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The problem of increasing the efficiency of computer adaptive testing for students in higher educational establishments

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O problema de aumentar a eficiência dos testes adaptativos por computador para estudantes em instituições de ensino superior

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El problema de aumentar la eficacia de las pruebas adaptativas por ordenador para los estudiantes de las instituciones de enseñanza superior

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Resumo: The development of adaptive tests is based on taking into account the predominant individual characteristics of students, that is the style characteristics of cognitive activity, making it possible to increase the effectiveness of tests, make them more attractive, and ultimately contribute to more effective learning. In this context, the paper presents the results of a study on the effectiveness of students' adaptive computer tests based on the consideration of the stylistic characteristics of their cognitive activity. Based on computer science and programming, variations of test items were developed and offered to undergraduate and graduate students at Herzen State Pedagogical University of Russia and ITMO University Saint-Petersburg. In the course of the study, it was revealed that since the adaptive test passing scores showed a stable improvement, the desirability and possibility of constructing tests based on the consideration of stylistic features of students' cognitive activity was experimentally proven. Similarly, the hypothesis about the effectiveness of using adaptive test questions in comparison with other types of questions was proven.

Palavras-chave: *Adaptive tests. Computer adaptive testing systems. Leading channel of information perception. Stylistic features of cognitive activity.*

Abstract: *O desenvolvimento de testes adaptativos baseia-se em levar em conta as características individuais predominantes dos estudantes, ou seja, as características de estilo da atividade cognitiva, tornando possível aumentar a eficácia dos testes, torná-los mais atraentes e, finalmente, contribuir para um aprendizado mais eficaz. Neste contexto, o artigo apresenta os resultados de um estudo sobre a eficácia dos testes adaptativos de computador dos estudantes, baseado na consideração das características estilísticas de sua atividade cognitiva. Com base em informática e programação, foram desenvolvidas variações de itens de teste, as quais foram oferecidas a estudantes de graduação e pós-graduação da Herzen State Pedagogical University of Russia and ITMO University*

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Saint-Petersburg. No decorrer do estudo, foi revelado que, como o resultado da aprovação nos testes adaptativos demonstraram uma melhora estável, a conveniência e a possibilidade de construir testes baseados na consideração das características estilísticas da atividade cognitiva dos estudantes foi comprovada experimentalmente. Da mesma forma, comprovou-se a hipótese sobre a eficácia do uso de questões do teste adaptativo em comparação com outros tipos de questões.

Keywords: *Canal líder de percepção da informação. Características estilísticas da atividade cognitiva. Sistemas de testes adaptativos por computador. Testes adaptativos.*

Resumen: *: El desarrollo de pruebas adaptativas se basa en tener en cuenta las características individuales predominantes de los alumnos, es decir, las características de estilo de la actividad cognitiva, lo que permite aumentar la eficacia de las pruebas, hacerlas más atractivas y, en definitiva, contribuir a un aprendizaje más eficaz. En este contexto, el artículo presenta los resultados de un estudio sobre la eficacia de las pruebas adaptativas por ordenador de los alumnos basado en la consideración de las características estilísticas de su actividad cognitiva. Sobre la base de la informática y la programación, se desarrollaron variaciones de los ítems de la prueba y se ofrecieron a los estudiantes de grado y posgrado de la Universidad Pedagógica Estatal de Herzen de Rusia y de la Universidad ITMO de San Petersburgo. En el transcurso del estudio se puso de manifiesto que, dado que los resultados de la superación de las pruebas adaptativas mostraban una mejora estable, se comprobó experimentalmente la conveniencia y la posibilidad de construir pruebas basadas en la consideración de las características estilísticas de la actividad cognitiva de los alumnos. Asimismo, se comprobó la hipótesis sobre la eficacia del uso de las preguntas del test adaptativo en comparación con otros tipos de preguntas.*

Keywords: *Canal líder de percepción de la información. Características estilísticas de la actividad cognitiva. Sistemas de pruebas adaptativas por ordenador. Pruebas adaptativas*

