Mathematical model of student's competence formation process in accordance with cross-disciplinary relationships

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Abstract

Authors describe the linear model of education process; upgrade this model in accordance with cross-disciplinary relationships and their effect to level of training in this article. Opportunity of usage the linear model of education process with cross-disciplinary relationships for modeling of the forming student's competences in accordance with new State Educational Standards is also considered. Method of integration this model in information system of graduates' employment in Rubtsovsk institute (branch) of Altay State University is shown in the end of this article.
Keywords: Linear model of education process; graduate's competence model; skills dynamics; competences

1. Introduction

Modern features of Russian education system imply the necessity of analysis and forecasting of students' training level. This is due to many reasons, for example, using the level of students' competences as a result of education process in universities and colleges by control authorities. The main metrics of training results are graduates' competences in the Third Generation of State Education Standards. The necessity of regulatory authorities as a result of the educational process to consider the level of competence of students and graduates of universities and colleges.

There are many scientific works dedicated of mathematical modeling of education process. For example, in article [1, p. 291] described a deterministic mathematical model of process of the growth of student's knowledge; in article [2, p. 60] presented the mathematical model of self-management of education process by student. There are methods of improving of education process using mathematical modeling in scientific works [3, p. 187; 4, p. 30].

2. The object of the study

The object of the study in this work is student's competence formation process in accordance with cross-disciplinary relationships.

In this article linear mathematical model of education process in accordance with cross-disciplinary relationships and their effect to level of training is described. The main goals of the research are improving linear model of education process [5, p. 152; 6, p. 281] in accordance with cross-disciplinary relationships and adaptation this model to graduate's competence model, used in educational process in colleges, universities.

3. Mathematical modeling of education process in accordance with cross-disciplinary relationships

3.1. Mathematical model of dynamics of competence's level with the consideration factors of learning and training of one student for two disciplines.

System of equations (see formula (1)) describes skills dynamics with the consideration factors of learning and training of one student for two disciplines.

$$\begin{cases} x_1(t+1) = \alpha x_1(t) + \beta V_1(t) + \gamma Z_1(t) + \delta_1 x_2(t) \\ x_2(t+1) = \alpha x_2(t) + \beta V_2(t) + \gamma Z_2(t) + \delta_2 x_1(t) \end{cases}, \tag{1}$$

where $x_i(t+1)$ – level of competence in discipline *i*, learning at the moment *(t+1)*;
$x_i(t)$ – level of competence in discipline (complex of disciplines), learning at the moment *t*;
$V_i(t)$ – factor of student training (tests, course works, practices, internships e.t.c.) in discipline *i*;
$Z_i(t)$ – factor of student learning (fundamental knowledge) in discipline *i*;

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α, β, γ – individual indicators of student potential;

δ_1, δ_2 – indicators of cross-disciplinary relationships between two disciplines.

For example, if $\delta_1 > 0$, $\delta_2 = 0$, then level of competence in discipline 2 has a positive effect on the level of competence in discipline 1. But level of competence in discipline 1 hasn't any effects in dynamics of competence's level in discipline 2.

Further we assume, that $\delta_1 \geq 0$, $\delta_2 \geq 0$. We imply all parameters of the system of equations (1) definite to study the dynamics of education process

Problem of the parameters' values is interesting also. We may assume, that the solution of the system of equations (1) will be unstable if the values of parameters (δ_1, δ_2) equals big positive values. So in case of any initial conditions the level of competence will tend to infinity. It is against the law of education process. Therefore it is necessary to consider this property to ensure sustainability when we identify of system (1) parameters.

There is the common solution of the system of equations (1) at the moment *k* (see formula (2)).

$$\begin{cases} x_1(k) = \alpha^k \cdot x_{01} + \beta \cdot \sum_{j=0}^{k-1} V_{1j} \cdot \alpha^{k-1-j} + \gamma \cdot \sum_{j=0}^{k-1} Z_{1j} \cdot \alpha^{k-1-j} + \delta_1 \cdot \sum_{j=0}^{k-1} x_{2j} \cdot \alpha^{k-1-j} \\ x_2(k) = \alpha^k \cdot x_{02} + \beta \cdot \sum_{j=0}^{k-1} V_{2j} \cdot \alpha^{k-1-j} + \gamma \cdot \sum_{j=0}^{k-1} Z_{2j} \cdot \alpha^{k-1-j} + \delta_2 \cdot \sum_{j=0}^{k-1} x_{1j} \cdot \alpha^{k-1-j}, \end{cases} \quad (2)$$

$$k = 1, 2, 3, \ldots$$

3.2. Mathematical model of dynamics of competence's level with the consideration factors of learning and training of one student for n disciplines (in accordance with cross-disciplinary relationships).

