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TRAINING AT SCHOOL AND UNIVERSITY: RESULTS OF THE IMITATING MODELING

ОБУЧЕНИЕ В ШКОЛЕ И УНИВЕРСИТЕТЕ: РЕЗУЛЬТАТЫ ИМИТАЦИОННОГО МОДЕЛИРОВАНИЯ

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Abstract: In the article the features of use of the computer simulations for study of the didactic systems are discussed. It is offered the three-component model of training of the learner interested by exact sciences, which after leaving school goes to university on physical and mathematical faculty.

The purpose and tasks. To study opportunities of construction of the “teacher-learner” model which takes into account: 1) division of the educational disciplines on the “exact” and "humanitarian-qualitative" subjects; 2) distributions of the educational information on years of training; 3) transitions of the weak (quickly forgotten) knowledge in the strong knowledge, which the pupil forgets slower; 4) dependences of the learner’s motivation and the assimilation coefficient from character of the learned subjects and year of training; 5) degrees of use of the studied material on various disciplines at the subsequent training and everyday life. To create the imitating model of training at school and university, to analyse the results of modeling.

Methodology. The methods of the qualitative, mathematical and computer (imitating) modeling are used. It is analysed the one-component model of the didactic system. The three-component model of training at school and university is created, the system of the differential equations is written, the computer program, which calculates the learner's knowledge in the various time moments, is submitted.

Results. The computer model of the system “teacher-learner” is offered. The graphs of temporary dependences of the strong and weak knowledge of the physical and mathematical and “humanitarian-qualitative” disciplines are received and analysed.

Conclusions. It is proved the possibility of creation of the imitating model of training at school and university which for any moment of time allows to calculate approximate quantity of: 1) the strong and weak knowledge of learner; 2) the knowledge of the “exact” and “humanitarian” subjects; 3) the pupil’s knowledge studied within concrete year of training.

Аннотация: В статье обсуждаются особенности использования компьютерных моделей для изучения дидактических систем. Предложена трехкомпонентная модель обучения ученика, интересующегося точными науками, который после окончания школы поступает в вуз на физико-математический факультет.

Цель и задачи. Изучить возможности построения модели дидактической системы, которая учитывает: 1) деление учебных дисциплин на «точные» и «гуманитарно-качественные»; 2) распределение учебной информации по годам обучения; 3) переход непрочных быстро забывающихся знаний в прочные, которые забываются медленнее; 4) зависимость мотивации учащегося и коэффициента усвоения от характера изучаемых предметов и года обучения; 5) степень использования изученного материала по различным дисциплинам при последующем обучении и в повседневной жизни. Создать имитационную модель обучения в школе и вузе, проанализировать результаты моделирования.

Методология. Используются методы качественного, математического и компьютерного (имитационного) моделирования. Проанализирована однокомпонентная и трехкомпонентная модели обучения в школе и вузе, записана система дифференциальных уравнений, представлена компьютерная программа, рассчитывающая состояние обучаемого в различные моменты времени.

Результаты. Предложена компьютерная модель дидактической системы «учитель–ученик». Получены и проанализированы графики временных зависимостей прочных и непрочных знаний ученика (студента) по дисциплинам физико-математического цикла и «гуманитарно–качественным» дисциплинам.

Выводы. Доказано, что возможно создать имитационную модель обучения в школе и вузе, которая для любого момента времени позволяет приблизительно рассчитать количество: 1) прочных и непрочных знаний обучаемого; 2) знаний точных и гуманитарных предметов; 3) знаний, изученных в течение конкретного года обучения.

Keywords: computer model, didactic system, imitating modeling, learning, training, pupil.

Ключевые слова: дидактическая система, имитационное моделирование, компьютерная модель, обучение, ученик, студент.

