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INVESTIGATION OF THE EFFECTIVENESS OF PERSONALIZED ADAPTIVE MATHEMATICS TEACHING

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The study aimed to empirically investigate the effectiveness of personalized adaptive learning in mathematics. To clearly explain this approach, we have deeply analyzed and used a mixed methodological approach to analyze satisfaction with the learning environment, perception, and attitude to the content provided, as well as general experience and personalized adaptive experience in the context of an electronic learning environment in mathematics. The students were distributed according to one of two conditions: an electronic learning environment known as personalized adaptive learning, and the same learning environment without the integration of a personalized adaptive learning platform. The necessity of using statistical methods for a reliable assessment of the results of experimental work in pedagogical research is considered, as well as the results of using two statistical criteria, and the difficulties that may arise during their implementation are analyzed on a practical example. To evaluate the effectiveness of adaptive personalized technologies, it was planned to use the Fisher criterion and the Student's t-criterion. They were chosen because they are based on two different types of scales: ordinal and interrelated.
Key words: personalized learning, adaptive learning, electronic learning environment, mathematics, efficiency, Fisher criterion, Student's t-criterion.

ИССЛЕДОВАНИЕ ЭФФЕКТИВНОСТИ ПЕРСОНАЛИЗИРОВАННОГО АДАПТИВНОГО ОБУЧЕНИЯ МАТЕМАТИКЕ

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Целью исследования было эмпирически исследовать эффективность персонализированного адаптивного обучения математике. Чтобы четко объяснить этот подход, мы глубоко проанализировали и использовали смешанный методический подход для анализа удовлетворенности учебной средой, восприятия и отношения к предоставляемому контенту, а также общего опыта и персонализированного адаптивного опыта в контексте электронной среды обучения математике. Учащиеся были распределены по одному из двух условий: электронная учебная среда, известная как персонализированное адаптивное обучение, и та же учебная среда без интеграции персонализированной адаптивной учебной платформы. Рассмотрена необходимость использования статистических методов для достоверной оценки результатов экспериментальной работы в педагогических исследованиях, а также на практическом примере проанализированы результаты использования двух статистических критериев и трудности, которые могут возникнуть при их внедрении. Для оценки эффективности адаптивных персонализированных технологий планировалось использовать критерий Фишера и t-критерий Стьюдента. Они были выбраны потому, что основаны на двух различных типах шкал: порядковых и взаимосвязанных.

Ключевые слова: персонализированное обучение, адаптивное обучение, электронная обучающая среда, математика, эффективность, критерий Фишера, t-критерий Стьюдента.

МАТЕМАТИКАНЫ ДЕРБЕС БЕЙІМДЕП ОҚЫТУДЫҢ ТИІМДІЛІГІН ЗЕРТТЕУ

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Зерттеудің мақсаты математиканы дербес бейімдеп оқытудың тиімділігін эмпирикалық түрде зерттеу болды. Бұл тәсілді нақты түсіндіру үшін біз оқу ортасының қанағаттануын, берілген мазмұнға қабылдау мен көзқарасты, сондай-ақ математиканы оқытудың электрондық ортасы контекстіндегі жалпы тәжірибе мен дербес бейімделу тәжірибесін талдау үшін аралас әдістемелік тәсілді терең талдадық және қолдандық. Оқушылар екі шарттың біріне бөлінді: дербес бейімделген оқыту деп аталатын электрондық оқу ортасы және дербес бейімделген оқу платформасын қолданбайтын оқу ортасы. Педагогикалық зерттеулердегі эксперименттік жұмыстың нәтижелерін сенімді бағалау үшін статистикалық әдістерді қолдану қажеттілігі қарастырылады, сондай-ақ практикалық мысалда екі статистикалық критерийді қолдану нәтижелері және оларды енгізу кезінде туындауы мүмкін қиындықтар талданады. Дербес бейімделген технологиялардың тиімділігін бағалау үшін Фишер критерийі мен Стьюденттің t критерийін қолдану жоспарланған болатын. Олар екі түрлі масштабқа негізделгендіктен таңдалды: реттік және өзара байланысты.