INTRODUÇÃO

At the present stage of the development of education in the world and Russia, its effectiveness strongly depends on the effectiveness of e-learning technologies, and, first of all, on the organization of processes in the digital educational environment, including checking the level of formation of learning outcomes. In the context of an increase in the share of distance interaction and, at the same time, an increase in the number of students with the number of teachers, rational automation of checking the formation of competency components is becoming critical. This requires the design of assessment tools and assessment procedures in such a way that the tools and technologies used to contribute to a more fine-tuning to the specifics of the cognitive characteristics of students, thereby ensuring not only the success of control but also the identification of gaps in educational results, to compensate for which it is planned to direct corrective educational activities.

One of the ways to solve the above problem is the design, development, and implementation of computer adaptive testing systems. As the analysis of modern testing systems and testing modules in distance and e-learning systems has shown, this is associated with solving problems of setting up software systems responsible for ensuring control. The experience of the authors of this article is in the field of teaching mathematics, information technology, and programming, which made it possible to develop an approach to the design of both assessment tools and assessment procedures with the maximum involvement of students and the optimal speed of implementation of the proposed improvements in the learning process.

In general, the analysis of the Russian and international experience of computer adaptive testing of university students showed that the directions of research in this area, conceptual approaches, principles of building such systems, and the results obtained during the implementation of computer adaptive testing systems do not have significant differences in Russian and foreign scientific thought. However, the interest of Russian researchers is more focused on the search for

new foundations and methods of adaptation that would take into account the specifics of subject areas and the individual characteristics of students.

2 LITERATURE REVIEW

To generalize modern views on the design of adaptive tests, 35 different theoretical sources were analyzed. Studies (2, 9, 16, 17, 25, 32, 34) substantiated the effectiveness of adaptive tests in comparison with traditional linear tests. Some empirical studies (22, 31) have shown that the use of computer adaptive testing systems can reduce the number of items and test time without degrading the measurement accuracy and that these systems are flexible enough and provide customization to ensure that all test takers are evaluated with the same accuracy. In the works of Russian and foreign scientists (3, 5, 7, 8, 14, 19, 20, 24, 28, 29, 33), the effectiveness of using computer-adaptive as a component of electronic and mobile learning is noted. Within the framework of the discourse on computer adaptive testing, scientists and specialists consider various approaches to the creation of adaptive tests (3, 4, 5, 6, 10, 19, 21, 23, 30), including based on the biological theory of human development by J. Piaget (12), varying the level of complexity according to various criteria (24, 30), methods of artificial intelligence (21), multistage (25, 34) and multi-segmentation to achieve various educational goals (25). In works (30, 34), it is also noted that computer adaptive testing systems can improve validation, reduce the load on test-takers and provide higher measurement accuracy and increase student motivation. Many Russian and foreign scientists have studied the problem of developing and including adaptive tests in the educational process (8, 16, 30, etc.). These studies considered, for example, the use of adaptive tests for monitoring bilingual education (11), in teaching English (12). Several studies are devoted to the use of computer-adaptive tests for psychological research (P. Kolyasnikov, E. Nikulchev, V. Belov, A. Silaeva, A. Kosenkov, A.Malykh, Z. Takhirova, S. Malykh, 2019), as well as for further pedagogical research on the problem of improving the effectiveness of teaching based on metadata of computer adaptive testing (M. Kuhfeld, J. Soland, 2020). Recently, there have been studies devoted to assessing Internet addiction using adaptive testing systems. (Y. Zhang, D. Wang, Y. Gao, D. Tu. Cai, 2019). One of the areas of research has also become the solution to the complex problem of developing computer systems for adaptive testing, including using artificial intelligence methods (21, 22, 32).

However, despite the many theoretical studies and a variety of approaches to the development of the content and structure of computer-adaptive tests, guidelines for their creation, the basis of adaptive test tasks in the vast majority of studies is the number of tasks presented to the student and the level of their complexity.