The aim of the didactics consists in the description and explanation of the training process, revealing of internal links and relations between didactic objects, disclosing of regularities and driving forces of the educational process development and conditions of its improvement [1]. Now for study of the didactic systems are used: 1) the methods of pedagogical experiment; 2) the methods of qualitative modeling (or qualitative reasonings); 3) the methods of the mathematical modeling; 4) the methods of the imitating modeling on the computer. The mathematical modeling supposes the construction of the mathematical model of the learner or process of training and its using for the analysis of various situations. The imitating modeling method consists in creation of the computer program, which simulates the “teacher-pupil” system behaviour, and realization of the series of numerical experiments with the purpose of understanding of this system functioning and finding of various strategy for its effective management.

The basic task of simulation of the educational process consists in determination the pupil's knowledge level after training; at this we take into account his initial level, the distribution of the educational material and used methods of training (i.e. external influence) [2, p. 4]. The existing variety of computer models is possible to divide on: 1) the continuous models based on the numerical solving of the differential equations system [2, p. 53-73]; 2) the discrete models, in which pupils or process of training are simulated with help of the Petri's networks or probabilistic automats [2, p. 26-47; 3]. The special interest represents the multi-agent modeling, at which the group of the pupils is simulated by set the program agents exchanging the information with each other and with the teacher [4].

This work is based on conviction that the method of imitating modeling is possible and necessary to use for study the didactic systems, as it allows to analyze the training process, to reveal its features, to establish dependences between distribution of the educational material, pupil’s parameters and the knowledge level at the end of training. The basic purpose of work consists in construction the imitating model of training at school and university which takes into account: 1) the division of the learner’s knowledge in dependence from the degree of the assimilation durability;

2) the use of the pupil's knowledge during a vacation and after university termination; 3) the stronger assimilation of the studied information, which applies by pupil in the education activity and everyday life.

1. Methodological Framework

In mathematical modeling of the didactic systems such scientists, as R. Atkinson, G. Bauer, E. Kroters [5], L. P. Leontiev and O. G. Gokhman [6], R. Bush and F. Mosteller, F. Roberts, A. P. Sviridov [7], V. V. Mayer [8] etc. were engaged. In last time the educational process simulation is closely connected with creation of the various automated testing and training systems [10]. As marks Yu. I. Petrov [9], the used model of the learner should contain the information about his knowledge, skills and abilities to training and tasks execution, the personal characteristic (ability to forgetting and restoration of the studied information) and other parameters. In the article [10] E. E. Bul analyzing various computer models of training, carried out their comparative analysis by the following criteria: the spread of the models types; using of parameters determining result and quality of the educational process. Usually at the creating of the learner models a scientists take into account the following features [10]: 1) the level of knowledge; 2) the psychological characteristics; 3) the speeds of training or mastering; 4) the execution of the tasks; 5) the abilities to training; 6) the degrees of the pupil's skills and abilities; 7) the methods or strategy of training; 8) the structure of an educational course.