Түйінді сөздер: дербес оқыту, бейімдеп оқыту, электрондық оқыту ортасы, математика, тиімділік, Фишер критерийі, Стьюденттің t критерийі.

Introduction. In the last few decades, one of the main innovations has been the use of computers as interactive learning devices that adapt to the student based on the student's responses. In a world where education has traditionally been "universal for everyone," adaptive systems provided the opportunity to customize learning or personalize it.

Currently, personalized learning approaches are discussed in the scientific community mainly in the context of the development of distance learning technology, individualization, and differentiation of learning. Among foreign scientists, the works of Canales Cruz A., Pena-Ayala A. (development of a web-based education system focused on the learning needs of an individual student) [1, p. 1076], Worsley D., Fox E., Landzberg J., Papagiotas A. (personalization of high school students learning through shift groups) [2, p. 136], Wilson S., Liber O., Johnson M., Beauvoir P., Sharpies P., Milligan C. (design of personal learning environments) [3, p. 27], Martin M. (personalized learning as a means of professional development) [4, p. 112], A.A. Vlasenko (development of an adaptive distance learning system, creation of a student model for an adaptive learning system) [5, p. 165]. Such Russian scientists as E.Y.Bidaibekov [6, p. 88842], D.N.Isabayeva [7, p. 27], and N.Oshanova [8, p. 34], made a great contribution to the development of the information environment of training and applied ideas of personalization and individualization. V.V. Grinshkun [9, p. 89], G.B.Kamalova [10, p. 14] (informatization of secondary education, the effectiveness of knowledge informatization tools, modern information technologies of education), G.G. Erkibayeva (technology of individually differentiated learning based on homogeneous groups) [11, p. 1], I.O.Sayfurova (personalized approach as a basis for improving the methodology of teaching programming) [12, p. 72], G.Samigulina, A.S. Shayakhmetova (intelligent IT distance learning for people with disabilities) [13, p. 109], G.Bekmanova (personalized learning model in a mixed format in universities) [14, p. 668], etc.

Taking into account the individual needs of students, scientists of the Republic of Kazakhstan have proposed plans for the introduction of personalized learning using technological learning tools. However, only a limited number of educational institutions have implemented these tools and this is due to a lack of empirical understanding of the success, challenges, and characteristics of personalized technology-based learning.

Educational institutions offering an individual approach to learning were able to better connect with students, find ways to engage them, keep their attention, and help them benefit from their strengths.

One of the main goals of this study was to study whether a personalized learning system can be successfully used to improve competence in mathematics in secondary vocational education. Subsequent questions focused on participants' perceptions and levels of satisfaction with their learning experience, attitudes to mathematics, perceptions, and levels of satisfaction with their experience using the software.

Prior to this study, personalized adaptive learning was not used in an educational institution. The students were invited to participate in the study, which was conducted for about one month, after which the data collected from the learning environment were analyzed quantitatively. In particular, this study aimed to investigate whether a personalized adaptive learning experience is a promising resource for bridging the gap between learning progress.

Two variants of the electronic learning environment were used for this study:

1) the software presented the lessons in a linear model, which meant that the software did not adapt to the student's answers;

2) the program was the same software built on an adaptive platform that allows you to ask questions adapted to students based on their answers, which gives them an individual experience.

The purpose of this personalized learning-based version was to provide students with an individual approach to learning the course material, allowing them to focus on those specific actions that optimized their time to complete the task and further increased engagement.

Methods and Materials. One of the goals of this study was to identify the main differences in learning between personalized and non-personalized learning experiences. Another goal was to analyze the user experience to identify the main differences in student attitudes toward users and satisfaction between these different environments.

A personalized learning experience involves an individual approach to the student. This means that the teacher or program adapts to the needs and abilities of each student. For example, if a student manages to easily complete tasks, he is given more complex tasks, or if a student has difficulties with a certain topic, teachers change the teaching methodology and give more time to study this topic.

