Adaptive Knowledge Quality Control in E-learning Using the Ranked Algorithm*

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Abstract

The paper deals with the issues related to the knowledge quality control in e-learning. The possibility of adaptive knowledge control is considered as one of the possible variants of realization of pedagogical measurement. The use of the ranked algorithm as the basis for the organization of such pedagogical measurement is proved. Possible outcomes of the algorithm implementation are calculated and proposals for its use for adaptive knowledge quality control are formulated.
Keywords: *MOOC, adaptive learning, higher education, teaching model quality, ranked algorithm*

1 Introduction

Nowadays the speed of change today is very high, and if, less than 10 years ago, we talked about finding information, today we are increasingly talking about the need to limit, "filter", selectively approach the flow of information that surrounds us. This requires the ability to build educational trajectories in the "information field" on the one hand, and adaptive, selective feed on the other. The development of technologies today is much faster than the ability of people to adapt to them, to keep up with these changes, it is necessary to understand what needs to be done to "shape the competence of tomorrow" not only in the young generation, but also in middle-aged and older people [Crowe et al., 2017, Noskova et al, 2018].

Today there is a lot of talk about the adaptability of the educational process Daniel. This can be an adaptive presentation of educational material, and adaptive construction of the educational process and, perhaps, the adaptability of other components of the educational process [Dauphin et al, 2015]. New technologies, e-learning technologies, actively implemented in the educational process allow managing this, thereby implementing the principle of "transformation and change of life through learning". At the same time, we should not forget that e-learning besides its supporters has many opponents who believe that this leads to profanation of education and reduces the level of training. That is why the question of assessing the knowledge quality today becomes even more urgent [Truong, 2016].

The aim of this study was to develop proposals for adaptive knowledge quality control in e-learning based on a ranked algorithm.

2 General task requirements

In e-learning, there are many more opportunities to organize testing. This can be entrance testing – to determine the knowledge level of students, and midterm testing. Usually, the pedagogical measurement is understood as the process of establishing a correspondence between the estimated characteristics of students and the points of the empirical scale, in which the relationship between the various assessments of characteristics is expressed by the properties of the numerical series [Dorozhkin et al., 2016].

The algorithm underlying the proposals is a special case of programmed control, which aims to determine which sections of the training course are mastered and what level of training of a student is at the moment. The effectiveness of the relevant program can be ensured only with the optimal selection of issues on the basis of priority and complexity [Atkinson et al, 1969] assessments (a set of recommendations) and possible restrictions on the control time and the number of questions. These differences, along with the requirement of a certain universality, are the basis for the choice of the algorithm.

3 Ranked algorithm principles.

The initial task is to fill and structure the database of questions on different levels of complexity. Pedagogical experience allowed the authors to conclude that it is necessary to use 3 - 4 levels of difficulty. The most common case involves **4 levels**.

The program offers students at least 12 questions. These questions are selected according to a certain algorithm from the database structured by the levels of complexity.

The lower level is the level of basic knowledge. It involves knowledge of basic concepts, definitions and laws. The next difficulty level requires knowledge of the basic laws that directly derive from the basic laws. A higher level involves a confident knowledge of the subject and the ability to solve simple problems. The highest level determines the quality of training and the result of successful testing.

Level numbers in ascending order of difficulty: 0,1,2,3. The choice of a question of a known level from the database of questions is made randomly. Randomization is not used only in the selection of zero-level questions (in the evaluation of basic knowledge the coverage of the material is more important). Possible repetition of questions at high levels does not contradict the didactic principles of knowledge control.

The method of determining the correct answer is selective, being the most convenient for algorithmization (in comparison with the constructed or coded methods). The probability of guessing can easily be minimized with a sufficiently large number of answers to the question. The number of 5-6 answers is almost enough.