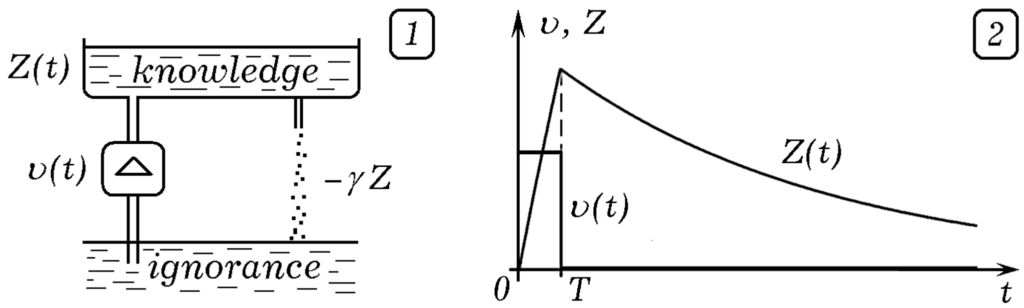

Figure 1. The hydraulic one-component model of training

2. One-component and multi-component model of training

The simple model of training is founded on the assumption, that all learning material elements (LME) are acquired by the schoolchild identical well and forgotten with equal speed. The speed of the pupil's knowledge increasing is equal: $dZ/dt = k\upsilon(t) - \gamma \cdot Z$, where $\upsilon = dI/dt$ – the speed of the information reporting, which is completely remembered by the learner, γ – the forgetting coefficient. We will consider the hydraulic model represented in a fig. 1.1: with the help of pumps the liquid goes up into the top tank with speed $\upsilon(t)$ (training, the knowledge $Z(t)$ grows); the liquid slowly flows from the tank through thin pipe, its quantity decreases (forgetting, $Z(t)$ reduces). Let us assume that training carries out during time T $(k=1)$, after that forgetting begins $(k=0)$. The turning out graphs of dependence $Z(t)$ is presented on Figure 1.2. Considered one-component model is very approximate, as it does not take into account that various LMEs are acquired unequally strongly and have various durability. That knowledge, which are included in the pupil's educational activity or applied by him in everyday life, are remembered much stronger than knowledge which he does not use.

The more exact multi-component model of training is based on the following assumptions [11–12]: 1) the pupil's knowledge Zn is divided into three categories: the weak knowledge $Z_1 = Z$, the knowledge of the average durability $Z_2 = U$ (abilities), the strong knowledge $Z_3 = N$ (skills); 2) at correct organization of the educational process the increasing speed of the weak knowledge approximately equals to speed of the teacher's information transfer $\upsilon(t) = dI(t)/dt$; 3) at training time dt the quantity $\alpha_1 Zdt$ of the first category knowledge becomes the knowledge of the second category, and the quantity $\alpha_2 Udt$ of the second category knowledge turns into the knowledge of the third category; 4) if learner does not training, in time dt the quantity $\gamma_3 Ndt$ of the knowledge of the third category transforms into the second category knowledge, and the quantity $\gamma_2 Udt$ of the knowledge of the second category becomes the first category knowledge; the quantity $\gamma_1 Zdt$ of the first category knowledge turns into ignorance (pupil forgets it). At this the pupil forgets the weak knowledge faster than the strong knowledge: $\gamma_1 > \gamma_2 > \gamma_3$.

The appropriate hydraulic model consists of three reservoirs with pipes and three pumps; while training the pumps swing up the liquid with different speeds. The liquid which is flowing out from the top tank in the lower reservoir corresponds to the pupil's knowledge transition in the category of the less strong knowledge and forgetting of part information. The discussed three-component model of training describes by system of the equations (at training $c = 1$, at forgetting $c = 0$):

$$dZ/dt = c\upsilon(t) - \alpha_1 Z - (1-c)(\gamma_1 Z - \gamma_2 U),$$
$$dU/dt = c(\alpha_1 Z - \alpha_2 U) - (1-c)(\gamma_2 U - \gamma_3 N),$$
$$dN/dt = c\alpha_2 U - (1-c)\gamma_3 N, \quad Zn = Z + U + N.$$

Here α_1, α_2 – the coefficients of "hardening" of the knowledge, γ_1, γ_2, γ_3 – the forgetting coefficients, which characterize the pupil [2, 11]. The functioning hydraulic model of training is created by V. V. Mayer more than 30 years back; the mathematical model of the didactic transient process is considered in [8].

3. The computer model of training at school and universities

With the help of the computer modeling method we shall analyze training the future expert at school and university. For definiteness let us suppose that when the learner was training in school, he shows interest to exact sciences and after 11th class he goes in high school on the physical and mathematical faculty, finishes it successfully and works on the speciality. The essential factor which influences on the result of training is the complexity of the mathematical models and reasonings using in this or that discipline. The mastering of the qualitative models and reasonings (history, biology, literature etc.) is usually connected with the smaller difficulties, than study of mathematical abstractions and quantitative models (mathematics, algebra, geometry, physics and chemistry). Therefore in this case all learned subjects can be divided into two groups: 1) the exact disciplines D1 (algebra, geometry, physics and in the lesser degree - chemistry) which uses the mathematical models; 2) all other "inexact" disciplines D2 (Russian and foreign languages, literature, history, geography, biology etc.), in which the qualitative reasonings dominates.