A non-personalized learning experience, on the other hand, applies the same approach to all students. Teachers follow unified programs and methods, regardless of the exact level of knowledge and abilities of students.

Highlighting the main differences between these two approaches, it can be noted that the personalized learning experience is more flexible and takes into account the characteristics of a particular student, which allows him to achieve higher learning results. The non-personalized learning experience, in turn, is more structured and is aimed at creating a uniform experience for all students, which ensures a more uniform learning outcome but does not always contribute to the maximum disclosure of the potential of each student.

Thus, the choice between personalized and non-personalized learning experiences depends on the goals and characteristics of each specific educational program, as well as on the individual needs and diversity of students.

A total of 103 first-year college students participated in this study (Table 1).

Table 1 – Age of students

Age of students	Middle age	Median age
15-17 years old	15,86 years old (SD = 0,97)	16 years old

The participants completed a general mathematics course at school, which means that they were introduced to basic algebra, which means they were not selected with honors or with an advanced level of training. Data from all participants, including matching scores before and after testing, were included in the analysis. The materials and equipment needed to complete this study included access to computer labs for classes and assessments before and after testing. We used two versions of the electronic curriculum, which were called:

- Personalized Adaptive Learning Platform (PALP) — as a condition for personalized learning;
- Non-Personalized Adaptive Learning Platform (NPALP) — as a control condition.

Participants were given a paper-based preliminary test assessment containing 25 multiple-choice questions to measure their prior knowledge of basic algebra. The questions were used to establish levels of prior knowledge regarding basic algebra. Each question in the preliminary test had a score of 1 for a correct answer and 0 for an incorrect answer. During the preliminary testing, it was possible to score a maximum of 25 points. The electronic content and themes on each platform were identical.

In this study, the learning environment was divided into three modules (Figure 1).

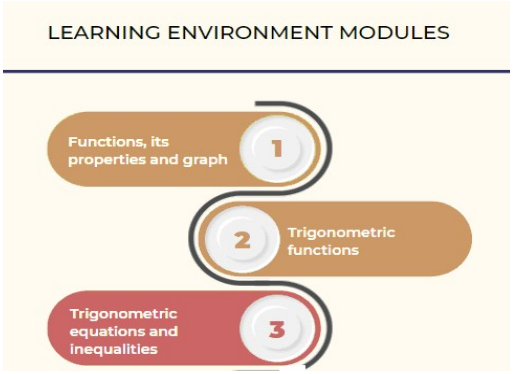

Figure 1. Learning environment modules

The NPALP condition consisted of a computer learning environment without a personalized component and contained multimedia content (i.e. short videos and embedded examples with tests) (Figures 2, 3). All students in this state passed the same lessons in the same sequential order, regardless of the results of the embedded tasks and tests.

Figure 2. Screenshot of a math lesson in NPALP conditions

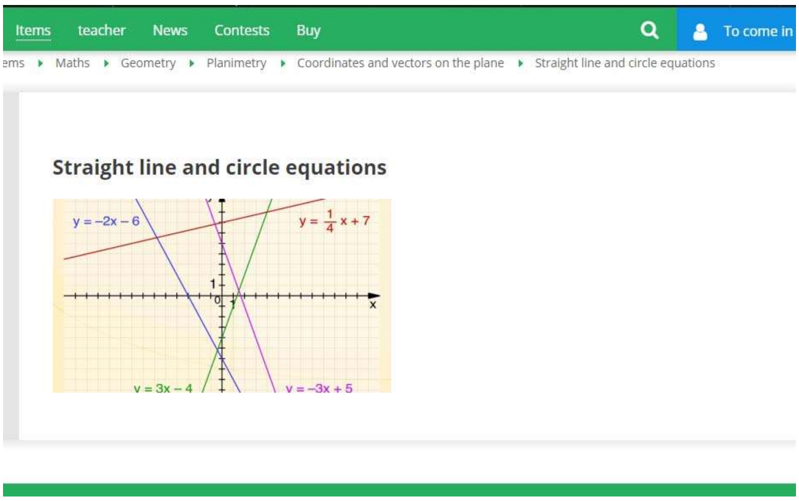

Figure 3. Screenshot of the graphics used in NPALP conditions

The computer learning environment on the platform of personalized adaptive learning provided the same content as the NPALP group (Figures 4, 5,6).