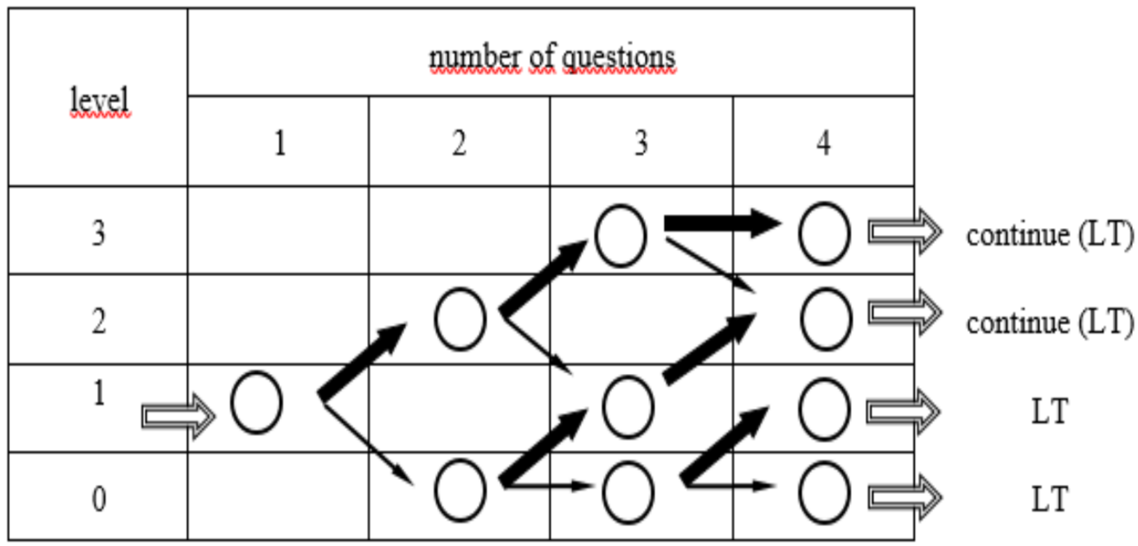

Figure 1: Diagram of transitions from question to question for the first block

The level of complexity of the next question depends on the answer received to the current question: the correct answer leads to the question of the complexity level, which is not lower than the level of the current question, and the wrong will not be higher than the specified level. Theoretical consideration of the conditions of transition from question to question [Davies, 1972] is reduced to the choice of the required programming system: linear, branched or adaptive.

The linear system involves a consistent increase in the level of complexity of question groups. The number of erroneous answers of the selected level determines the degree of preparation. With a large number of questions at each level, it is easier to choose the right option, as the questions begin to "overlap". With a small number of questions, the test becomes too difficult and the coverage of the material decreases sharply. Branched system is characterized by transitions from a lower to a higher level of tasks when choosing the right answers, which can significantly increase the speed of testing. Errors lead to explanatory questions, the number of which increases as the significance of the error increases. Adaptive programming system involves transitions to both higher and lower levels based on the criterion of the number of errors made. The program includes elements of each of these systems.

All subjects are divided into those, who have passed and have not passed the testing in the process of passing the program on the condition of absence of erroneous answers at lower levels of complexity (0, 1, 2). In order to simplify the algorithm, the specified condition is checked after passing four test questions, combined into a block. Those, who have not passed the testing, answer the questions of the chosen program level of complexity (0, 1, 2). The term linear testing (LT) is applied to them.

In this block, there are questions of all four levels; the level of difficulty of the first question is the first (double arrow). With the correct answer, the level of the next question increases or remains the maximum (bold arrows). If the answer is incorrect, the level of the next question is lowered or remains minimal (thin arrows). At the end of the first block, the transition to the second one occurs under the condition of three correct answers

("CONTINUE", double arrows at levels 2 and 3). Otherwise, there is a transition to LT, and the level of testing per unit below the level of unresolved issues, that is zero or the first level. The second block consists of three levels of questions (zero excluded). The first question of the second block depends on the background; it can be both the second and the third levels (see Figure 1). The third block consists of questions of the second and the third levels (zero and first are excluded). For the third block, the first question is of the third level.

At the end of the second block, the transition to LT of the first or of the second level occurs when you select a negative answer to the questions of the corresponding levels. At the end of the third block, the transition to the LT of the second level occurs when you select a negative answer to the questions of the second level. At the same time, both correct answers to the questions of the test level or of a higher one, and incorrect answers of the LT level are counted and the number of additional questions is determined. The total number of questions depends on their level. For LT of zero, the first or the second level this number is 16, 12 or 8, respectively.

The requirement of limited testing time is provided by the response time limit: 2, 3, 4 and 5 minutes for zero, the first, the second or the third levels respectively. The first set of questions can be completed successfully in no more than 17 (16) minutes. Question difficulty levels: 1, 2, 3, 3 (1, 2, 3, 2). For subjects who have received the highest possible test score, the total time is increased by 40 minutes (2 stages of 4 question/answer of the third level) and is not more than 57 minutes. Those who answered incorrectly to each of the questions of the first stage complete it in 9 minutes (difficulty levels 1, 0, 0, 0) and receive an additional 26 minutes for solving 13 zero-level problems, only 35 minutes. All other testing options, including those moving to LT, are within the upper limit of 60 minutes.