In order that the computer imitation corresponds to a reality more precisely, it is necessary to take into account that the result of training depends from: 1) the assimilation coefficient k_i, which is equal to a share of the acquired educational information during i–th year of training; its volume depends on amount and complexity of the learned information, and the learner's abilities to perceive a new material; 2) the quantities of the educational information L_i, which the teacher reports in 1, 2, 3, … 16 years of training; 3) the shares b_i of education information studied in i–th class ($i = 1$, 2,

…, 16), which are used by the pupil in the subsequent training and everyday life. The greater b_i, the faster Z_i increases in the next years of training and slower Z_i decreases owing to forgetting.

If the learner was trained at school during 11 years, and then five years in university, his knowledge (the state of didactic system) at any moment of time t is determined by matrixes $Z_i = (Z_1, Z_2, \ldots, Z_{16})$, $U_i = (U_1, U_2, \ldots, U_{16})$ and $N_i = (N_1, N_2, \ldots, N_{16})$. This matrixes shows quantities of the acquired knowledge of the first, second and third categories, which are included into the programs of the 1-st, 2-nd, …, 16-th years of training. The pupil's total knowledge for $i-$th year is equal $Zn_i = Z_i + U_i + N_i$ (Mayer, 2014).

The distribution of educational information during the whole time of training at school and university (16 years) can be set by two matrixes: 1) for disciplines D1: L_i^1 = (10, 13, 17, 22, 28, 36, 45, 56, 67, 78, 90, 100, 100, 100, 100, 100); 2) for disciplines D2: L_i^2 = (20, 25, 30, 38, 46, 64, 72, 82, 94, 106, 118, 60, 30, 0, 0, 0). Thus it is taken into account, that: 1) the quantities of the information in the school textbooks on D2–disciplines approximately in 2 times more than for D1–disciplines; 2) on the first, second and third university courses (12 - 14 years of training) the student not so deeply studies D2–disciplines (history, psychology, foreign language); 3) during all term of training in university (the 12th-16th years of training) the student actively studies D1–disciplines of the physical and mathematical cycle.

As the training lasts about 8 months in one year, the transfer speed of the information in $i-$th class is equal $\upsilon_i = L_i / 8$ (LME/month). Taking into account that the pupil studies the exact sciences more assiduously, it is possible to set the assimilation coefficient so: 1) for the D1–disciplines of the physical and mathematical cycle k_i = (1, 0.95, 0.9, 0.9, 0.9, 0.9, 0.8, 0.8, 0.8, 0.7, 0.7, 0.7, 0.7, 0.7, 0.7, 0.7); 2) for the "humanitarian-qualitative" D2–disciplines k_i = (1, 0.95, 0.9, 0.8, 0.7, 0.7, 0.6, 0.6, 0.5, 0.5, 0.5, 0.5, 0.5, 0, 0, 0). This choice of k_i is caused by the following factors: 1) increasing of the educational material complexity; 2) growing of its volume; 3) increasing of the learner's ability to acquire the studied information. Let's use the variables b_i which shows the part of the received in $i-$th year information which applies by learner in training and further life; they are set by matrixes: for the D1–disciplines b_i =(1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0.9, 0.8, 0.7, 0.6, 0.6); for the D2–disciplines b_i =(1, 0.95, 0.9, 0.8, 0.7, 0.7, 0.6, 0.6, 0.5, 0.5, 0.5, 0.5, 0.5, 0, 0, 0). At repetition of the educational material studied in previous $i-$th year ($i < j$, j – year of training) the speed of knowledge growing is proportional to a difference $b_i L_i$ and Zn_i (if $b_i L_i$ more Zn_i).

