APPLICATION OF ADAPTIVE COMPUTER TESTING AS A MEANS OF INTERACTIVE LEARNING FOR BUILDING AN INDIVIDUAL EDUCATIONAL TRAJECTORY OF A STUDENT

Assoc. Prof. Dina Yu. Eliseeva[1]
Dr. A.Yu. Fedosov[2]
Assoc. Prof. Olga L. Mnatsakanyan[3]
Assoc. Prof. Svetlana V. Grigoreva[4]
Assoc. Prof. Tatiana V. Dmitrieva[5]
[1, 3, 4] Russian State Social University, Moscow City pedagogical University, Russia
[2] Russian State Social University, Russia
[5] Russian State Social University, Finance University, Russia

ABSTRACT

Building the process of education effectively and qualitatively taking into account educational needs and students' individual characteristics is possible by developing of the special technics of education, in terms of which a student not only will repeat the actions of a teacher but first of all will use different interactive and adaptive educational technologies.

Modern computer technologies because of high crucible carrier size and high processing speed allow to enlarge the borders of materials used in an educational process because of highly developed ways of analysis of a dialogue with a user and considerably adopt transfer of knowledge to a concrete learner.

The teaching technique of computer testing suggests the realization of new approaches to a building of teaching courses by a special organization of information block of a discipline in the form of sections and modules, structuring of test materials due to the module division in accordance with information structure of learning material, division of module testing material into the groups of test questions and tasks in keeping with the content and arrangement of groups in order of difficulty of testing materials, the appliance of consistent approach allowing to realize several sorts of adaptiveness while testing students' knowledge.

We offered the consistent approach, allowing to realize practically several types of adaptiveness while estimating knowledge by computer testing.

1.   The changing of the strategy of examination depending on the student's answers, legalized by means of special structure of examining algorithm.
2.   Testing on assignment, which is divided into the training, realized independently for the estimation of knowledge by a student himself, and control, realized under the supervision of a teacher for the objective estimation of real knowledge, and progress check and final check are important and particular case.

3.   Testing on the profoundness of the examination – to the examination level.

4.   The testing by volume of the checked material subdivided depending on material volume (the module, the section or several sections (progress check), all discipline (final check).

The given possibilities are provided with the organization of the information and testing material for subsections of a course and are considered in the testing algorithms.

The offered approach maximally takes into account essential characteristics of the computer process of an examination and allows to build an individual path of training students by using various interactive means.

Keywords: interactive teaching technics, adaptation, computer testing, testing algorithm

INTRODUCTION

The use of adaptive computer testing as a way of interactive learning for building an individual educational trajectory of a student. There is a principle of comprehensive registration the individual features of the students and the fullest satisfaction of their educational needs is based on the construction of a modern effective educational process. The realization of such learning process is possible thanks to the way of introduction of the special methods based on using the interactive and adaptive learning technologies.

The modern information technologies make it possible to use resources which linked with the educational processes, and widen the possibilities of materials used in the learning process, also due to the fact that developed methods of analyzing the dialogue with the user, and substantially give the opportunity to adapt the transfer of individual knowledge to a particular student [2].

A wide using of testing in Western countries associated with the definition of professional suitability and skill level was due to a number of reasons [5], [6], [7]:

•   a business interest to the maximum effective using of human resources;
•   the aspiration to reward a talent regardless of its social background;
•   the need of Americans in national standards, the desire of society to maximize the return on each of his abilities and the availability of methods to identify these abilities.

The classical testology of foreign countries is based on the following basic postulates:

•   human abilities are inborn and therefore, practically, unchanged (exactly this statement led to a comparison of abilities with the level of knowledge);
•   a high level of abilities is rare and the ability of people is distributed in accordance with the law of Gauss;

- ignoring the qualitative development of a person - both mental and psychical, understanding the differences in the abilities of people to quantitative indicators;
- the principle "decided - did not decide" namely control is subject to only to the final result of the intellectual activity when task execution is not diagnosed and not considered [4].

Of course, there is a modern trend, which puts in doubt the basic approaches to testing, there is a rethinking of the role of education in the development of human abilities;

For the period from the early 90s of the 20th century to the present time, there has been a branch of science in Russia - the theory of pedagogical measurements, which has its own methodology, methods, instrument for developing and implementing qualitative pedagogical tests, magazines, innovative works, collections of materials on test subjects are published.