With the aim of differentiation of self-test results regarding the scores they received, the progressive scale of points based on the difficulty level of the questions is used.

For the correct answer to the question of zero, the first or the second level, respectively, 1, 2 or 4 points are given. The correct answer to the question of the third level is estimated at 8 points. All wrong answers are not evaluated. The results of LT are estimated by counting the number of correct answers.

Depending on the assessment, recommendations for improving the knowledge level are offered

4 Algorithm description

1. List of symbols $A_j{}^\alpha$ - the preparation state for the first question of block α, j - the level of complexity of the question. For example, A_1^1 - the preparation state for the first question of the first level of complexity.

A_{ij}(n) - event, the answer to the question of the i - the level of complexity. j - the level of complexity of the next question. n - the number of points obtained for the answer. If the answer is correct, then j = i + 1 for i = 0,1,2 and j = i at i = 3. If the answer is incorrect, then j = i - 1 for i = 1,2,3, j = i at i = 0 (n = 0).

Transitions: «→» - the transition from state to state or from event to event. «$\doteq|$» - transition from event to event with the increasing level of complexity. «$^=|$» - a similar transition with decreasing level of complexity.

		Start of the test	Answer variant to the questions №№				End of the block
			one	2	3	four	
Level of questions	3				A_{33} (8)→ A_{32} (0) ╕	A_{33} (8)→ A_{32} (0) ╕	(successfully?) **YES,** A_{32} **NOT,** L_0 (L_1)
	2			A_{23} (4) ╛ A_{21} (0) ╕		A_{23} (4) ╛ A_{21} (0) ╕	(successfully?) **YES,** A_{22} **NOT,** L_0
	one	A_1^1 →	A_{12} (2) ╛ A_{10} (0) ╕		A_{12} (2) ╛ A_{10} (0) ╕	A_{12} (2) ╛ A10 (0) ╕	L_0 (L_1)
	0			A_{01} (1) ╛ A_{00} (0)→	A_{01} (1) ╛ A_{00} (0) →	A_{01} (1) ╛ A_{00} (0) →	L_0

Note:
1). A_3^2, A_2^2 — preparation state for the second block on the third and second levels, respectively;
2). L_0 (L_1) — preparation state for the linear testing of 0 (1) level.

Figure 2: Scheme of possible events in the answers to the questions of the first block

$\left(\sum_{k=1}^{k-4} n_k, x_1\right)_j^{\alpha}$ - a state achieved after passing block α, k = 1,2,3,4 - number of questions, n_k - number of points obtained for the answer to the k-th issue. x_1 = 0,1,2,3,4 - the number of correct answers. j – the level of the first question of the next block ($A_j^{\alpha+1}$).

L_0 (x_1, x2, 16 - (x_1 + x_2)) – event, start of linear testing at level 0. X_1 - number of correct answers to be counted by the beginning of testing, x_2 - number of incorrect answers to be counted by the beginning of testing, 16 - the total number of questions under evaluation, 16 - (x_1 + x_2) - the number of additional questions.

L_1 (x_1, x_2, 12 - (x_1 + x_2)) – event, start of linear testing at level 1. X_1 - number of correct answers to be counted by the beginning of testing, x_2 - number of incorrect answers to be counted by the beginning of testing, 12 - the total number of questions under evaluation, 12 - (x_1 + x_2) - the number of questions of the linear test.

L_2 (x_1, x_2, 8 - (x_1 + x_2)) – event, start of linear testing at the level 2 x_1 - number of correct answers to be counted by the beginning of testing, x_2 - number of incorrect answers to be counted by the beginning of testing, 8 - the total number of questions under evaluation, 8 - (x_1 + x_2) - the number of questions of the linear test.

A_{jj}(n) - event, answer to the question of the j-th level of the linear testing with the same level of complexity of the next question. n - the number of points obtained for the answer.

If the answer is correct, then n = 1, if it is incorrect, then n = 0.

S - the preparation state for the evaluation.

S (L) - the preparation state for the evaluation of the results (for linear testing).

2. Variants of events. Variants of events in the answers to the questions of each of the three blocks are given in figures 2-4 (end-to-end numbering of questions is in brackets).