We receive the following three-component model of training:

During training ($C = 1$):

$$dZ_i / dt = f \cdot k_i \upsilon_i + B(b_i L_i - Zn_i) - A\alpha_1 Z_i - (1-b_i)\gamma_1 Z_i,$$

$$dU_i / dt = A(\alpha_1 Z_i - \alpha_2 U_i) - (1-b_i)\gamma_2 U_i,$$

$$dN_i / dt = A\alpha_2 U_i - (1-b_i)\gamma_3 N_i, \quad Zn_i = Z_i + U_i + N_i, \quad i = 1, 2, \ldots, 16.$$

$$Zn(t) = \sum_{i=1}^{16} Zn_i(t), \quad Z(t) = \sum_{i=1}^{16} Z_i(t), \quad U(t) = \sum_{i=1}^{16} U_i(t), \quad N(t) = \sum_{i=1}^{16} N_i(t).$$

During vacation and after training ($C = 0$):

$$dZ_i / dt = q \cdot [B(b_i L_i - Zn_i) - A\alpha_1 Z_i] - (1-b_i)\gamma_1 Z_i,$$

$$dU_i/dt = q\cdot A(\alpha_1 Z_i - \alpha_2 U_i) - (1-b_i)\gamma_2 U_i,$$
$$dN_i/dt = q\cdot A\alpha_2 U_i - (1-b_i)\gamma_3 N_i,\quad Zn_i = Z_i + U_i + N_i,\quad i = 1, 2, \ldots, 16.$$
$$f = \begin{cases} 1, & i = j, \\ 0, & i \neq j; \end{cases} \quad A = \begin{cases} f + 0{,}33b_i, & i \le j \\ 0, & i > j; \end{cases} \quad B = \begin{cases} 0{,}02, & i < j, \\ 0, & i \ge j; \end{cases} \quad q = \begin{cases} q', & i \le j, \\ 0, & i > j. \end{cases}$$

For $t = 0$ we will accept the beginning of training in the 1-st class; thus $Z_i = U_i = N_i = 0$ (i = 1, …, 16). If i equals to year of training j, then $f = 1$, and Z_i during training is increasing with speed $k_i v_i$; differently $f = 0$. In the j – th class the study of the material for j – th class and recurrence of the material for the 1st, 2nd, 3rd, …, $(j-1)$ – th classes occurs. Summand $B(b_i L_i - Zn_i)$ allows to take into account increasing of knowledge Z_i which was studied in the previous classes ($i < j$) due to repetition and their use in j – th class. While training the weak knowledge of the learner becomes stronger; at $i \le j$ the speeds of transition of the weak knowledge into strong ones are equal $A\alpha_1 Z_i$ and $A\alpha_2 U_i$. Summand $A\alpha_1 Z_i$ allows to take into account the transition of the weak knowledge of the first category in knowledge of the second category; if $i = j$, then $f = 1$ and speed of transition is proportional b_i and equals $(1 + 0{,}33b_i)\alpha_1 Z_i$. If $i < j$ (the knowledge Z_i is received earlier), then the speed of growing for Z_i is less and equal to $0{,}33b_i\alpha_1 Z_i$. Summand $A\alpha_2 U_i$ allows to take into account the transformation of the knowledge of the second category into the strong knowledge of the third category.

The knowledge which frequently uses in everyday life is forgetting slower. Therefore the forgetting speeds are proportional to the quantities of knowledge of the corresponding category and they must decrease with growth b_i. The forgetting speeds equal: $-(1-b_i)\gamma_1 Z_i$, $-(1-b_i)\gamma_2 U_i$ and $-(1-b_i)\gamma_3 N_i$. Let us suppose, that during a vacation the intensity of use of earlier acquired knowledge is in the 10 times less, than while training; then $q' = 0{,}1$. After ending of university the knowledge of the exact D1–disciplines are used more actively, for them $q' = 0{,}3$, and for the D2–disciplines $q' = 0{,}1$. At the same time there is the transition of the weak knowledge in the strong knowledge (summands $qA\alpha_1 Z_i$ and $qA\alpha_2 U_i$).