Modern Russian testology develops in several directions:

- theoretical and methodological foundations of the testology are considered by such scientists as V.S. Avanesov, A.V. Abramova, M.S. Bershtein, M.I. Pobedovy and the others;
- a place of testology in the system of pedagogical sciences - B.P. Bittinas, L.I. Nataeva, I.I. Tikhonov and the others;
- the questions of the typology of test tasks are studied by V.S. Avanesov, V.P. Bespalko, D.S. Gorbatov and the others;
- the features of psychological testing are studied by A. Anastasi, G.S. Kovaleva, V. Kline and the others.
- Computers have been widely used in testing since the beginning of the 21st century. There is a whole direction in pedagogical research - computer testing, which has a number of undeniable advantages over traditional testing, namely [3]:
- it's an opportunity to use more different types of visibility (audio and video fragments, diagrams, drawings, computer models, etc.);
- the computer more than the presence of the experimenter, motivate the examinee on its own, and at the end the diagnostic value of the results are higher;
- the influence of the personality features of the experimenter and random behavioural factors are reduced;
- it becomes possible to compare the experimental facts, obtained by different researchers;
- any complicated information is automated, it is possible to get quickly comparable results from large block of information, to save and compare it's;
- it is enough easy to combine the functions of diagnostics and correction of knowledge in training systems;
- there is an opportunity to use such forms as imitation exercises, the analysis of situation, action tests which are associated with simulators;

- the opportunity to include the psychodiagnostic elements, attitudes, feelings, impressions, influence of cognitive styles in the testing sphere;
- the opportunity to use an adaptive testing strategy when the research strategy changes depending on the results obtained previously.

Besides this, computer testing allows you to save material resources, which usually are spent on the production of blank tests. With its help, you can improve information security by protecting electronic files, increase the range of measured skills and abilities, using a variety of computer capabilities - interactivity, multimedia, etc. Students usually have a positive attitude to computer testing, noting the convenience of quickly obtaining test results and the absence of various forms that need to be filled, it is enough to choose the answer with the mouse button, the innovative nature of control, a more accurate mark of knowledge and skills. But, at the same time, it is indicated several inconveniences, for example, that often there is a fixed order of the task, strictly limited time for each task after which the computer itself passes to the next task, regardless of the testee's desire, sometimes it is not possible to look through the test at the beginning of work with it, change the answers to the previous task, pass the task, and also there are difficulties in writing mathematical calculations.

It should be attributed to attention to the fact in computer testing, that it's necessary to account for the different level of computer skills among the students, because it influences on the validity of the test results. It's usual practice to include training exercises, instructions, in advance introduce students to the interface, do the repetition testing to reduce the influence of this indicator on the test results.

Hardware or computer tests have some significant differences from the traditional tests, in particular they can be classified by the degree of automation for:

- automated - are held by the teacher using computer facilities
- automatic - are held using computer facilities

Computer testing can be in various forms.

1. The test is entered in a special sheath that allows you to display the task on the computer screen, evaluate the results of the task, generate a table of test results, process the results.
2. Testing with the help of automated generation of variants of the test options, which is done with the use of tools. The variants of tests are formed from a bank of calibrated test tasks before testing or directly during the testing procedure.
3. Computer adaptive testing is based on the principle that the student does not have the sense to give tasks that he will surely do without any difficulties or vice versa, he will not do because of a high degree of difficulty, so the computer chooses a test task depending on the previous answer of the person who solves its test.

Test tasks that use the possibilities of computer testing are the most perspective direction in the development of pedagogical measurements because of the increase in the content validity and the great potential of such tasks for increasing the informativeness of pedagogical measurements. Using tests tasks, it is possible to much wide the range of assessment of knowledge, skills, and various indicators of mental activity that cannot always reveal traditional blank testing: the level of analytical and synthetic activity of the student, the flexibility of the cogitative process, the speed of generalization of information, etc.

It is possible to include visual information here when develop test tasks for computer testing - realistic nature (cinema, photo) and synthesized nature (animation, drawings), which introduces dynamics in the performance of the test, as well as audio information requiring a voice answer. Nevertheless, it is necessary to take into consideration the fact that the variety of sound and visual images during testing makes the students get tired, which requires a shortening of the length of test.

It has several of features and a system for calculating final marks. If the interactive and multimedia technologies were not included there the calculation is made in the traditional way - summing up the points for each task. In case if the test uses modern multimedia and interactive technologies, it leads to the need to assess a number of different skills - creative, communicative, and subject-specific, which requires polygamous evaluations. Such verification requires a more complicated automation process, the need to "training" a computer program to evaluate any detailed answers.