If individual indicators of student potential are different in disciplines (for example, student study well in math, but has not high results in history), then the mathematical model (1) can be changed like in formula (3).

$$\begin{cases} x_1(t+1) = \alpha_1 \cdot x_1(t) + \beta_1 \cdot V_1(t) + \gamma_1 \cdot Z_1(t) + \delta_{12} \cdot x_2(t) + \cdots + \delta_{1n} \cdot x_n(t) \\ x_2(t+1) = \alpha_2 \cdot x_2(t) + \beta_2 \cdot V_2(t) + \gamma_2 \cdot Z_2(t) + \delta_{21} \cdot x_1(t) + \cdots + \delta_{2n} \cdot x_n(t) \\ \ldots \\ x_n(t+1) = \alpha_n \cdot x_n(t) + \beta_n \cdot V_n(t) + \gamma_n \cdot Z_n(t) + \delta_{n1} \cdot x_1(t) + \cdots + \delta_{n,n-1} \cdot x_{n-1}(t) \end{cases}, \quad (3)$$

where $x_i(t+1)$ – level of competence in discipline *i* (complex of disciplines), learning at the moment *(t+1)*;

$x_i(t)$ – level of competence in discipline (complex of disciplines), learning at the moment *t*;

$V_i(t)$ – factor of student training (tests, course works, practices, internships e.t.c.) in discipline *i*;

$Z_i(t)$ – factor of student learning (fundamental knowledge) in discipline *i* (complex of disciplines);

$\alpha_i, \beta_i, \gamma_i$ – individual indicators of student potential in discipline *i* (complex of disciplines);

$\Delta = \begin{pmatrix} \delta_{11} & \delta_{12} & \ldots & \delta_{1n} \\ \delta_{21} & \delta_{22} & \ldots & \delta_{2n} \\ \delta_{31} & \delta_{32} & \ldots & \delta_{3n} \\ & \ldots & & \\ \delta_{n1} & \delta_{n2} & \ldots & \delta_{nn} \end{pmatrix}$ – matrix of indicators of cross-disciplinary relationships between disciplines (complex of disciplines), $\delta_{ij}(i \neq j) \geq 0, \delta_{ij}(i = j) = 0$.

There is the common solution of the system of equations (3) at the moment *k* (see formula (4)).

$$x_i(k) = \alpha_i^k \cdot x_{0i} + \beta_i \cdot \sum_{j=0}^{k-1} V_{ij} \cdot \alpha_i^{k-1-j} + \gamma_i \cdot \sum_{j=0}^{k-1} Z_{ij} \cdot \alpha_i^{k-1-j} + \quad (4)$$

$$+ \Delta \cdot \sum_{i=1}^{n} \sum_{j=0}^{k-1} x_{ij} \cdot \alpha_i^{k-1-j}, i = 1, 2, 3, \ldots, n; k = 1, 2, 3, \ldots$$

This model (3) can be used for measuring of competence level of colleges and universities students.

Level of competence $x_i(k)$ compares with competence *i* described in Federal State Educational Standards. Each competence is formed by the complex of disciplines. Students have tests and examination points at the end of these disciplines. We rate student's level of competence at the moment of time *t* during tests and exams.

Then we get following indicators for mathematical model (3): $x_i(k)$ – student's level of competence *i* at the moment of time *k*; x_{0i} – student's level of competence *i*, rated before learning the first discipline in curriculum; $V_i(k)$ – factor of student training (tests, course works, practices, internships e.t.c.); $Z_i(k)$ – factor of students learning (fundamental knowledge). As a result the table is formed with all student's level of competence in information system of graduates' employment in Rubtsovsk Institute (branch) of Altay State University [6, p. 6].

4. Results and Discussion

The result of current research is improving linear model of education in accordance with cross-disciplinary relationships on level of student's knowledge. Also authors can identify new mathematical model (3) with the procedure of estimation pupil's level of competence using in schools, colleges and universities.

5. Conclusion

Authors offered the mathematical linear model of dynamics of competence's level with the consideration factors of learning and training of one student in accordance with cross-disciplinary relationships.

Opportunity of usage the linear model of education process with cross-disciplinary relationships for modeling of the forming student's competences in accordance with new State Educational Standards is also considered. Method of integration this model in information system of graduates' employment in Rubtsovsk institute (branch) of Altay State University is shown in the end of this article.

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