		Start of the test	Answer variant to the questions №№				End of the block
			1 (5)	2 (6)	3 (7)	4 (8)	
Level of questions	3	A_3^2 →	A_{33} (8)→ A_{32} (0) ╕	A_{33} (8)→ A_{32} (0) ╕	A_{33} (8)→ A_{32} (0) ╕	A_{33} (8)→ A_{32} (0) ╕	(successfully?) **YES, A_{33}** **NO, L_1 (L_2)**
	2	A_2^2 →	A_{23} (4) ╛ A_{21} (0) ╕	A_{23} (4) ╛ A_{21} (0) ╕	A_{23} (4) ╛ A_{21} (0) ╕	A_{23} (4) ╛ A_{21} (0) ╕	(successfully?) **YES, A_{33}** **NO, L_1 (L_2)**
	1			A_{12} (2) ╛ A_{11} (0)→	A_{12} (2) ╛ A_{11} (0)→	A_{12} (2) ╛ A_{11} (0)→	L_1 (L_2)

Figure 3: Scheme of possible events in the answers to the questions of the second block

		Start of the test	Answer variant to the questions №№				End of the block
			1 (9)	2 (10)	3 (11)	4 (12)	
Level of questions	3	A_3^3 →	A_{33} (8)→ A_{32} (0) ╕	A_{33} (8)→ A_{32} (0) ╕	A_{33} (8)→ A_{32} (0) ╕	A_{33} (8)→ A_{32} (0) ╕	(successfully?) **YES, S** **NO, L_2**
	2			A_{23} (4) ╛ A_{22} (0) →	A_{23} (4) ╛ A_{22} (0) →	A_{23} (4) ╛ A_{22} (0) →	(successfully?) **YES, S** **NO, L2**

Note:

1). List of possible events: A_{33} (8), A_{23} (4), A_{32} (0), A_{22} (0).
2). L_2 -state preparation of a linear testing Level 2

Figure 4: Scheme of possible events in the answers to questions of the third block

State, characteristics of LT	Number of question				x_1^1
	1	2	3	4	
$(22,4)_3^1$	2	4	8	8	3
$(10,3)_3^1 \to (10,3)_2^1$	2	4	0	4	2
$(8,3)_3^1 \to L_1(3,0,9)$	2	**0 (2)**	2	4	—
$(7,3)_3^1 \to L_0(3,0,13)$	**0 (1)**	1	2	4	
$(14,3)_2^1$	2	4	8	0	2
$(3,2)_2^1 \to L_0(2,1,13)$	**0 (1)**	**0 (0)**	1	2	—
$(6,2)_1^1 \to L_1(2,0,10)$	2	4	0	**0 (2)**	
$(4,2)_1^1 \to L_1(2,0,10)$	2	**0 (2)**	2	**0 (2)**	
$(3,2)_1^1 \to L_0(2,0,14)$	2	**0 (2)**	**0 (1)**	1	
$(2,2)_1^1 \to L_0(2,0,14)$	**0 (1)**	1	**0 (1)**	1	
$(1,1)_1^1 \to L_0(1,2,13)$	**0 (1)**	**0 (0)**	**0 (0)**	1	
$(2,1)_0^1 \to L_0(1,1,14)$	2	**0 (2)**	**0 (1)**	**0(0)**	
$(1,1)_0^1 \to L_0(1,1,14)$	**0 (1)**	1	**0 (1)**	**0(0)**	
$(0,0)_0^1 \to L_0(0,3,13)$	**0 (1)**	**0 (0)**	**0 (0)**	**0(0)**	

Note:

1) In bold are the states leading to linear testing (LT) of the zero or the first level respectively: L_0 (x_1, x_2, 16- (x_1 + x_2)) or L_1 (x_1, x_2, 12- (x_1 + x_2)). The number of correct answers x_1 (1 point for answer) corresponds to the number of correct answers to questions of LT level or of a higher level. The number of incorrect answers x_2 (0 points) corresponds to the number of incorrect answers of the LT-level questions. Incorrect answers to questions of a higher level are not taken into account. In bold are also negative answers at levels below the third one (№ level is in brackets).

2). The first question of the second block for the state $(10,3)_3^1$ - level 2 $(10,3)_3^1 \to (10,3)_2^1$.

3). x_1^1 - the number of correct answers that are counted at the transition to the second level LT after the second (third) stage (the question block).

Figure 5: The number of possible points earned when answering the questions of the first block

3. State after passing the stages of the algorithm. The states, realized after passing the first block, are summarized in Figure5. The states, realized after passing the second block, are summarized in Figure 6. The states, realized after passing the third block, are summarized in Figure 7.