However, in this version, the learning environment was adaptive and personalized, as a profile was created for each student. The profile of each student was supplemented with evaluation data as the new module on the platform was completed. Using this data, the student's profile was constantly updated and analyzed using data from other students in the platform repository. Then recommendations were given on the appropriate module based on this data. Teachers and students had access to this data.

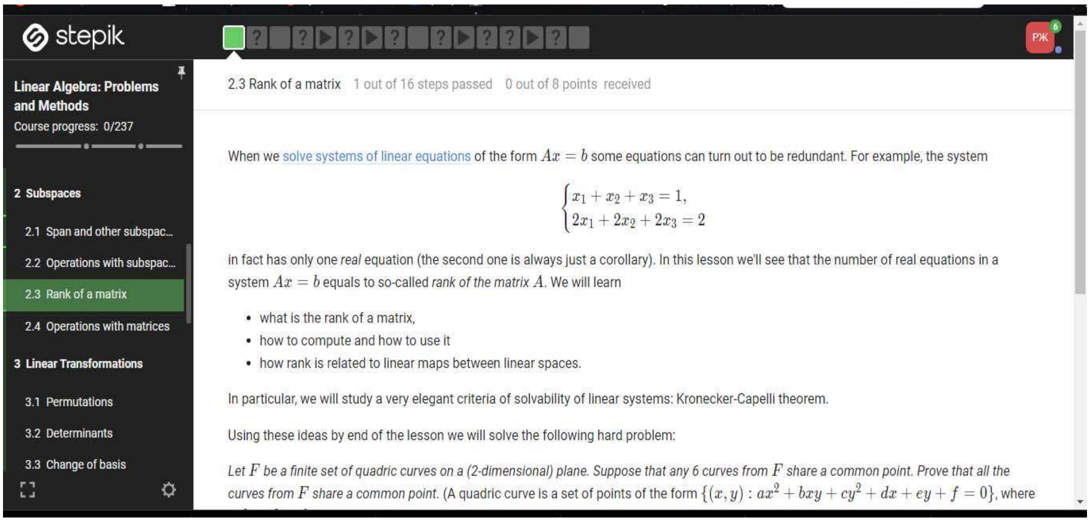

Figure 4. Screenshot of the task in the PALP condition

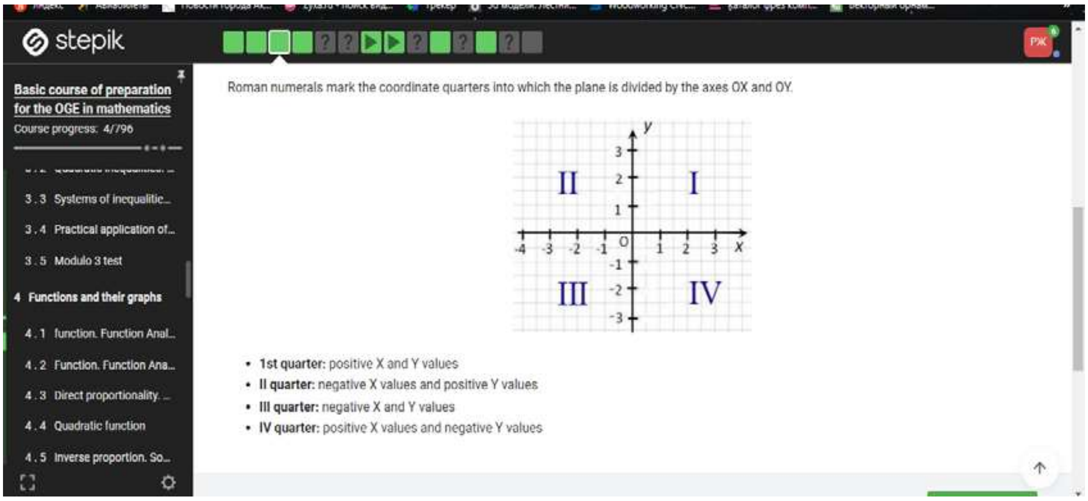

Figure 5. Screenshot of PALP with progress bar and workspace

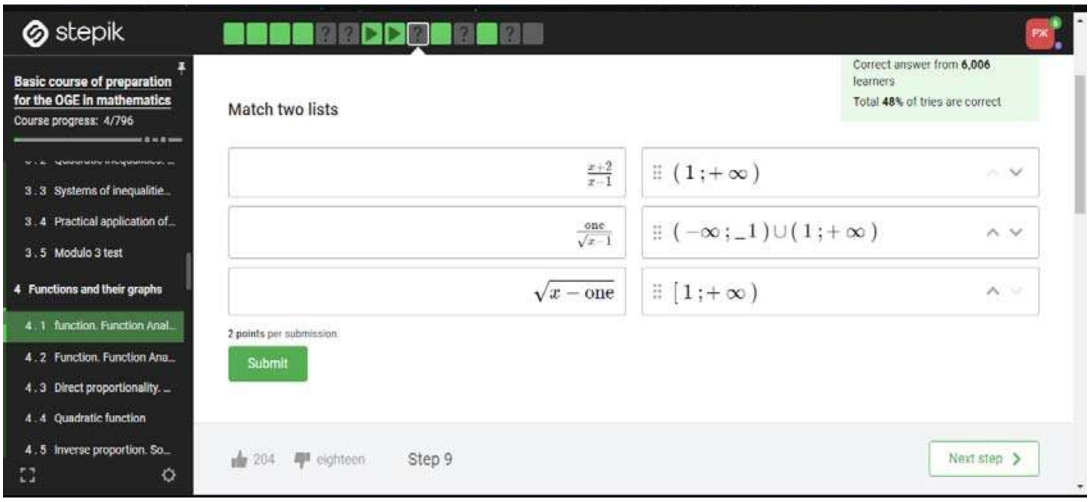

Figure 6. Screenshot of PALP tasks

After the training experiment, a test consisting of 10 questions on basic algebra was conducted. The questions asked after testing were similar to the questions asked before testing, but used different numerical values and were presented in a different order. Correct answers were given a score of 1, and incorrect answers were given 0 points.

The course consisted of three modules, and students had one week to complete each module. The modules were divided into several sub-lessons.

Participants participated in the study for four weeks. They performed tasks related to basic algebra and worked on them until completion. After each weekly assignment, teachers viewed the data that had been filled in both personalized learning and non-personalized learning platforms. After four weeks, a post-test evaluation was performed.