The creation of the structure of knowledge is a separate problem, when the general concepts and objectives of the course are formulated in the early stage of training, and the objects are built in the next phases, the tasks of the discipline are studied. When the material is considered this structure is always followed, however, this condition is not always taken into consideration. A typical situation is a chaotic mixture of test tasks that refers to the different phases of learning.

From the point of view of the creation a rational structure of knowledge, it is necessary not only to correctly define the structure of single tests, but also the structure of all the mass of test tasks. It is possible to divide large parts (sections) into parts for more convenient organization of computer testing of educational material that will differ from ordinary section.

APPROACH

We used the method of analysis of literature and Internet sources on philosophical, social and psychological issues such testology and computer testing, as well as the study and synthesis of psychological and educational experience; pedagogical experiments to the approbation of the methodology of adaptive computer testing.

BUILDING AN INDIVIDUAL EDUCATIONAL TRAJECTORY OF A STUDENT ON THE BASIS OF APPLYING THE ADAPTIVE COMPUTER TESTING

The methodology of adaptive computer testing offers the realization a new methods to the design of educational disciplines thanks to the special organization of the information block of discipline in the form of sections and modules, the structuring of test materials based on a modular breakdown following the information structure of the educational material, the separation of the modular test material into groups of test questions and tasks in accordance with their content and ordering of groups by the degree of complexity of test materials, using a single method which allows to realize the several types of adaptability in testing students' knowledge.

It was created the invisible way by the authors, which helps to realize in practice several types of adaptability in the diagnosis of students' knowledge by computer testing.

1. Adaptability, which is related to the interview strategy depending on the student's answer- it's a traditional way of adaptability, it can be realized thanks to the construction of a special structure of the interview algorithm.
2. Adaptability in depending on the purpose of testing - is divided into:
a) educational, which is carried out individually to assess knowledge by the students themselves,
b) control, which is carried out under the supervision of a teacher for an objective assessment of the real level of knowledge, midterm and final control are important special events.
3. Adaptability which is associated with the depth of the interview (the level of knowledge testing) - is possible one-level, two-level and three-level - by the number of groups of test tasks.
4. Adaptability which is associated with the structuring of the volume of the test's material (at the level of a subsection (module), section or several sections and at the level of the material of the whole discipline) - these opportunities are provided by the organization of information and testing material on the sub-sections of the course and are taken into consideration in the testing algorithms.

A method that has been offered takes into consideration the maximum level all essential characteristics of the computer knowledge verification process and allows you to build an individual trajectory of student learning using various interactive tools.

If it's possible, while you create a computer training systems, it is necessary not only to copy the actions of the teacher, but also to introduce new adaptive methods that are realized only with the help of computer systems. The most convenient form of single tests for computer knowledge testing are tasks with one correct answer. To construct an adaptive algorithm for testing

knowledge, along with the approach adopted in the theory of modelling and parameterization of pedagogical tests (Item Response Theory), it is suggested to use the following ways: to present all testing process as a series of steps consisting of single test tasks logically connected to each other or independent from each other. At this stage, the all strategy is unchanged. The transition between the steps is based on the results of the answer to the tasks. Thus, at every step of the test, the automated system must do two main functions:

1. the mark of the student's actions at this step (answers to single test questions) is an evaluation function,
2. the transition to the next step (determining the number of tests on it, its content, etc.) is a control function.

The verification of the knowledge of each individual student is necessary both for all forms of individual training and for group training. Examine the possibilities of adapting computer knowledge control for these types of verification.

For individual verification, it was offered to introduce a two-level adaptation of the knowledge control process:

1. adaptive evaluation of the results of each single alternative test given to the student,
2. adaptive construction of the entire testing process, taking into account the composition of test materials and the correctness of these responses.

Consider the first level of adaptation.

A general formula for estimating the results of a single test is proposed. It has a multiplicative structure that contains the R+ - basic component of the assessment, and R- - the penal component of the assessment.

$$R = R (\{V\}, N, \{P\}) = R+(\{V\}, N) \times R-(N, \{P\}) \tag{1}$$

R - the final evaluation of the student's response to the test task,

R+ ($\{V\}$, N) - the basic component of the assessment, the valuation function,

R- (N, $\{P\}$) - the penalty component of the evaluation, which reduces it.