State, characteristics of LT	Number of question				x_1^2
	1(5)	2(6)	3(7)	4(8)	
$(32,4)_3^2$	8	8	8	8	4
$(28,4)_3^{2*}$	4	8	8	8	
$(20,3)_3^2$	8(8,0)	8(0,4)	0(4,8)	4(8,8)	3
$(16,3)_3^{2*}$	4(4)	0(8)	4(0)	8(4)	
$(14,3)_3^{2*} \rightarrow L_2(4,1,3)$	**0 (2)**	2	4	8	—
$(8,2)_3^2$	0	4	0	4	2
$(6,2)_3^2 \rightarrow L_2(4,1,3)$	0	**0 (2)**	2	4	—
$(6,2)_3^{2*} \rightarrow L_1(5,1,6)$	**0 (2)**	**0 (1)**	2	4	
$(24,3)_2^2$	8	8	8	0	3
$(20,3)_2^{2*}$	4	8	8	0	
$(12,2)_2^2$	8	0	4	0	2
$(10,2)_2^2 \rightarrow L_2(4,1,3)$	8	0	**0 (2)**	2	—
$(8,2)_2^{2*}$	4	0	4	0	2
$(6,2)_2^{2*} \rightarrow L_2(3,1,4)$	4	0	**0 (2)**	2	—
	0 (2)	2	4	0	
$(4,2)_2^{2*} \rightarrow L_1(5,1,6)$	**0 (2)**	2	**0 (1)**	2	
$(2,1)_2^2 \rightarrow L_1(5,1,6)$	0	**0 (2)**	**0 (1)**	2	
$(2,1)_2^{2*} \rightarrow L_1(4,2,6)$	**0 (2)**	**0 (1)**	**0 (1)**	2	
$(16,2)_1^2 \rightarrow L_2(5,1,2)$	8	8	0	**0 (2)**	
$(12,2)_1^{2*} \rightarrow L_2(4,1,3)$	4	8	0	**0 (2)**	
$(8,1)_1^2 \rightarrow L_1(5,1,6)$	8	0	**0 (2)**	**0 (1)**	
$(4,1)_1^2 \rightarrow L_2(4,1,3)$	0	4	0	**0 (2)**	
$(2,1)_1^2 \rightarrow L_2(4,2,2)$	0	**0 (2)**	2	**0 (2)**	
$(2,1)_1^{2*} \rightarrow L_1(4,1,7)$	**0 (2)**	**0 (1)**	2	**0 (2)**	
	0 (2)	**2**	**0 (2)**	**0 (1)**	
$(0,0)_1^2 \rightarrow L_1(4,2,6)$	0	**0 (2)**	**0 (1)**	**0 (1)**	
$(0,0)_1^{2*} \rightarrow L_1(3,3,6)$	**0 (2)**	**0 (1)**	**0 (1)**	**0 (1)**	

Note:

1). In bold are the states leading to linear testing of the first or second level L_1 (x_1, x_2, 12- ($x_1 + x_2$)) or L_2 (x_1, x_2, 8- ($x_1 + x_2$)) .. Also in bold are negative answers at levels below the third one (№ level is in brackets).

2). The first question of the third block for all states - level 3 ($\left(\sum_{k=1}^{k=4} n_k, x_1\right)_2^2 \rightarrow \left(\sum_{k=1}^{k=4} n_k, x_1\right)_3^2$).

3). x_1^2 - the number of correct answers counted in the transition to L_2 after the third block.

4). * - states corresponding to the start of the first block from the second level (all others are from the third one).

Figure 6: The number of possible points obtained when answering the questions of the second block

State, characteristics LT	Number of questions				x_1^3	x_2^3
	1(9)	2(10)	3(11)	4(12)		
$(32,4)_3^3$	8	8	8	8	—	—
$(20,3)_3^3$	0(8,8)	4(0,8)	8(4,0)	8(8,4)		
$(12,2)_3^3 \rightarrow L_2$	0	**0**	4	8	2	1
	8	0	**0**	4		
$(8,2)_3^3$	0	4	0	4	—	—
$(4,1)_3^3 \rightarrow L_2$	0	**0**	**0**	4	1	2
$(24,3)_2^3$	8	8	8	0	—	—
$(12,2)_2^3$	8	0	4	0		
$(8,1)_2^3 \rightarrow L_2$	8	0	**0**	**0**	1	2
$(4,1)_2^3 \rightarrow L_2$	0	4	0	**0**	1	1
$(0,0)_2^3 \rightarrow L_2$	0	**0**	**0**	**0**	0	3

Note:

1). In bold are the states leading to linear testing of the first or second level L_2 (x_1, x_2, 8- ($x_1 + x_2$)). The number of correct answers $x_1 = x_1^1 + x_1^2 + x_1^3$. Also, in bold are negative answers of the second level.