Results. To test the theoretical propositions put forward, a pedagogical experiment was conducted with two groups of students: experimental (50 students) and control (53 students). Two statistical criteria were planned to be used to evaluate the effectiveness of adaptive personalized technologies: the Fisher criterion and the Student's t-criterion. They were chosen because they are based on two different types of scales: ordinal and relationships. To work with the scale of relations, which took into account the results of solving tests by the number of correct answers about the number of students who gave such several correct answers, the Student's t-criterion is used. Fischer's criterion, on the contrary, is designed for an ordinal scale, which takes into account the number of students who confirmed and did not confirm the availability of the necessary amount of knowledge. When checking the level of knowledge through testing in the experimental and control groups before and after the experiment, the following data were obtained (Table 2).

Table 2 – Results of measurements of the level of knowledge in the control and experimental groups before and after the experiment

The number of correct answers during testing	The number of students who have passed such a number of correct answers during testing			
	before the experiment		after the end of the experiment	
	control group	experimental group	control group	experimental group
Number of students, person	53	50	53	50
Average number of correct answers	10,6	10,3	12,8	17,5

It should be noted that the calculation of the average number of correct answers as a calculation of the average score for a group cannot be correct for making conclusions within the framework of pedagogical science. In our work, this only allowed us to assume that the changes received may be positive.