$\{V\}$ - information received from the student (one or more options for the correct answer),

N is the number of answer options,

$\{P\}$ is a penalty function.

We define the basic estimate R+ of the answer to the test task.

We will understand by the basic evaluation of the answer the "pure" numerical characteristic of the answer, which estimates only its truth - proximity to the correct answer variant.

The classical way (logical evaluation):

$$R = \begin{cases} 0 \text{- if the answer is wrong (incorrect)} \\ 1 \text{ - if the answer is right (correct)} \end{cases}$$

The suggested way (real valuation): $R \in [0,1]$.

In the classical version, the answer "yes-no" is actually a logical value. It is more convenient for the teacher, but, at the same time, it is much more simplified than the material estimate and does not allow you to subtly assess the various nuances in the verification of knowledge. This shortcoming is intended to eliminate the proposed continuous real valuation.

{V} – the information received from the student (plurality of possible answers).

The classical way.

The plurality {V} must contain one answer.

The offered way.

The student can indicate several possible options for the correct answer {V}, which, in his opinion, include the correct answer to Vist. The transition to the multiple response allows more flexible take into account the level of knowledge, taking into account their temporary forgetting, the psychological factors of the examination situation. In this case, the basic component of the estimate R+ ({V}, N) is suggested to be performed using the following relationship:

$$R = \begin{cases} 0, \text{if } |V| = 0 \text{ or Vist} \notin \{V\}; \\ R(|V|), \text{Vist} \in \{V\}, |V| > 0. \end{cases} \tag{2}$$

The evaluation function R+ ({V}, N) in formula (2), means an estimate that is made when there is a correct answer in the group of |V|.

Linear, quadratic and cubic dependences were investigated during constructing the function R (|V|). The best results are given by cubic dependence. It is represented by the formula (3):

$$R^+(X, N) = (N - V)^2[(-N^3 + 9N^2 - 21N + 15).(N - V) + (N^2 - 6N + 7)] / [2(N-1)^2(N-2)^2] \tag{3}$$

The verification of the formula for practically significant values of N = 3☐10 (the number of variants of the answer) showed that the monotonicity of the estimation function is provided only at N = 3,4,5,6. However, the using of increased values of N for computer testing systems is irrational due to an increase in the total time spent on testing knowledge. As practice shows, the optimal value is N = 5. With it, on the one hand there is a small positive

estimate with random guessing of the answers (0.2). On the other hand, the number of answer options is not too large and does not do the testing process long. At the modern level of information technology development, it is possible to effectively track only the r time of answer. To calculate the optimal response time of the Topt (N) was suggested to use the formula (4).

$$Topt\ (N) = T_{answer} + N.T_{question},$$
$$(4)$$

where T_{answer} is the time for evaluating the correct answer to the test question, $T_{question}$ - the time for evaluating one answer option.

The values of T_{answer} and $T_{question}$ should be determined, based on complexity of the questions. To construct a penalty function for {P} = T, it was offered:

1. to accept the waiting time limit equal to three times the maximum response time;
2. linear decrease of the penalty function R- (N, {P}) from 1 (where T= T opt (N)) to 0 (where T = 3T opt (N));
3. for T> 3T opt (N), the quantity R- (N, {P}) = 0, i.e. a very high time of waiting for a response about the use of unacceptable sources to respond to the test.

In the analytical form, we have the piecewise linear dependence which is represented by the formula (5)

$$R^{-}\left(N, \{P\}\right) = \begin{cases} 1, \text{if } T \le T_{opt} ; \\ 0,5(3 - T/T_{opt}), \text{if } Topt < T \le 3Topt \\ 0, \text{if } T > 3Topt. \end{cases}$$

Thus, it was defined a number of formal features, according to which it is possible to effectively adapt a single alternative test and was given the corresponding mathematical model of the test, for which it is possible to implement a software implementation.

Let's consider the second level of adaptation [1].

The following structure of the main materials on the academic discipline was offered for practically implement various types of adaptability in the submission and control of knowledge: the informational block consists of 3 - 5 sections, and each section consists of 3 - 5 subsections - modules. As electronic training materials are always built on the basis of a literary presentation of the material, it were offered the following actions to highlight modules and sections:

1. to take one paragraph as a module, which have an independent meaningful or several consecutive paragraphs containing a common meaningful content;

2. one section is placed in the information area, in which the completed part of the studied discipline or several interdependent consecutive chapter is fully revealed.