As part of the study, an additional analysis was carried out of 15 computer testing systems positioning one or another degree of adaptation. One of the ways to adapt is by the number of test items or questions presented to the test taker. With this approach, access to the next test item (set of test items) is opened only if the previous test item (set of test items) has been completed. If the test taker is presented with a set of tasks corresponding to the content block, the number of completed tasks is counted, the learning factor for the corresponding content block is calculated, and the results are recorded. With this approach, tests can be supplemented with tips, as well as links to additional material that must be mastered by the test taker.

Another common way to adapt is by test execution time. In this case, it is supposed to introduce a time limit for the execution of the entire test or individual tasks. In some cases, different execution times can be defined for different sets of tasks corresponding to meaningful blocks.

These two approaches are used in the following computer testing systems: Let's test, MuTestX Pro, Indigo, Expert-CMS, linear testing in TESTOR.RU, linear testing in computer testing systems, such as SunRav WEB Class, SunRav and TestOfficePro, in SKT Ball, AST-Test,

etc.). Based on the same approaches, most of the testing units in the LMS are implemented (Teachbase, eLearning Server 4G, WebTutor Testing module, Mirapolis LMS, iSpring, Stepik, Moodle, etc.).

Another common basis for test adaptation is difficulty adaptation. This approach is implemented in some computer adaptive testing systems, for example, Adaptest®, CATSim, Assessment Center, WINS TEPS, CatR, project R, mirtCAT, as well as in testing units of some LMS.

With this approach, testing begins with assessing the starting level of the student's training (the first stage). Then the system selects tasks, the difficulty level corresponds to the starting level determined at the first stage. The test taker performs these tasks at the second stage. Based on the results of completing the tasks of the second stage, the test taker is invited to complete either a test task of a lower level of complexity (did not complete the task of the previous stage) or a higher level of complexity (the task of the previous stage was completed successfully). The sequence and duration of the next stages are determined by the test completion criteria, which is determined by the required accuracy of the assessment of the results.

In none of the studies and none of the testing systems existing and implemented today, we have not been able to find a statement of the problem of constructing adaptive tests based on taking into account the individual characteristics of students, except for their success in completing tasks of different levels of complexity.

3 MATERIALS AND METHODS

A research team of teachers from two universities: the Herzen Russian State Pedagogical University (Herzen Russian State Pedagogical University) and the National Research University ITMO (ITMO University) conducted a joint study aimed at studying the effectiveness of using adaptive testing in the preparation of students and undergraduates.

To conduct an experimental study, the following requirements for the development of a system of adaptive tests were identified and formulated:

a) The principle of completeness

The system of tests for each section of the content of an academic discipline should cover all content and activity components (knowledge and skills) inherent in this academic discipline, while each test task can be aimed at mastering one specific or several components.

b) The principle of considering individual characteristics

Test tasks assume orientation to different leading channels of information perception and include different methods of coding (presentation forms) of information.

c) The principle of complication

The presence or absence of a transition from one way of presenting information to another in a test task is one of the indicators of the task complexity along with the traditional ones.

The set of principles for designing test items following the individual characteristics of students is highlighted for the first time and built based on taking into account the style features of the cognitive activity of students and the specifics of the educational material. Concerning research, the set of principles is preserved for academic disciplines in programming and ICT with some modification of the first principle, since the activity components for different training courses are somewhat different. For other academic disciplines, the stated principles require clarification in the framework of additional research.

The results of the research can be used primarily to recognize the appropriate and necessary transformation of test items used in the organization of current and intermediate control to improve the quality of training students.

Diagnostics of the dominant perceptual modality to identify the stylistic features of students' cognitive activity was carried out according to the S. Efremtseva method.

Experimental research (research and control stages), was organized and conducted by teachers of two universities: Herzen RSPU

and ITMO University among students of the direction 09.03.01 "Informatics and Computer Engineering" in the disciplines "Programming", "Management of software projects" as well as among the undergraduates of the educational program "Web Technologies" in the disciplines, "Server Web Technologies and Content Management Systems" and "Web Language and Technology Ecosystem Studies".