4. Results of Modeling and Discussion

Frequently at creation of the imitating model of the complex process, the problem of the reasonable choice of the large number of the various parameters appears. The expert set them, as a rule, from the assumptions which received as a result of the analysis of small quantity of the data [13]. At the same time the behavior of model has to correspond to a real situation as much as possible. In our case the parameters of model of the learner were selected so that the turning out results corresponded to training of the schoolchild or student, who copes with the educational program successfully (on 70-80 %). It is used the program 1 written in Free Pascal.

The Figure 2 shows the dynamics of changes of the knowledge $Zn(t)$, $U(t) + N(t)$ and $N(t)$, which correspond to the exact disciplines D1. It is visible, that while training at school and university the total level of the learner's knowledge $Zn(t)$ on disciplines D1 almost repeats the graph $I = I(t)$. After ending university the man continues to use the D1-knowledge which was received at training. At this the weak knowledge becomes stronger, the quantity of the strong knowledge $N(t)$ grows. The quantity of knowledge $Z_{11}(t)$ acquired in the 11th class gradually grows up to the maximal value $L_{11}(t)$ (Figure 2).

The Figure 3 shows the change of the learner's knowledge on the disciplines D2. It is visible, that at the chosen parameters of the model the increase of the knowledge $Zn(t)$ lags behind from $I(t)$ much stronger, reaches a maximum while training in university, and then decreases owing to forgetting. After termination of an university the quantity of the strong knowledge $N(t)$ remains practically constant. While training in the 8th class the quantity of knowledge Zn_8 of the D2–disciplines for the 8th class is growing. At the next years Zn_8 remains constant and then reduces slowly. It is explained so: the disciplines D2 are used by the given man in lesser degree (b_i is small), the motivation to their study is low (k_i is not enough).

