x^{z-\text{in}}_{k, i_k^{z-\text{in}}},\ k = \overline{1, K},\ i_k^{z-\text{in}} = \overline{1, I_k^{z-\text{in}}}\}$. ,
where input X_k^z and output Y_k^z sets of slave tasks Z_k,</td></tr>
<tr><td colspan="2">Target task solution morphology:
$Z = \{Z_k, k = \overline{1, K}\}$, $R^z \subset X^z \times Y^z;\ R_k^z \subset X_k^z \times Y_k^z$,
where: $X^z = \{x_i^z, i = \overline{1, I}\};\ X_k^z = \{x^z_{k, i_k}, i_k = \overline{1, I_k}\}$;
$Y^z = \{y_j^z,\ j = \overline{1, J}\};\ Y_k^z = \{y^z_{k, j_k}, j_k = \overline{1, J_k}\}$.
$\Leftarrow \quad R^z_{i1, i2_{i1}, \dots, iu^z_{\dots i2_{i1}}} = \mathop{\circ}\limits_{i(u^z+1)_{\dots i2_{i1}} = 1}^{I(u^z+1)_{\dots i2_{i1}}} R^z_{i1, i2_{i1}, \dots, i(u^z+1)_{\dots i2_{i1}}}$</td>
<td></td>
<td></td></tr>
</table>

Source: compiled by the authors

3. Results

As part of the preliminary experiment with second-year students majoring in Mathematical Methods in Economics and Applied Information Science in Economics on the use of ILS for generating an individual educational environment, testing was conducted with the aim of identifying the level of competence in the Numerical Methods discipline after the first month of training. Eighty-eight second-year students were tested, comprising 28 students majoring in Mathematical Methods in Economics, 25 in Applied Information Science in Economics, and 35 in Information Science. The results of testing the students majoring in Mathematical Methods in Economics are presented in Table 1.

Table 1
Results of testing second-year students majoring
in mathematical methods in economics

Grade	Excellent	Good	Passing	Failing	Total
Number of students	5	8	10	5	28

Let us find the numerical characteristics of the resulting sample. The arithmetic mean is calculated by the formula,

$$\bar{x} = \frac{x_1 n_1 + x_2 n_2 + \dots + x_k n_k}{n} = \sum_1^k \frac{x_i n_i}{n}. \qquad (17)$$

In this case, the sample size is n = 28, while the frequencies are n1 = 5, n2 = 8, n3 = 10, and n4 = 5. Therefore, the arithmetic mean is $\bar{x} = \frac{5 \cdot 5 + 4 \cdot 8 + 3 \cdot 10 + 2 \cdot 5}{28} = 3.46.$ We calculate the sample variance using the following formula:

$$D = \frac{\sum_1^k n_i (x_i - \bar{x})^2}{n}. \qquad (18)$$

For this purpose, we draw up a calculation table.

Table 2
Sample variance
calculation table

$\bar{x}$	ni	$x_i - \bar{x}$	$(x_i - \bar{x})^2$	$(x_i - \bar{x})^2 \cdot n_i$
5	5	1.54	2.36	11.79
4	8	0.54	0.29	2.3
3	10	–0.46	0.22	2.16
2	5	–1.46	2.14	10.72
Total	28			26.96

Thus, the sample variance is $D = \frac{26.96}{28} = 0.96.$

Table 3
Results of testing second-year students majoring
in applied information science in economics

Grade	Excellent	Good	Passing	Failing	Total
Number of students	8	5	5	7	25

In exactly the same way as for the first sample, we find the sample mean by the formula (17). In this case, the sample size is n = 25, and the frequencies are n1 = 8, n2 = 5, n3 = 5, and n4 = 7. Therefore, the arithmetic mean is $\bar{x} = \frac{5 \cdot 8 + 4 \cdot 5 + 3 \cdot 5 + 2 \cdot 7}{25} = 3.56.$. For calculating the sample variance, we draw up a calculation table.

Table 4
Sample variance
calculation table

$\bar{x}$	ni	$x_i - \bar{x}$	$(x_i - \bar{x})^2$	$(x_i - \bar{x})^2 \cdot n_i$
5	8	1.44	2.07	16.59
4	5	0.44	0.19	0.97
3	5	-0.56	0.31	1.57
2	7	-1.56	2.43	17.04
Total	25			36.16

Thus, the sample variance is $D = \frac{36.16}{25} = 1.45.$.