2). x_1^3 - the number of correct answers counted in the transition to LT.
$x_2 = x_2^3$ - the number of incorrect answers of the second level.

Figure 7: Scheme of possible events during the linear testing

4.Transitions to the linear test. By the beginning of the linear testing, the results of the answers to the already passed questions of the corresponding blocks are counted. Figure 8 shows the variants of events when passing additional questions of LT.

LT variant	(Number of questions)			End of the test
$L_0(x_1, x_2, 16-(x_1+x_2))$	**(x_1+x_2+1) $A_{00}(1)\rightarrow$ $A^0_{00}(0)\rightarrow$**	…	**(16) $A_{00}(1)\rightarrow$ $A^0_{00}(0)\rightarrow$**	**S(L)**
$L_1(x_1, x_2, 12-(x_1+x_2))$	**(x_1+x_2+1) $A_{11}(1)\rightarrow$ $A^0_{11}(0)\rightarrow$**	…	**(12) $A_{11}(1)\rightarrow$ $A^0_{11}(0)\rightarrow$**	**S(L)**
$L_2(x_1, x_2, 8-(x_1+x_2))$	**(x_1+x_2+1) $A_{22}(1)\rightarrow$ $A^0_{22}(0)\rightarrow$**	…	**(8) $A_{22}(1)\rightarrow$ $A^0_{22}(0)\rightarrow$**	**S(L)**

Note:

1). x_1 – the number of correct answers counted by the beginning of the linear test,
x_2 – the number of incorrect answers counted by the beginning of the linear test.
2). List of possible events: $A_{ii}(1)$, $A^0_{ii}(0)$.

Figure 8: Scheme of possible events during the linear testing

In Figure 9,10 states, causing the transition to the linear tests are summarized, the conditions of transition and the initial characteristics of linear tests are described.