Progam 1 (Free Pascal).

```
program Model_school_university;
{$N+}Uses crt, graph; Const dt=0.01; Mt=1.8; M=0.65; e=2.72; Y=600; L: array[1..16]of
integer=(10,13,17,22,28,36,45,56,67,78,90,100,100,100,100,100); b: array[1..16] of
single=(1,1,1,1,1,1,1,1,1,1,1,0.9,0.8,0.7,0.6,0.6); ku:array[1..16] of single=(1,0.95,
0.9,0.9,0.9,0.9,0.8,0.8,0.8,0.7,0.7,0.7,0.7,0.7,0.7,0.7); Var A,AA,BB,SUM,SUN,SN,Inf,
gZ,gN,t,q,f,a1,a2,g1,g2,g3: single;  i,j,k,k3,c,DV,MV: integer; v,Z,U,N,Zn,UN: array
[1..18] of single;
BEGIN DV:=Detect; InitGraph(DV,MV,''); For i:=1 to 16 do begin v[i]:=L[i]/8; end; a1
:=0.1; a2:=a1/e; g1:=0.03; g2:=g1/e; g3:=g2/e; Repeat t:=t+dt; c:=1; If (round(t) mod
12>=8)or(t>12*16-4) then c:=0; j:=round(t) div 12+1; Sum:=0; SUN:=0; SN:=0; If t>12*
16-3 then j:=16; Inf:=Inf+c*v[j]*dt;For i:=1 to j do begin If i=j then f:=1 else f:=0;
If i<=j then A:=(f+b[i]/3) else A:=0; If i>=j then BB:=0 else BB:=0.02;If i<=j then q
:=0.1 else q:=0; If b[i]*L[i]>Zn[i] then AA:=BB*(b[i]*L[i]-Zn[i]) else AA:=0; If c=1
then begin Z[i]:=Z[i]+f*ku[i]*v[i]*dt-A*a1*Z[i]*dt+AA*dt-(1-b[i])*g1*Z[i]*dt; U[i]:=
U[i]+A*(a1*Z[i]-a2*U[i])*dt-(1-b[i])*g2*U[i]*dt; N[i]:=N[i]+A*a2*U[i]*dt-(1-b[i])*g3*
N[i]*dt; end; If c=0 then begin Z[i]:=Z[i]+q*(AA-A*a1*Z[i])*dt-(1-b[i])*g1*Z[i]*dt;
U[i]:=U[i]+q*A*(a1*Z[i]-a2*U[i])*dt-(1-b[i])*g2*U[i]*dt; N[i]:=N[i]+q*A*a2*U[i]*dt-(1
-b[i])*g3*N[i]*dt; end; Zn[i]:=Z[i]+U[i]+N[i]; UN[i]:=U[i]+N[i]; SUN:=SUN+UN[i]; SN:=