Table 5
Results of testing second-year students
majoring in information science

Grade	Excellent	Good	Passing	Failing	Total
Number of students	10	8	11	6	35

Let us find the numerical characteristics of this sample. First, we calculate the sample mean as follows: $\bar{x} = \frac{5 \cdot 10 + 4 \cdot 8 + 3 \cdot 11 + 2 \cdot 6}{35} = 3.63.$. Next, we draw up a calculation table of the sample variance.

Table 6
Sample variance
calculation table

$\bar{x}$	ni	$x_i - \bar{x}$	$(x_i - \bar{x})^2$	$(x_i - \bar{x})^2 \cdot n_i$
5	10	1.37	1.88	18.81
4	8	0.37	0.14	1.10
3	11	-0.63	0.40	4.35
2	6	-1.63	2.65	15.91
Total	35			40.17

The sample variance is $D = \frac{40.17}{35} = 1.15.$. We aim to test the hypothesis that the level of formedness of the Numerical Methods competence in students majoring in different subjects after a month of training does not differ considerably. To that end, we conduct a pairwise comparison of the sample populations. To test this hypothesis, we use an approximate test for comparing two randomly distributed parent population means:

$$Z_{obs} = \frac{\bar{x} - \bar{y}}{\sqrt{{D(X)}/{n} + {D(Y)}/{m}}}. \qquad (19)$$

For two independent samples with sizes n = 25 and m = 28, the sample means $\bar{x} = 3.56$ and $\bar{y} = 3.46$ and sample variances, D(X) = 1.45 and D(Y) = 0.96 were found above. At a significance level of 0.05, we check the null hypothesis H0: M(X) = M(Y). Substituting the available data into equation (17) for calculating the observed value of the approximate test, we obtain Zobs = 0.33. The critical section is right sided. We shall find the critical point via the formula, F(Zcr) = (1 – 2α)/2 = (1 – 2·0.05)/2 = 0.45. According to Laplace's function table, we find Zcr = 1.64. Since Zobs < Zcr, specifically, 0.33 < 1.64, there is no reason to discard the null hypothesis. Next, let us test the null hypothesis at a significance level of 0.05 for two independent samples with sizes of 35 and 25. The following values were found above: a) sample means: 3.63 and 3.56; and b) sample variances: 1.15 and 1.45.

Let us consider the null hypothesis H0: M(X) = M(Y) with the competing hypothesis M(X) > M(Y). We calculate the observed value of the approximate test in this case to obtain Zobs = 0.23. The critical section is right sided. The critical point F(Zcr) = (1 − 2α)/2 = 0.45. According to Laplace's function table, we find Zcr = 1.64. Since Zobs < Zcr, (0.23 < 1.64), we conclude that both samples belong to the same parent population. Similarly, we can verify that there is no reason to discard the null hypothesis for two independent samples with sizes of 35 and 28. Thus, the results allow for the conclusion that the level of Numerical Methods competence of the second-year students after the first month of training is not much different. This conclusion allows us to form a control group in the framework of the training program in Mathematical Methods in Economics (Table 1) and an experimental group based on the training program in Applied Information Science in Economics (Table 3). The final assessment of the level of Numerical Methods competence among the second-year students as part of the experiment was made in the fourth semester. Testing was held in the ILS that provided each student with a tailored educational environment by generating a set of possible learning paths upon completing the course in Numerical Methods.

Table 7
Results of final assessment of numerical methods competence of students majoring in mathematical methods in economics (control group)

Grade	Excellent	Good	Passing	Failing	Total
Number of students	4	9	12	3	28

Les us find the sample mean: $\bar{x} = \frac{5 \cdot 4 + 4 \cdot 9 + 3 \cdot 12 + 2 \cdot 3}{28} = 3.5$. Then, we draw up a calculation table for the sample variance:

Table 8
Sample variance calculation table

$\bar{x}$	ni	$x_i - \bar{x}$	$(x_i - \bar{x})^2$	$(x_i - \bar{x})^2 \cdot n_i$
5	4	1.50	2.25	9.00
4	9	0.50	0.25	2.25
3	12	-0.50	0.25	3.00
2	3	-1.50	2.25	6.75
Total	28			21.00

whereby $D = \frac{21.00}{28} = 0.75$. The results of the final assessment of the experimental group are shown in Table 9.