At the initial stage of the research stage, to identify the stylistic features of the student's cognitive activity, the diagnosis of the dominant perceptual modality was carried out according to the S. Efremtseva method. According to the diagnostic results, 27 people were excluded from the formed sample (119 people) after interpreting the results of the students, for whom kinesthetic (tactile perception) and discrete (digital perception) were determined by the dominant modalities, they did not participate in the next stages of the study.

Thus, the initial sample was reduced to 92 people (64 people are undergraduate students of the Herzen Russian State Pedagogical University and 28 people are undergraduate students of ITMO University) aged 18 to 35, in a ratio of 65 - males, 31 - females. Because of the diagnostics, the number of students with leading visual perception ("visuals") was 50 people, and with auditory ("audials") - 42 people.

To test the hypotheses of the conducted two-stage study, which included research and control stages, we used Student's t-test for independent samples. The assumption of independence assumed that the representatives of the two samples did not make up a pair of correlated values of the trait under study. Experimental data were extracted from learning management systems used in universities.

The distribution of the studied trait approximately corresponds to the normal one; the variances of the trait in the two samples are approximately the same (homogeneous).

Further, as part of the current monitoring of progress throughout the research stage, students in the independent mode were asked to perform tests, each of which consisted of at least 10 test tasks dedicated to the material covered.

Teachers for each discipline have developed sets of test items that fully cover the content of the taught courses. In the learning management system, a separate category for test tasks was created for each semantic block of the course. Each developed test task, which tests the competence of the student in a certain semantic fragment of the course, was presented in several versions, implying the use of a certain channel of perception.

Within the framework of tests conducted on one topic for students who are visuals and auditors, a set of test tasks was formed, implying the use of various channels of perception. For each such group, within the framework of two tests, it was first proposed to perform test tasks (answer questions), adapted to their leading type of perception, and then to test tasks created for students with a different type of perception. Thus, the test results of each group were the control for the other groups.

4 RESULTS

The obtained results for each test were presented as a value on a 100-point scale. The data was downloaded from the learning management system in the form of CSV files, anonymized, and compiled into a single table. Table 1 shows an example with a fragment of the anonymized data of the first test.

Table 1. - An example of a snippet of anonymized data for the first test

Student ID	Test result for topic 1
2-2019-4-1	85.3
2-2019-4-2	80.0
2-2019-4-3	70.8
2-2019-4-4	95.4
2-2019-2-1	100.0
2-2019-2-2	98.2
2-2019-2-3	90.9
2-2019-2-4	65.6

Prepared by the authors (2020).

Further, for each group with a certain type of perception, the average values for each test were calculated. An example for the first test is shown in Table 2.

Table 2- Example of calculating the average value for the first test

Group 1: "audials"	Group 2: "visuals"
$N_1 = 42$ $M_{11} = 88$, $\sigma_{11}^2 = 13.5$ $M_{12} = 91.5$, $\sigma_{12}^2 = 6.9$	$N_2 = 50$ $M_{21} = 86$, $\sigma_{21}^2 = 14$ $M_{22} = 93.2$, $\sigma_{22}^2 = 14.9$

Prepared by the authors (2020).

The table presents M_{11}, M_{21} as mean values of testing audials (group 1) and visuals (group 2) using tests adapted for "audials".

M_{12} и M_{22} are the average values of testing audials (group 1) and visuals (group 2) using tests adapted for "visuals".

During the experiment, it was checked whether the success of solving tasks by students with certain style features of cognitive activity depends on the form of presentation of information in this task.

Let us call the "test result" the average value obtained by a group of learners "audials" and "visuals".

The following hypotheses were formulated:

For the "audials" group:

H0 – the result of testing "audials" exceeds the result of testing "visuals" on test items adapted for "audials".

H1 – the result of testing "audials" is equal to the result of testing "visuals" on test items adapted for "audials".

For the "visuals" group:

H2 – the result of testing "visuals" exceeds the result of testing "audials" on test tasks adapted for "visuals".