For the calculations carried out, the significance level p = 0.05 was determined, which meant the probability of an error consisting in the rejection (non-acceptance) of the null hypothesis, i.e. the probability that the differences were considered significant, and they are random, in other words, the probability of error was not more than 5%.

To correctly calculate the Fisher criterion, we needed to process the data obtained and make a distribution in the resulting sample according to only two criteria. We used the division into "coped/failed with the task" based on "coped" — 16 or more correct answers in the test; less than 16 correct answers — "failed". The critical values of the Fisher criterion and other statistical criteria are presented in publicly available distribution tables, so there is no need to calculate them additionally, we will use the available data. According to the table of critical values of the Fisher criterion for our sample, the critical value is 1.64, i.e. if the obtained criterion is less than this value, then the differences between the two samples are insignificant, if more, the samples differ significantly.

As a result of the calculations, the following empirical values of the Fisher criterion were obtained (Table 3).

With the critical value of the Fisher criterion equal to 1.64, we compared the results obtained in the experimental and control groups before and after the experiment. As can be seen from the calculated data, before the experiment, the experimental and control groups had no significant differences, which was necessary for the reliability of the evaluation of the results of the experiment.

However, the Fisher criterion has several limitations and is used to calculate the differences between two samples only if the results are divided into two groups. Therefore, it seems necessary to check the difference in the samples obtained additionally by the Student's t-criterion. To apply the Student's t-test, the following conditions must be met: the measurement can be carried out in a scale of intervals and ratios, and the compared samples must be distributed according to the normal law. The T-criterion is calculated for related (dependent) and unrelated (independent) samples.

Table 3 – Empirical values of the Fisher criterion

Group	The control group before the experiment	Experimental group before the start of the experiment	The control group after the end of the experiment	Experimental group after the end of the experiment
The control group before the experiment	0	0,05	0,84	2,79
Experimental group before the start of the experiment	0,05	0	0,79	2,72
The control group after the end of the experiment	0,84	0,79	0	2,41
Experimental group after the end of the experiment	2,79	2,72	2,41	0

In our experiment, related samples are samples of results obtained within the same group (control or experimental) before and after the experiment. The results obtained in different groups are independent (comparison of the results in the control and experimental groups before the experiment and comparison of the results obtained in the control and experimental groups after the experiment).

The results of the Student's t-test calculation are presented in Table 4. The critical values for the confidence probability of 0.95 are indicated in parentheses when comparing the specified characteristics of the groups.

Table 4 – Results of Student's t-test calculation

Group	The control group before the experiment	Experimental group before the start of the experiment	The control group after the end of the experiment	Experimental group after the end of the experiment
The control group before the experiment	0	0,20 (1,98)	4,03 (2,00)	—
Experimental group before the start of the experiment	0,20 (1,98)	0	—	3,75 (2,00)
The control group after the end of the experiment	4,03 (2,00)	—	0	3,92 (1,98)
Experimental group after the end of the experiment	—	3,75 (2,00)	3,92 (1,98)	0

When analyzing the data obtained, it is difficult to draw an unambiguous conclusion in favor of the results of the experimental group, since according to the calculated criteria, more significant differences are observed within the control group before and after the experiment, although the critical value is greater than when comparing the results between the groups. At the same time, all the values obtained, except for the comparison of groups before the experiment, exceed the critical values, which indicates a significant difference.

For a reliable comparison of the data obtained, we additionally used the criterion χ2 (chi-square). This statistical criterion is also intended to compare two statistical samples.

Like other statistical criteria, the criterion χ2 (chi-squared) has limitations: it is applicable provided that for any value of the score in any of the compared samples at least five of its members received this score, i.e. ni ≥5, mi ≥ 5, i = 1, 2, ..., L. In addition, L must be at least three. Due to these limitations, we were forced to slightly change the table, combining the original data into groups according to the number of correct answers: 1-5, 6-10, 11-15, 16-20, and 21-25. With the presented samples, the critical value of the criterion χ2 for the significance level α = 0.05 is 11.07. The results of the calculation of this criterion are given in Table 5.