The testing block is consists of structured test tasks for all course modules. Each module, in accordance with part of its content, is suggested to highlight the following groups of test questions and tasks that for each specific subsection should be arranged in order of increasing complexity: basic interview, theoretical questions of a high complexity, standard tasks for the material passed.

It was offered a unification of content and test materials which gives as opportunity to break the study of the material and effective control of its assimilation into separate finished parts. Each group of testing materials is divided and contains a set of 20-30 questions or tasks. This method of the structuring test's materials allows in a computerized version to implement a step-by-step increase in the complexity of verification tasks. These opportunities are provided by the organization of information and testing material on the sub-sections of the course and are taken into account in the testing algorithms.

As the generating polling tree that realized the polling algorithm with the minimum number of single tests, we will take the structure which is shown in Figure 1.

The generating tree is built on the basis of rules.

If there are all the basic answers are incorrect, the final evaluation is 0 points (the leftmost top in the upper tier), the poll stops.

      a   b   c
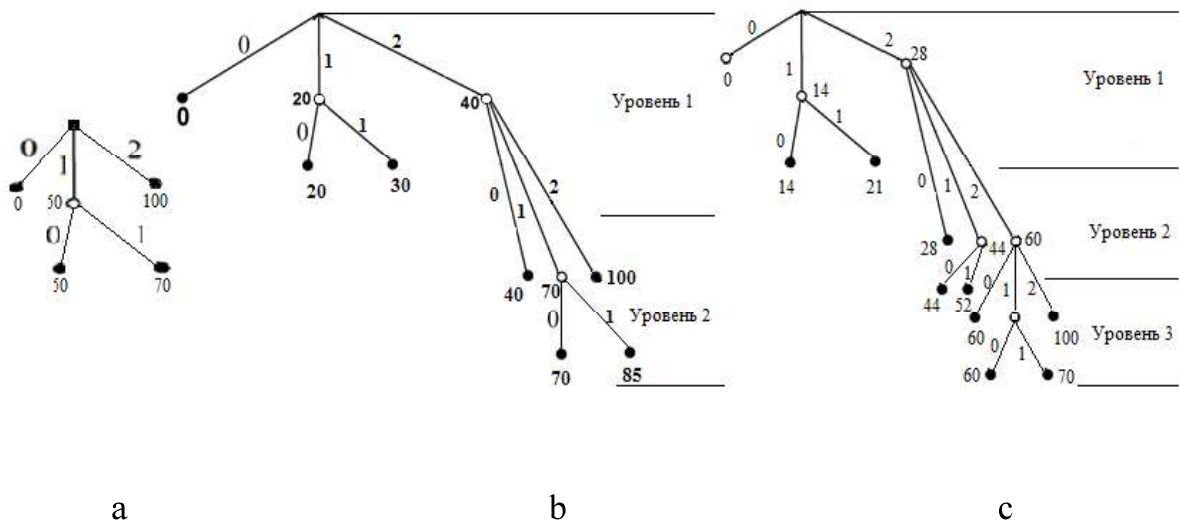
Picture 1. The structure of the generating tree for model testing of the first (a), the second (b), and the third (c) levels

2. If there are all the basic answers are correct, the final evaluation is 100 points (the extreme right top in the upper tier), the poll stops.

3. If there are one correct answer in the base phase (the middle top in the upper tier), the intermediate evaluation is 50 points, the poll continues in the specifying phase (the lower tier).

4. There is a number of questions reduced by half compared to the base phase in the specifying phase.

5. If there is an incorrect answer was given to the specifying question, the number of points are the same as in the intermediate phase - 50 (the extreme left top in the lower tier).

6. If there is the correct answer was given to the specifying question, the number of points is increased to 70 (as a result, the percentage number of correct answers is

100 * (2/3) 70) - (the extreme right top in the lower tier).

It was suggested to use two extra rules, when you build the algorithm trees for two- and three-level model testing.

1. Entering the distribution of the initial 100 points according to the levels of testing, taking into account their value.
2. It is necessary to use the next control function at the each level:
•   in case when the estimate given before does not exceed the half of the maximum possible estimate, there is a transition to the specifying phase of testing with the next level of finishing test
•   otherwise there is the transition to the base phase of the next level with the continue of the testing process.

The evaluation and control functions of the unit testing algorithm were described before in a formal form, and was graphically presented as trees for the situation of a classic single test. The formalization of both testing functions allows to use it in case of an adaptive single test and create an suitable algorithm.

Examine its verbal definition.