H3 – the result of testing "visuals" is equal to the result of testing "audials" on test items adapted for "visuals".

Hypotheses about the difference in test results were tested at the level of α=0,05.

Let us check the formulated hypotheses for "audials".

Let us calculate the empirical value of the Student's t-test by the formula:

$$t_э = \frac{|M_{11} - M_{21}|}{\sqrt{\frac{\sigma_{11}^2}{N_1} + \frac{\sigma_{21}^2}{N_2}}} \quad (1)$$

Since the number of samples varies markedly, the formula below was also used for the exact calculation:

$$t_э = \frac{|M_{11} - M_{21}|}{\sqrt{\frac{(N_1 - 1)\sigma_{11}^2 + (N_2 - 1)\sigma_{11}^2}{N_1 + N_2 - 2}\left(\frac{1}{N_1} + \frac{1}{N_2}\right)}} \quad (2)$$

The resulting value according to the formula (1) $t_э$=2,5789, according to the formula (2) $t_э$= 2,5748, ***df***=90.

Let us determine the p-level of significance from the table of critical values of the Student's t-test. For ***df***=90, the empirical value is between the critical for ***p*** = 0.05 and p = 0.01. Hence, ***p*** < 0.05.

Let us formulate a statistical solution and formulate a conclusion: the statistical hypothesis H1 is rejected. The average values for "audials" are higher than for "visuals" when using "auditory" test items, hypothesis H0 is accepted.

Let us check the formulated hypotheses for "visuals" in a similar way.

The resulting value according to the formula (1) $t_э$=2,2205, according to the formula (2) $t_э$= 2,2004, ***df***=90.

Let us determine the p-level of significance from the table of critical values of the Student's t-test. For ***df***=90, the empirical value is between the critical for ***p*** = 0.05 and ***p*** = 0.01. Hence, ***p*** < 0.05.

Let us formulate a statistical solution and formulate a conclusion: the statistical hypothesis H_3 is rejected. The average values for "audiences" are higher than for "visuals" when using "auditory" test items, hypothesis H_2 is accepted.

For the control stage, 22 candidates were randomly selected from the studied sample of students (92 people) (group 1). Also involved were 23 candidates from those previously excluded from participation in the research stage, whose dominant modality was determined as kinesthetic and discrete (digital perception) (group 2).

Further, similar to the research stage, these two groups were tested using specially designed adaptive test items, which took into account the style characteristics of the students.

During the control stage, it was checked whether, as a result of the completion of the research stage, the students for whom it was possible to determine the individual style features of cognitive activity showed an improvement in the results.

We will call the "test result" the average value obtained by each group of students participating in this stage.

The following hypotheses were formulated for group 1:

H_0 – the test result of group 1 exceeds the test result of group 2 on adaptive test items.

H_1 – the test result of group 1 is equal to the test result of group 2 on adaptive test items.

Hypotheses about the difference in test results were tested at the level of alpha = 0.05.

Let us check the formulated hypotheses and calculate the empirical value of the Student's t-test according to the formula (1)

The resulting value according to the formula (1), t_e = 2.6775, $df = 43$

Let us determine the p-level of significance from the table of critical values of the Student's t-test. For the empirical value is between the critical for $p = 0.05$ and $p = 0.01$. Hence, $p < 0.05$.

Let us formulate a statistical solution and formulate a conclusion: the statistical hypothesis H1 is discarded. The average values for group 1 are higher than for group 2 when using adaptive test items, hypothesis H0 is accepted.

5 DISCUSSION

The transition to blended learning and the increase in the proportion of interactions mediated by the electronic information and educational environment has led to an increase in the importance of monitoring and automated control of the formation and development of the required knowledge, abilities, skills, and competencies of students. This emphasis on control requires rationalization and experimental justification of the utilized testing tools. The development of adaptive tests is based on taking into account the prevailing individual characteristics of students, namely the style features of cognitive activity, making it possible to increase the effectiveness of tests, make them more attractive, and ultimately contribute to more effective learning.