Table 9
Results of final assessment of numerical methods competence of students majoring in applied information science in economics (experimental group)

Grade	Excellent	Good	Passing	Failing	Total
Number of students	10	8	6	1	25

Let us calculate the sample mean: $\bar{x} = \frac{5 \cdot 10 + 4 \cdot 8 + 3 \cdot 6 + 2 \cdot 1}{25} = 4.08$. Then, we draw up a calculation table for the variance:

Table 10
Sample variance calculation table

$\bar{x}$	ni	$x_i - \bar{x}$	$(x_i - \bar{x})^2$	$(x_i - \bar{x})^2 \cdot n_i$
5	10	0.92	0.85	8.46
4	8	-0.08	0.01	0.05
3	6	-1.08	1.17	7.00
2	1	-2.08	4.33	4.33
Total	25			19.84

Based on the data in Table 10, we find the sample variance: $D = \frac{19.84}{25} = 0.79$. At a significance level of 0.05, for the last two samples we test the null hypothesis: H0: M(X) = M(Y) with the competing hypothesis M(X)> M(Y). To that end, we calculate the observed value of the approximate test for the samples under consideration using formula (17) to obtain Zobs = 2.40.

The critical section is right-sided. We find the critical point by the formula: F (Zcr) = (1 - 2 α)/2 = (1 - 2·0.05)/2 = 0.45. According to Laplace's function table, we find Zcr = 1.64. In contrast to the sample for testing the second-year students, in this case we have inequality Zobs > Zcr, (2.40 > 1.64).

This means that the control and experimental group samples belong to different parent populations. The result can be interpreted as follows: the students in the experimental group have significantly higher Numerical Methods competence obtained in the ILS that generates a set of possible learning paths based on different abilities and background knowledge of the system users than the students in the control groups.

4. Discussion

The above model of information interaction of the intelligent learning system components aims to solve general and (or) specific tasks arising in ILSs, namely to assess students' individual abilities and the knowledge acquired, to generate an individual learning path, to form information content from the knowledge database, and to monitor the acquired competencies in real time mode. The tasks are carried out by means of software from among the information support and by implementing the information functions of the intelligent instructional components in the ILS.

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Bibliographic references

Afanasyev, A., & Voyt, N. (2010). Intelligent training system for the conceptual design of automated systems. *Bulletin of the Samara Scientific Center of the Russian Academy of Sciences, 12*(4-2), 465-468.

Ben-Jacob, M., Levin, D., & Ben-Jacob, T. (2000). Learning Environment in XXI. *International Journal of Educational Telecommunications, 6*(3), 201-213.

Bespalko, V. (1995). *Pedagogy and progressive learning technologies.* Moscow.

Brusilovsky, P. (n.d.). Adaptive and Intelligent Technologies for Web-based Education. In C. Rollinger, & C. Peylo, *Special Issue on Intelligent Systems and Teleteaching, Konstliche Intelligenz* (pp. 19-25).

Brusilovsky, P., Ritter, S., & Schwarz, E. (1997). Distributed intelligent tutoring on the Web. *Proceedings of AI-ED'97, 8th World Conference on Artificial Intelligence in Education*, 482-489.

Butorin, D. (2007). Intelligent adaptive learning system for distance education. *Computer science and education, 10*, 126-128.

Cemile, S., Nur, A., & Lakhmi, C. (2008). Intelligent learning system for online learning. *International Journal of Hybrid Intelligent Systems - Recent Advances in Intelligent Paradigms Fusion and Their Applications archive, 5*(3), 129-141.

Ding, G., Jiang, J., Zhang, H., Ma, X., Li, R., Zou, Y., & Zhang, J. (2016). Development and challenge of digital design of high-speed trains in China. *Journal of Southwest Jiaotong University, 51*(2), 251-263.

Dolotina, E. (2013). Features of the use of expert systems in intelligent computer-based training systems. *Proceedings of the International Symposium Reliability and Quality, 1*, 276-278.

Fardinpour, A., Mohsen, P., & Burkle, M. (2014). Intelligent Learning Management Systems: Definition, Features and Measurement of Intelligence. *International Journal of Distance Education Technologies, 12*(4), 19-31.

Federal Law. (2012). *"On education in the Russian Federation": Federal Law No. 273 as of December 29, 2012.* Retrieved from http: //www.rg.ru/2012/12/30/obrazovanie-dok.html

Federal Standard. (2018). *The federal state educational standard of higher education – a bachelor's degree in training 44.03.05 Pedagogical education (with two training profiles).* Retrieved from http://fgosvo.ru/uploadfiles/FGOS%20VO%203++/Bak/440305_B_3_

Khashbulatova, B. (2016). The principles of building intelligent learning systems. *E-learning in continuing education, 1*, 957-962.