The initial data:

1) t - it's the scaling coefficient,

2) N - is the number of test's levels in the module,

3) P [1: N] - the allocation of points by levels.

The formulation of the problem. It is necessary to conduct testing and obtain a final score T, which assesses the level of knowledge of the student.

The following algorithm was made to solve the problem.

The algorithm for modular adaptive testing.

Step 1. Initial assignments: $T := 0$;

Step 2. Arithmetic cycle by test levels, variable i varies from 1 to Nu.

Step. 2.1. Testing at level i ($2t$ single tests), the result of which is the determination of the real number of correct answers responses and their score B_{ib}.

Step 2.2. Testing the effectiveness of testing: $B_{ib} \leq 0,5\ P_i$.

If the condition does not hold go to Step 2.3, otherwise on Step 2.4.

Step 2.3. Clarification of knowledge at the actual level i – implementation t single tests. As a result, a real number of correct answers riu and additional points are determined: Biu $= 0,25\ r_{iu}\ (Pi\ /t)$.

Step 2.4. The determination of full assessment at level i by formula (2.21):

$B_i = B_{ib} + B_{iu}$, if i had done both form,

$B_i = B_{ib}$, if only basic testing has been done.

Step 2.5. Increasing the total score: $T:=T+ Bi$.

Step 2.6. If clarifying testing has been done, the procedure is completed, otherwise-the transition to the next level of testing.

Step 3. The receiving the test's result: total score T.

The developed algorithm has no complicated structure, it is simple in software implementation.

The considered model of a single alternative test raises the degree of adaptability in comparison with the limit classical test due to a more flexible evaluation of response options and consideration of the time parameters of the response. To realize adaptivity in the proposed model in the extended version use the capabilities of the computing system. It allows to realize more fully an individual attitude in computer training at the first stage of knowledge testing – at the level of a single test. The suggested variant takes into attention to the maximum the essential characteristics of the computer process of knowledge testing.

When the individual testing of students will be done in the whole group the teacher must give the evaluation based on the scores received during testing, and in the case if there are students who not so good in studying, make a decision on the group correction of their knowledge level.

Group forms of studies in the universities are supplemented by the individual consultations, which have an auxiliary character in relation to group classes. The main types of correction in practice are:

1. individual study using the sources of information recommended by the teacher,
2. the consultation in addition to the main training lessons (individual or group),
3. additional explanation of the material during lessons (group),

4.   studying the educational material on short-term courses (group).

The first variant of corrective actions is the independent study by the student the material which was missed by different reasons and imply primary (in case of missing lessons) or deep study of missed topics in the main extra and educational literature (in case of special interest on the part of the student). It gives a positive effect, mainly, only for students with a tendency for independent study.

The second type of correction basically use when the student has not understood any particular issues of the studied material during the class. Then he can ask clarifying questions to the teacher in specially extra consultation hours or during the break between lessons. This type of correction is made for an individual type of knowledge correction.

The third type of corrective actions is a shortened version of the material, taking into attention the results of testing. It expected the teacher, studying the results of group testing, makes the conclusion that it is necessary to repeat some part of the same passed material in short time, emphasis the students' attention on a certain basic moment and for this purpose takes some extra time during one of the lesson. The method is effective, because in the process of preparation and testing itself, students already on a semantic level learn the material being studied, and the teacher's second explanation is more deeper for them.

The fourth type of correction is used in case when there is a group of students who for one or an another reason have not studied a significant part of the material (pass, illness, etc.). It is economically good to use this type of correction in the group variant, because such lessons give extra pay hours for teacher's time, reservation of the audit fund, etc.

The definition of the optimal type of correction for all students in group is a very complicated problem even for an experienced teacher. With the automated analysis of the results of computer testing, the corresponding computer program lacks the skills and intuition of the teacher. It should be changed sufficiently by the corresponding calculation algorithm, in which all the basic steps are presented in a formalized form.

We will use the following designations to do more formal writing of the algorithm:

- R – the total score of the final control given in the university,

- Δ - the permissible part of the total score when the student is allowed to the final certification,

- D – part where R is in the final evaluation.

After computer testing in the group for the specified sections of the course, the analyzing algorithm must determine:

1.   sub-group with low achievers,

2. to form a correction group,
3. determine the best ways to correct knowledge in this group.

The algorithm for group testing analysis and determination of optimal corrective actions.