At the same time, the accuracy of the approach to determining the style features of the cognitive activity of students needs to be improved. In conditions of predominantly remote interaction, it is more difficult to judge the manifestation of style features, since in any case, the visual channel of perception dominates. This, to a certain extent, reduces the effectiveness of the proper design of adaptive test items, but still does not have a decisive effect on the research results.

It seems promising to integrate the selected approach to the design of adaptive tests with the methodology for constructing test items based on coding (presentation form) of information described in one of the authors' studies (13), as well as based on accounting for cognitive styles: a narrow-wide range of equivalence (analyst-synthetic) and cognitive simplicity-complexity. This will make it possible to implement the principle of a double sequence (or double transition): the transition from a test task of one level of complexity to another is determined both by the success of the task in the priority coding style and in the non-priority one; the transition to a test task of the next level of complexity is determined both by the success of the task in the priority strategy (determined by the cognitive style) and in the non-priority one.

Represents the problem and technological support for the development of adaptive tests. Analysis of the capabilities of learning environments (such as Moodle, Blackboard,

and edX) showed that the tools offered as part of their software are insufficient to support full-fledged adaptive testing (14). Besides, internal surveys show that teachers mainly use simpler types of tests and need further training in the design and implementation of adaptive tests in the educational process.

These problems create a prospect for the development of research in the directions we have indicated, including research in the development of an appropriate software environment, optimized for the design, debugging, and implementation of adaptive tests based on several adaptation bases.

At the same time, taking into account the pace of changes in the educational environment, the need for urgent implementation of solutions that improve the efficiency and profitability of the educational process, the approach proposed and tested by us experimentally, already at this stage, can be used to improve the characteristics and indicators of educational activities of students.

6 CONCLUSIONS

Modern research shows the effectiveness of adaptive tests in the implementation of control measures. At the same time, research, as well as testing systems in their current state, do not take into account the individual characteristics of students, which results in a decrease in the effectiveness of tests.

So that the control of results does not form negative motivation and does not turn into a purely formal procedure, the appropriate means and tools should evoke a response from students in the aspect of their individuality, should arouse interest, and stimulate proactivity. This can be achieved by adaptive tests, built taking into account the individual characteristics of the cognitive activity of students. They are used as an independent form of control, as a component of e-learning and mobile learning.

The approach proposed by the authors of this article meets these requirements.

In the course of the study, it was revealed that as a result of passing the adaptive tests developed by a team of teachers, students, and undergraduates of both universities demonstrated a stable improvement in the results obtained, thus the expediency and possibility of constructing testing based on taking into account the stylistic features of the cognitive activity of students was experimentally substantiated, and the hypothesis was also confirmed on the effectiveness of using adaptive test questions in comparison with other types of test questions.

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Note 1 - Scientific novelty: a new approach has been developed to the construction of adaptive testing based on taking into account the stylistic features of the cognitive activity of students.

Theoretical significance: for the first time, a set of principles for constructing a system of adaptive tests was formulated, taking into account the individual style features of the cognitive activity of students and the specifics of the educational material (principles of completeness, taking into account individual characteristics, complication). A new basis for constructing adaptive tests, the leading channel of information perception, has been identified.

Note 1 - Practical relevance: adaptive tests have been developed that take into account the stylistic features of cognitive students (the leading channel of information perception) in the disciplines “Programming”, “Management of software projects” for bachelor students studying in the direction 09.03.01 “Informatics and Computer Engineering” (Herzen RSPU), as well as in the disciplines “Server Web Technologies and Content Management Systems” and “Research of Ecosystems of

Web Languages and Web Technologies" for undergraduates of the educational program "Web Technologies" (ITMO University). Approbation of the developed adaptive test items showed the effectiveness of their use in comparison with other types of test items.

Note 3 - Limitations of the experimental study: students with dominant kinesthetic (tactile perception) and discrete (digital perception) modalities did not participate in the experiment (they were excluded from the formed sample at the first, diagnostic, stage). The formulated principles of constructing a system of adaptive tests, taking into account the individual style features of the cognitive activity of students and the specifics of the educational material, also require clarification for other academic disciplines.