Passed block of questions. The transition to LT. The initial characteristics of LT	State, $\left(\sum_{k=1}^{k=4} n_k, x_1\right)_j^{\alpha}$	Event list	LT
First block, questions 1-4. Negative answer to level 1 $A_{10}(0)$ or 2 level $A_{21}(0)$ lead to the transition to LT, respectively, zero or first level. The number of counted correct answers x_1 corresponds to the number of correct answers to questions of LT level or of a higher one. Number of incorrect answers x_2 corresponds to the number of incorrect answers to questions at the LT level. Incorrect answers to questions of a higher level are not taken into account.	$(8,3)_3^1$	A_1^1, $A_{12}(2)$, $A_{21}(0)$, $A_{12}(2)$, $A_{23}(4)$	$L_1(3,0,9)$
	$(7,3)_3^1$	A_1^1, $A_{10}(0)$, $A_{01}(1)$, $A_{12}(2)$, $A_{23}(4)$	$L_0(3,0,13)$
	$(3,2)_2^1$	A_1^1, $A_{10}(0)$, $A_{00}(0)$, $A_{01}(1)$, $A_{12}(2)$	$L_0(2,1,13)$
	$(6,2)_1^1$	A_1^1, $A_{12}(2)$, $A_{23}(4)$, $A_{32}(0)$, $A_{21}(0)$	$L_1(2,0,10)$
	$(4,2)_1^1$	A_1^1, $A_{12}(2)$, $A_{21}(0)$, $A_{12}(2)$, $A_{21}(0)$	$L_1(2,0,10)$
	$(3,2)_1^1$	A_1^1, $A_{12}(2)$, $A_{21}(0)$, $A_{10}(0)$, $A_{01}(1)$	$L_0(2,0,14)$
	$(2,2)_1^1$	A_1^1, $A_{10}(0)$, $A_{01}(1)$, $A_{10}(0)$, $A_{01}(1)$	$L_0(2,0,14)$
	$(1,1)_1^1$	A_1^1, $A_{10}(0)$, $A_{00}(0)$, $A_{00}(0)$, $A_{01}(1)$	$L_0(1,2,13)$
	$(2,1)_0^1$	A_1^1, $A_{12}(2)$, $A_{21}(0)$, $A_{10}(0)$, $A_{00}(0)$	$L_0(1,1,14)$
	$(1,1)_0^1$	A_1^1, $A_{10}(0)$, $A_{01}(1)$, $A_{10}(0)$, $A_{00}(0)$	$L_0(1,1,14)$
	$(0,0)_0^1$	A_1^1, $A_{10}(0)$, $A_{00}(0)$, $A_{00}(0)$, $A_{00}(0)$	$L_0(0,3,13)$
The second block, questions1-4 (5-8). Negative answers $A_{11}(0)$ or$A_{21}(0)$ lead to the transition to LT level 1 or 2. x1 consists of the correct answers to the questions of the level of testing or of a higher one, obtained by solving the first block of questions and the number of correct answers to questions of the level of LT or of a higher one in the second block. x_2 corresponds to the number of incorrect answers to questions of LT level. Incorrect answers to questions of a higher level are not taken into account. For state $(22,4)_3^1$ four questions of the first level or three questions of the second level are counted. For states $(10,3)_3^1$, $(14,3)_2^1$, three questions of the first level or two questions of the second level are counted. (start of the fifth question from the second level, sign * in the state column), event A_2^2 (see Table 4).	$(14,3)_3^{2*}$	A_2^2, $A_{21}(0)$, $A_{12}(2)$, $A_{23}(4)$, $A_{33}(8)$	$L_2(4,1,3)$
	$(6,2)_3^2$	A_3^2, $A_{32}(0)$, $A_{21}(0)$, $A_{12}(2)$, $A_{23}(4)$	$L_2(4,1,3)$
	$(6,2)_3^{2*}$	A_2^2, $A_{21}(0)$, $A_{11}(0)$, $A_{12}(2)$, $A_{23}(4)$	$L_1(5,1,6)$
	$(10,2)_3^2$	A_3^2, $A_{33}(8)$,$A_{32}(0)$, $A_{21}(0)$, $A_{12}(2)$	$L_2(4,1,3)$
	$(6,2)_2^{2*}$	A_2^2, $A_{23}(4)$, $A_{32}(0)$, $A_{21}(0)$, $A_{12}(2)$ A_2^2, $A_{21}(0)$, $A_{12}(2)$, $A_{23}(4)$, $A_{32}(0)$	$L_2(3,1,4)$
	$(4,2)_2^{2*}$	A_2^2, $A_{21}(0)$, $A_{12}(2)$, $A_{21}(0)$, $A_{12}(2)$	$L_1(5,1,6)$
	$(2,1)^2{}_2$	A_3^2, $A_{32}(0)$, $A_{21}(0)$, $A_{11}(0)$, $A_{12}(2)$	$L_1(5,1,6)$
	$(2,1)^2{}_2{}^*$	A_2^2, $A_{21}(0)$, $A_{11}(0)$, $A_{11}(0)$, $A_{12}(2)$	$L_1(4,2,6)$
	$(16,2)_1^2$	A_3^2, $A_{33}(8)$, $A_{33}(8)$, $A_{32}(0)$, $A_{21}(0)$	$L_2(5,1,2)$
	$(12,2)_1^{2*}$	A_2^2, $A_{23}(4)$, $A_{33}(8)$, $A_{32}(0)$, $A_{21}(0)$	$L_2(4,1,3)$
	$(8,1)_1^2$	A_3^2, $A_{33}(8)$, $A_{32}(0)$, $A_{21}(0)$, $A_{11}(0)$	$L_1(5,1,6)$
	$(4,1)_1^2$	A_3^2, $A_{32}(0)$, $A_{23}(4)$, $A_{32}(0)$, $A_{21}(0)$	$L_2(4,1,3)$
	$(2,1)_1^2$	A_3^2, $A_{32}(0)$, $A_{21}(0)$, $A_{12}(2)$, $A_{21}(0)$	$L_2(4,2,2)$
	$(2,1)_1^{2*}$	A_2^2, $A_{21}(0)$, $A_{11}(0)$, $A_{12}(2)$, $A_{21}(0)$ A_2^2, $A_{21}(0)$, $A_{12}(2)$, $A_{21}(0)$, $A_{11}(0)$	$L_1(4,1,7)$
	$(0,0)_1^2$	A_3^2, $A_{32}(0)$, $A_{21}(0)$, $A_{11}(0)$, $A_{11}(0)$	$L_1(4,2,6)$
	$(0,0)_1^{2*}$	A_2^2, $A_{21}(0)$, $A_{11}(0)$, $A_{11}(0)$, $A_{11}(0)$	$L_1(3,3,6)$