Khramtsova, E. (2017). Intelligent learning systems. *Theory. Practice. Innovation, 12*(24), 56-62.

Khutorskoy, A. (2001). *Modern didactics: Textbook for universities.* St. Petersburg: Piter.

Korolev, L. (1989). *Software equipment and decision making issues: Collection of scientific papers.* Moscow: Publishing House of Moscow State University.

Krasilnikova, V. (2012). *The use of information and communication technologies in education: a training manual.* Orenburg: Orenburg State University.

Krechetnikov, K. (2002). *Designing a creative educational environment based on information technology at a university. Monograph.* Moscow: Goskoor Center.

Kudryashova, E. (2007). The structure of an automated teaching system based on the recommendations of the Bologna conference. *Successes in modern science, 7*, 115.

Kupeeva, I., Ravodin, R., & Efremov, A. (2015). Intelligent training systems as an element of a system for improving the quality of medical care. *Health Protection Manager, 1*, 51-56.

Lalov, B. (1982). *Didactic basis for the use of automated teaching aids: Abstract of the dissertation of the Candidate of Sciences (Pedagogy).* Moscow: MSPI.

Liaudis, V. (1985). *Psychological principles of constructing interactive training programs in a situation of computer training. Psychological, pedagogical and psychophysiological problems of computer training.* Moscow: Pedagogy.

Lim, W. (2017). Improving student engagement in higher education through mobile-based interactive teaching model using socrative. *IEEE*, 404-412.

Liu, Y., & Xie, C. (2016). An intelligent learning system for supporting interactive learning through student engagement study. *12th International Conference on Natural Computation, Fuzzy Systems and Knowledge Discovery (ICNCFSKD)*, 618-623.

Mashbits, E. (1988). *Psychological and pedagogical problems of the computerization of education.* Moscow: Pedagogy.

Mona, H., & Sanaa, H. (2016). An intelligent tutoring system for teaching the grammar of the Arabic language. *Journal of Electrical Systems and Information Technology, 3*(2), 282-294.

Obraztsov, P. (2000). *Psychological and pedagogical aspects of the development and application in the university of information technology training.* Oryol: Oryol State Technical University.

Ohlsson, S. (1993). Constraint-Based Student Modeling. *Journal of Artificial Intelligence in Education, 3*(4), 429.

Okolelov, O. (1999). *Distance Learning.* Lipetsk: Publishing House of LSTU.

Pospelov, D. (1986). *Situational management. Theory and practice.* Moscow: Nauka.

Richardson, J., Morgan, A., & Woodley, A. (1999). Approaches to studying in distance education. *Higher Education, 37*(1), 23-55.

Salih, S.Q. (2019). A new training method based on black hole algorithm for convolutional neural network. *Journal of Southwest Jiaotong University, 54*(3). Retrieved from http://jsju.org/index.php/journal/article/view/304

Selevko, T. (1998). *Modern educational technology.* Moscow: Public Education.

Shaik, M., Al Balushi, M., Omar, A., Singh, A., & Ramaiah, C. (2017). E-learning tools to enhance student learning experience: A practice on control system engineering. *Reliability Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO) 2017 6th International Conference*, 674-677.

Shiyanov, E., & Kotova, I. (1999). *Personality Development in Learning.* Moscow: Akademiya.

Stern, M., Woolf, B., & Kuroso, J. (1997). Intelligence on the Web? *Proceedings of AI-ED'97, 8th World Conference on Artificial Intelligence in Education*, 490-497.

Tikhomirov, O. (1977). *Psychological mechanisms of targeting.* Moscow: Nauka.

Trembach, V. (2013). Electronic educational systems using intelligent technologies. *Open Education, 4*.

Verbitsky, A., & Bakshaev, N. (1998). The development of motivation in intensive learning. *Alma Mater, 1-2*, 47-50.

Verbitsky, A., & Kruglikov, V. (1998). Contextual education: the formation of motivation. *Higher education in Russia, 1*, 101-107.

Xu, D., Wang, H., & Wang, M. (2005). A conceptual model of personalized virtual learning environments. *Expert Systems with Applications: An International Journal, 29*(3), 525-534.

Yakhneeva, I.V., Agafonova, A.N., Fedorenko, R.V., Shvetsova, E.V., & Filatova, D.V. (2020). On collaborations between software producer and customer: A kind of two-player strategic game. *Advances in Intelligent Systems and Computing, 908*, 570-580.

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[Index]