REFERENCES

BROVKA N.V., DYACHUK P.P., NOSKOV M.V., PEREGUDOVA I.P. Markov mathematical model of dynamic adaptive testing of an active agent. **Informatics and Education**, v. 10, p. 29-35, 2018.

CHOI Y, MCCLENEN C. Development of adaptive formative assessment system using computerized adaptive testing and dynamic bayesian networks. **Applied Sciences**, v. 10, n. 22, 2020.

DELGADO-GÓMEZ D., LARIA J.C., RUIZ-HERNÁNDEZ D. Computerized adaptive test and decision trees: a unifying approach. **Expert Systems with Applications,** v. 117. p. 358-366, mar., 2019.

DYACHUK P.P., DYACHUK JÚNIOR, P.P., Shkerina L.V. **Dynamic adaptive test simulators in teaching mathematics**. Electronic libraries, v. 23, n. 1-2, p. 57-64, 2020.

DYACHUK P.P., SHKERINA L.V., SHADRIN I.V., PEREGUDINA I.P. **Dynamic adaptive testing as a way of self-study of students in the electronic problematic environment of mathematical objects**. Bulletin of the Krasnoyarsk State Pedagogical University named after V.P. Astafieva, v. 1, n. 43, p. 48-59, 2018.

EGGEN T.J.H.M. Multi-segment computerized adaptive testing for educational testing purposes. **Frontiers in Education**, v. 3, n. 111, 2018.

GOMEDE E., BARROS R.M., MENDES L.S. **Deep autoencoders to adaptive e-learning recommender system**. Computers and Education: Artificial Intelligence, v. 2, 2021.

IVANOV E.A. Some problems of teaching IT disciplines. **Scholarly notes of the Institute of Social and Humanitarian Knowledge**, v. 17, n. 1, p. 236–241, 2019.

KINGSBURY, G. GAGE, STEVEN L. Wise. Three measures of test adaptation based on optimal test information. **Journal of Computerized Adaptive Testing**, v. 8, n. 1, 2020.

KOCHETKOVA T.O., KARNAUKHOVA O.A. Adaptive educational strategy for teaching mathematics to students in an electronic environment. **Bulletin of the Astafiev Krasnoyarsk State Pedagogical University**, v. 2, n. 44, p. 50-56, 2018.

KOLYASNIKOV, P., NIKULCHEV, E., BELOV, V., SILAEVA, A., KOSENKOV, A., MALYKH, A., TAKHIROVA Z., MALYKH, S. Analysis of software tools for longitudinal studies in Psychology. **International Journal of Advanced Computer Science and Applications**, v. 8, n. 10, p. 21-33, 2019.

KOMLEVA N.V., VILYAVIN D.A. Digital platform for creating personalized responsive online courses. **Open education**, v. 24, n. 2, p. 65-72, 202.

KUHFELD, M., SOLAND, J. Using assessment metadata to quantify the impact of test disengagement on estimates of educational effectiveness. **Journal of Research on Educational Effectiveness**, v. 13 n. 1, p. 147-175, 2020.

LARIN S.N., GERASIMOVA L.I., GERASIMOVA E.V. Adaptive testing of the level of knowledge of trainees as a toolkit for the implementation of the principles of individualization and differentiation of learning. **Pedagogical Journal,** v. 8, n. 2A, p. 48-57, 2018.

LOUHAB F.E., BAHNASSE A., TALEA M. Towards an adaptive formative assessment in context-aware mobile learningprocedia. **Computer Science**, v. 135, p. 441-448, 2018.

LOUHAB F.E., BAHNASSE A., TALEA M. Considering mobile device constraints and context-awareness in adaptive mobile learning for flipped classroom. **Education and Information Technologies**, p. 2607-2632, may., 2018.

MASLOVA L.A., POPOVA E.O. Features of creating an effective adaptive test. **Digital Humanities and Technologies in Education (DHTE 2020): collection of materials of the All-Russian Scientific and Practical Conference with International Participation**, nov. 19-21, 2020. Moscow: Publishing house: Moscow State Psychological and Pedagogical University, p. 379-389.