Figure 9: Summary table of states that cause the transition to LT

Passed block of questions. The transition to LT The initial characteristics of LT	State, $\left(\sum_{k=1}^{k=4} n_k, x_1\right)_j^{\alpha}$	Event list	x_1^3	x_2^3
The third block, questions 1-4 (9-12). A negative answer to the question of the second level $A_{22}(0)$ leads to transition to $L_2(x_1, x_2, 8-(x_1 + x_2))$, where $x_1 = x_1^1 + x_1^2 + x_1^3$, $x_2 = x_2^3$. x_1^1 — the number of counted correct answers on successful completion of the first block of questions. Possible values $x_1^1 = 2, 3$. x_1^2 — the number of counted correct answers on successful completion of the second block of questions. Possible values $x_1^1 = 2, 3, 4$. x_1^3 , x_2^3 — the number of correct and incorrect answers in this block.	$(12,2)^3{}_3$	A_3^3, $A_{32}(0)$, $A_{22}(0)$, $A_{23}(4)$, $A_{33}(8)$ A_3^2, $A_{33}(8)$, $A_{32}(0)$, $A_{22}(0)$, $A_{23}(4)$	2	1
	$(4,1)^3{}_3$	A_3^3, $A_{32}(0)$, $A_{22}(0)$, $A_{22}(0)$, $A_{23}(4)$	1	2
	$(8,1)^3{}_2$	A_3^2, $A_{33}(8)$, $A_{32}(0)$, $A_{22}(0)$,$A_{22}(0)$		
	$(4,1)^3{}_2$	A_3^2, $A_{32}(0)$, $A_{23}(4)$, $A_{32}(0)$,$A_{22}(0)$	1	1
	$(0,0)^3{}_2$	A_3^2, $A_{32}(0)$, $A_{22}(0)$, $A_{22}(0)$,$A_{22}(0)$	0	3

Figure 10: Summary table of states that cause the transition to LT (end)

5. Evaluation of results. For the subjects having passed the testing, the total score is calculated:

$y = \sum_{k=1}^{k-4}$ n$_k$, where $\alpha = 1, 2, 3$ – number of unit, n_k –number of points obtained for the answer to k-th question of block α, 6 - «start» points for the first two questions of the first block. Recognized practice shows that the correct answers to 80-90% of the questions are rated "excellent", and 50-60% — "satisfactory". Possible values y are summarized in table 1[1].

Table 1: Evaluation of test results

y	n * = y / 8	Evaluation
80, 72, 68	10, 9, 8.5	"Excellent"
64, 60, 56	8, 7.5, 7	"Good"
52, 48, 44	6.5, 6, 5.5	"Satisfactory"
40, 36, 32, 28, 24, 20	≤ 5	"Poor"

On the basis of the calculated values the subjects tested get evaluation recommendations.

The results of the linear testing are estimated, for example, according to Table 2[2].

On the basis of Table 2, the subjects, who have not passed the test, get the assessment of knowledge and recommendations for improving the level of education.

[1] **Note:**n* - the number of correct answers given to the third level ($n^* \leq 10$)

[2] **Note:**

1. X^1(j)- the total number of correct answers when passing LT of level j.
2. % (j) - the number of correct answers as a percentage of maximum possible value.
3. When passing the second-level linear testing the number of correct answers cannot exceed 7.

Table 2: Evaluation of the results (*conventional*) of linear testing

X1 (0)	% (0)	X1 (1)	%(one)	X1 (2)	% (2)	Conventional evaluation
15, 16	94, 100	11, 12,	92, 100	7	88	"Excellent"
13, 14	81, 88	9, 10	75, 83	6	75	"Good"
10, 11 12	63, 69, 75	7.8	58, 67	five	63	"Satisfactory"
≤ 9	≤ 56	≤ 6	≤ 50	≤ 4	≤ 50	"Poor"

5 Conclusion

Based on the requirements for the problem of self-testing, an algorithm for solving the problem was developed, taking into account the level of complexity of the questions, the evaluation of the answers received, and performing the transition from one level to another. This algorithm will assess the knowledge of the subject depending on the degree of complexity of the tests, and, in addition, makes it possible to fairly objectively determine in which direction to move to improve their knowledge.

The author does not claim the optimal choice of specific characteristics of the algorithm, which can be adjusted depending on external conditions. For example, with a large amount of material discipline, self-testing is recommended for each of the sections.

Control in e-learning today is a serious problem. That is why adaptive testing algorithms based on multi-step strategies are preferred to be used as a dominant approach in the implementation of e-learning. The advantage of such algorithms lies in the possibility of rapid response to the results of training tasks at each level of adaptive testing, which allows monitoring quickly the knowledge quality and improves the quality of training.

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