Initial information:

1. points $\bar{B} = \{B^1, B^2,..., B^k\}$ for a group of k students received during testing educational material,
2. the attendance and part of attended lessons $\bar{q} = \{q_1, q_2,..., q_k\}$ by students during the period of studying the tested material.
3. the minimal part of the attended classes $[q]$, which necessary for the quality understanding of the tested material.

The formulation of the problem. It's necessary to: 1) define a subgroup with reduced student's achievement, 2) form correction groups, 3) define the best ways to correct knowledge.

Step 1. *Exception pseudo-zero assessment*. After checking the condition $B \leq 100(1/N)$ with $N=5$ and dropping students with these estimates, we get a new adjusted group of s students ($s \leq k$) and their test results $B' = \{B^{1\prime}, B^{2\prime},..., B^{s\prime}\}$. There are all estimates exceed the value of 20.

Step 2. *Statistical analysis of the corrected group*. The calculation of the center of gravity C', dispersion D' and SKO S' for the corrected group by the set of its test results $\bar{B'}$.

Step 3. *The formation of a subgroup with reduced academic progress.* We include all students who have the results $B^{j\prime\prime}$ and satisfy the double inequality: $C' - 1{,}5\,S' \leq B^{j\prime\prime} \leq C' + 0{,}5\,S'$.

As a result, we get a characteristic subgroup with a reduced level of testing results. The number of students in it will be denoted by r.

Step 4. The definition of the corrective score λ for a subgroup with reduced academic progress:

$$d = \bar{C'} - 1{,}1\,\Delta, \quad \lambda = \begin{cases} d, & npu\,|d| \leq 5; \\ 5 - uначе. \end{cases}$$

Step 5. The calculation of modified scores for a subgroup with reduced academic progress: For j = 1, ..., r

If $d \geq 0$, то $B^{j\prime\prime\prime} = B^{j\prime\prime} + \lambda$, otherwise $B^{j\prime\prime\prime} = B^{j\prime\prime} - \lambda$.

We also correct the lower and upper limits of the PPU.

Step 6. The formation and analysis of the correction group (mark less than Δ). It consists of two subgroups:

    a)   students whose test's marks are less than the lower limit of the subgroup with reduced academic progress$(C'-1,5S')$ (pseudo-zero estimates and estimates lying in the range of 20 points to the lower limit of the PPU).

    b)   students from the PPU group, whose marks is lower than the permissible Δ:

-     $B^{j''''} < \Delta$.

Step 7. *The correction of knowledge in subgroup a)*. The whole subgroup is sent to courses because of its low level of knowledge.

Step 8. *The correction of knowledge in subgroup b).* The total number of students in subgroup b) is denoted by p. It is necessary to find out in what form it is rational to carry out group correction. For each student of the subgroup, the condition of sufficient presence verify: $q_i \geq [q]$. Denote the part of the subgroup for which this condition is not satisfied by pn. The following rule for choosing the optimal form of knowledge correction is offered.

Step 8.1. If $pn < 0,3p$ (who missed the lessons really rarely, but they have a level of achievement close to the minimum acceptable), use only the form 3 (additional group explanation of the material during the main lessons) in this group in order to minimize the value of additional courses.

Step 8.2. If $0,3p \leq pn \leq 0,7p$ (there are a lot of students who missed the lessons, but they do not in the whole subgroup b)), then both forms 3 and 4 should be used together. In this case, there is a large group of students with a large number of absences they attend courses together with those who got pseudo-zero and close marks. For students who did not understand training material rather good during a stable attendance of lessons, it's enough to explain the main training course.

Step 8.3. If $pn > 0,7p$ (students who missed many lessons compose almost the entire subgroup b)), then use only Form 4 (additional courses), as students who attended lessons basically passed the tests successfully.

THE COMPLETION OF THE ALGORITHM

Suggested algorithm has the following features.

1.   The initial exclusion from the analysis of pseudo-zero estimates, as some students who understand educational material not so good and who are not fully involved in the educational process can significantly affect on the overall average group assessment of knowledge. At the same time, their level of knowledge does not reflect the level of knowledge of students actually participating in the educational process.

2.   The asymmetric shift of the estimate relative to the mathematical expectation when a subgroup with reduced academic performance is singled out allows highlight the core of the group, "suspicious" to an insufficient level of knowledge.