NOSKOV M.V., PEREGUDOVA I.P., DYACHUK P.P., DENISENKO O.I. Dynamic adaptive audio tests-simulators as a means of monitoring bilingual education. I**nformatics and Education**, v. 10, n. 30, p. 46–54, 2019.

PEREGUDOVA I.P. Dynamic adaptive testing of educational activity of students in the study of the times of the English language. **Pedagogical sciences**, v. 10, n. 100, p. 40–45, 2020.

PODKHODOVA N.S., ORLOVA A.V., SNEGUROVA V.I. Stylish features of students as one of the foundations for the design of adaptive tests in mathematics. **The Emissia Offline Letters:** electronic scientific journal, v.10, oct., art. 2877, 2020.

SHERSHNEVA V.A., WEINSTEIN YU.V., KOCHETKOVA T.O. Adaptive learning system in an electronic environment. Software systems: **theory and applications,** v. 9-4, n. 39, p. 159–177, 2018.

SIMCHENKO N.N., ARISTANOV A.A. Designing a learning system with adaptive testing. **Innovative Science**, v. 6, p. 64-68, 2019.

SNEGUROVA V.I., GOTSKAYA I.B. On the results of the analysis of computer adaptive testing systems. **The Emissia. Offline Letters: electronic scientific journal**, v. 10, oct., Art. 2879, 2020.

STOLYAROVA I.V. Electronic test method of control at the stage of frontal polling in computer science lessons for secondary school students. **Russian Journal of Education and Psychology,** v. 11, n. 3, 2020.

TSIBULSKY G.M., WEINSTEIN YU.V., ESIN R.V. **Development of adaptive e-learning courses in the LMS Moodle environment**: monograph. Krasnoyarsk: Siberian Federal University, 2018.

TOMASHEV M.V., AVDEEV A.S., KRASNOVA M.V. Adaptive testing as a means of managing the quality of education. **Informatics and Education**, v. 9, n. 298, p. 27–33, 2018.

UTEMOV V.V., GOREV P.M. Interdisciplinary technology of adaptive teaching and testing in school education. **Scientific-methodical electronic journal "Concept"**, v. 3, p. 1–11, 2018.

VINOGRADOV, V.O., Efimova V.G. Adaptive testing as a way of organizing computer testing by disciplines in electronic courses LMSMoodle. **Spiritual sphere of society**, v. 15, p. 23-32, 2018.

RECKASE M., JU U., KIM S. How adaptive is an adaptive test: are all adaptive tests adaptive? **Journal of Computerized Adaptive Testing**, v. 7, n. 1, 2019.

RODRÍGUEZ-CUADRADOA J., DELGADO-GÓMEZ D., LARIA J.C., RODRÍGUEZ-CUADRADO

S. (2020). Merged Tree-CAT: A fast method for building precise computerized adaptive tests based on decision trees. **Expert Systems with Applications**, v. 143, apr. , 2020.

SAMSUDIN M. A., SOM CHUT T., ISMAIL M. E. Evaluating computerized adaptive testing efficiency in measuring students' performance in science TIMSS. J**ournal Pendidikan IPA Indonesia (Indonesian Journal of Science Education) 2019**, v. 8, n. 4, p. 547-560, 2019.

SHERSHNEVA V., VAINSHTEIN Y., KOCHETKOVA T., ESIN R. A technological approach to the development of an adaptive e-learning system. **SHS Web of Conferences,** 2019.

MARTIN, A. J., LAZENDIC, G. Computer-adaptive testing: implications for students' achievement, motivation, engagement, and subjective test experience. **Journal of Educational Psychology**, v. 110, n. 1, p. 27-45, 2018.

ZHANG Y., WANG D., GAO, Y. CAI, D. TU. Development of a computerized adaptive testing for internet addiction. **Front Psychol**, v. 10; PMC6514228, 2019.

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