SN+N[i];SUM:=SUM+Zn[i]; end; circle(10+round(Mt*t),Y-round(M*Inf),1); circle(10+round
(Mt*t),Y-round(M*SUM),1); circle(10+round(Mt*t),Y-round(M*SUN),1); circle(10+round(Mt
*t),Y-round(M*SN),1); circle(10+round(Mt*t),Y-round(M*(Zn[9])),1); circle(10+round(Mt
*t),Y,1); until (KeyPressed)or(t>800); Repeat until KeyPressed; CloseGraph; END.
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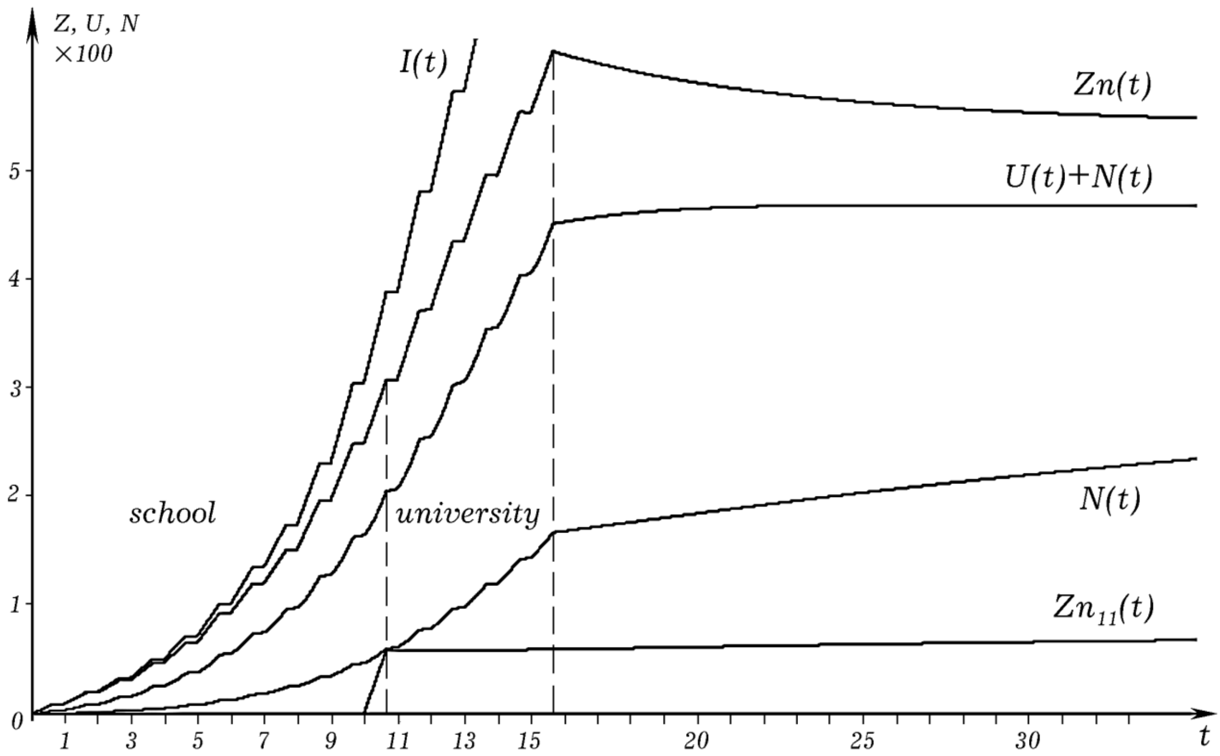

Figure 2. The change of the D1–disciplines knowledge (exact sciences)

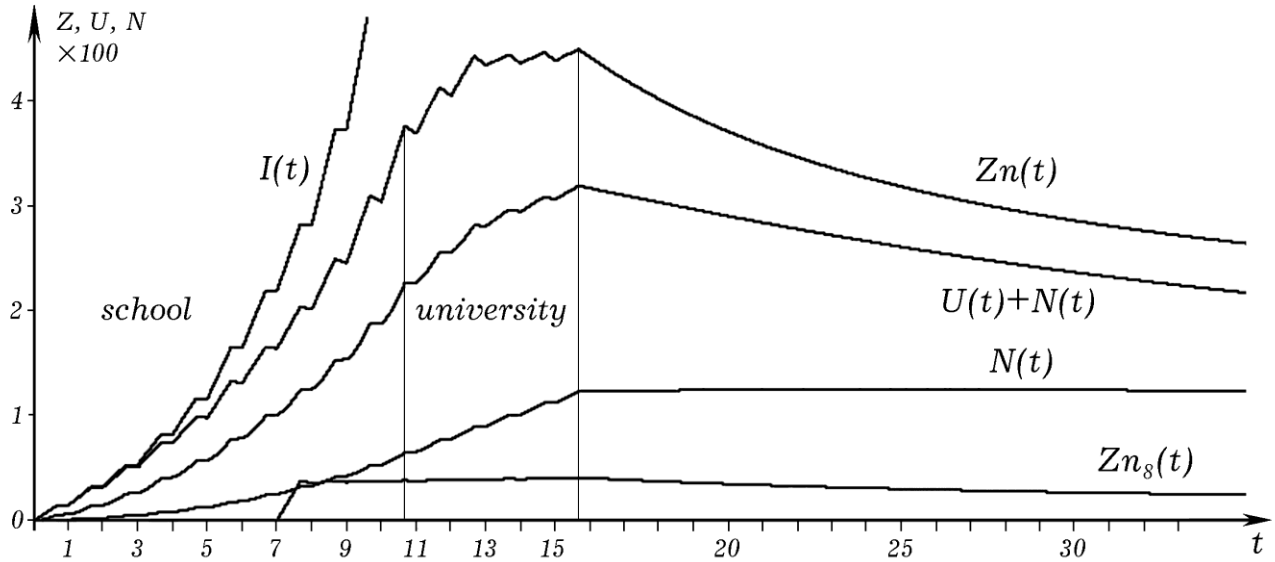

Figure 3. The change of the D2–disciplines knowledge (inexact sciences)

Conclusion

In article the multi-component model of training at school and university of the learner, who is interested by exact sciences, is offered; the results of computer modeling are given. Thus it is taken into account: 1) the transitions of the weak (which forgets quickly) knowledge in the strong knowledge, which forgets slower; 2) the use of the learned information at the subsequent training and in everyday life; 3) the dependences of the assimilation coefficient from the character of the studied discipline and the year of training; 4) the distributions of the educational information quantity in dependence from the year of training for various types of disciplines. The further development of the model requires of the its specification and detailed elaboration, for example, consideration of a features of the separate subjects study etc.

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