3. Using the modified assessment allows us to take into reasonable limits account the average level of academic achievement in the group and stimulate the interaction of the students of the group in the studying process.
4. The suggested algorithm makes it possible to discover the true reasons for the lowered academic achievement in the group and organize correction of knowledge with minimal additional costs of teaching work.
5. In addition to all the above, it is necessary to take into account the modular estimates in the boundary and final control of knowledge. One of the problems is the joint consideration of test results on various topics, for example, 1) on a set of modules or 2) on a set of sections in the evaluation of midterm control in the final evaluation. Due to the different significance of the individual modules in the acquisition of competencies in the studied discipline, it is suggested to use normalized weight coefficients and appropriate summation formulas for it.

At the same time of testing a set of p modules (for example, with a boundary knowledge control), they are treated with their partial weights $W_1,$ $W_2, \ldots W_p.$ Suppose, as a result of testing, were got evaluations of $B_1, B_2, \ldots B_p.$ As a general, the following estimate is taken:

$$B = (W_1 B_1 + \ldots + W_p B_p)/(W_1 + \ldots + W_p).$$
$$(6)$$

When taking into account the results of the boundary control $Br_1,$ $Br_2, \ldots Br_k$ on the final attestation of knowledge, these evaluations are also considered with their partial weights $Wr_1, Wr_2, \ldots, Wr_k.$. The generalized estimate of the boundary control in the final evaluation is the following:

$$Br = (Wr_1 Br_1 + \ldots + Wr_k Br_k)/(Wr_1 + \ldots + Wr_k).$$
$$(7)$$

If the partial weights $Wr_1, Wr_2, \ldots, Wr_k$ are normalized, the denominator in the formula 7 is equal to 1.

CONCLUSION

It was held the experimental commission of of the suggested method of adaptive computer testing in one of the Russian universities, which showed an increase in the motivation of the training activities of students of the experimental group, improving the quality of acquired knowledge in the discipline "Programming", increasing the desire to cooperate in the group, mastering various aspects of professional competencies.

The positive opinions were received not only from students of experimental groups, but also from teachers who taught students in subsequent related disciplines, who observed a higher level of knowledge among undergraduate students who mastered the course on this method, and also noted an increase in the overall positive working mood in the study course of discipline on the developed methodology in the experimental groups, which

was expressed in the desire of students to assimilate the educational material of the course in the framework of training sessions, greater concentration and accuracy in carrying out tasks of laboratory and test tasks.

Thus, the results of the pedagogical experiment confirmed the effectiveness of the developed method of adaptive computer testing to improve the quality of professional education of undergraduate students.
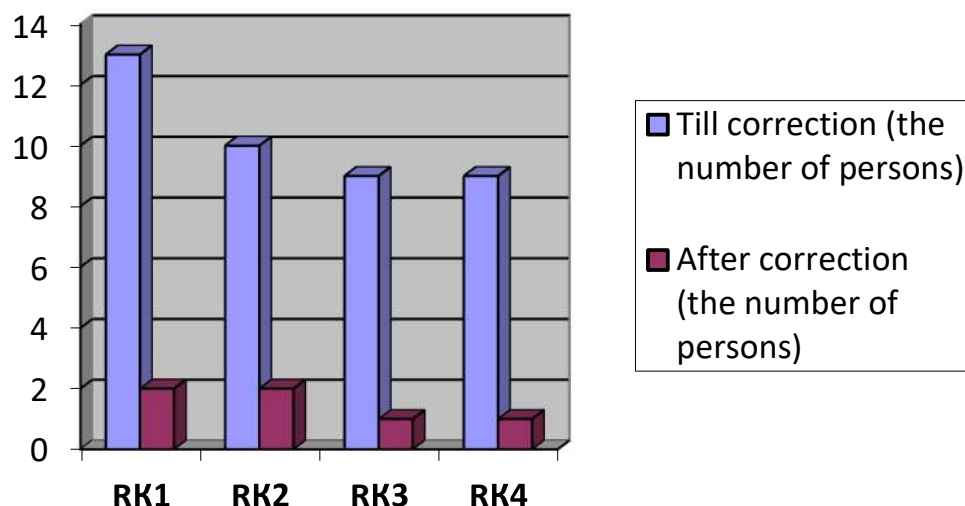
Diagram 1. Change in the number of students failing by sections of the course in the experimental group

The method of adaptive computer testing offered by the authors gives an opportunity to take a fresh look at the problem of designing educational disciplines in the format of interactive learning, to adapt the process of computer testing of students' knowledge simultaneously by several parameters and to achieve higher educational indicators when teaching students at the universities, to build an individual trajectory of training.

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