Table 5 – The results of the calculation of the criterion χ2 (chi-square)

Group	The control group before the experiment	Experimental group before the start of the experiment	The control group after the end of the experiment	Experimental group after the end of the experiment
The control group before the experiment	0	2,48	7,61	—
Experimental group before the start of the experiment	2,48	0	—	32,20
The control group after the end of the experiment	7,61	—	0	13,50
Experimental group after the end of the experiment	0	2,48	7,61	—

The above-calculated data convincingly show the presence of significant differences between the groups after the end of the experiment and also indicate significant differences in the results within the experimental group before and after the end of the experiment.

Thus, we see that a balanced approach to the use of statistical methods is necessary for pedagogical research. They should be applied to take into account the available data, the limitations of various statistical criteria should be taken into account, and actions should be taken (whenever possible) to bring the available data in line with the requirements of the relevant statistical criteria. In addition, the above calculation examples demonstrated that using any one criterion, it is not always possible to draw correct and unambiguous conclusions about the results of the experiment. More reliable is the use of various criteria designed for different types of scales and different sensitivities.

Conclusions. The purpose of this study was to investigate the extent of the role of personalized adaptive learning in math acquisition. The main conclusion in the results showed that participants who were presented with a personalized adaptive learning experience perceived a higher level of satisfaction with the personalized nature of the learning environment than their overall experience with the program. The conducted arithmetic calculations and calculations based on three statistical criteria proved that the use of personalized adaptive learning experience in mathematics is justified. The introduction of personalized adaptive technologies into the educational process brings positive results, more significant than when using personalized adaptive technologies in the educational process

As personalized adaptive learning systems continue to evolve along with technology, and research continues to identify ways to maximize student achievement, it is important to note the social aspect of learning and how this is lacking in technology-based learning. In addition, understanding the audience and their needs is the first step in developing a successful learning experience. To get the maximum learning experience, it is important to take another step forward and understand the individual needs of each student in the classroom.

As personalized learning becomes more common in education, researchers should continue to explore the relationship between the social aspect of learning and technology, the importance of sound usability principles in the development of educational content, and the impact these factors can have on student achievement and learning.

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Мақалада дуальды оқытудың ерекшеліктері мен артықшылықтары педагогикалық университеттің қазіргі жағдайында кәсіптік оқыту бакалаврларын даярлау технологиясы ретінде қарастырылады. Мақалада педагогикалық университеттің қазіргі жағдайында кәсіптік оқыту бакалаврларын даярлау технологиясы ретінде дуальды оқытудың артықшылықтары мен кемшіліктері қарастырылған. Бүгінгі таңда «дуальды оқыту» тақырыбы педагогикалық алаңда өте өзекті мәселе болып отыр. Қазіргі Қазақстанда дуальды оқыту жүйесіне ерекше қызығушылық кездейсоқ емес. Өйткені кәсіптік білім беру ешқашан өндірістік сектормен байланыссыз ойластырылған емес. Авторлар басқа елдерде дуальды оқыту қалай жүзеге асырылатынын, сондай-ақ Қазақстанда дуальды оқыту моделі қалай енгізілетінін сипаттайды. Дуалды оқыту элементтерін енгізуді сипаттау үшін мысал ретінде Ә. Марғұлан атындағы Павлодар педагогикалық университетінің дуалды оқыту жүйесі ұсынылған. Жалпы, ЖОО-да дуальды оқыту туралы жалпы ереже, оқытушы-тәлімгердің негізгі функциялары сипатталған, бағалау саясаты, нормативтік-құқықтық және оқу-әдістемелік құжаттаманың ерекшеліктері ұсынылған. Мақалада бұл технология орта кәсіптік білім беру жүйесі үшін педагогикалық кадрларды даярлау бойынша педагогикалық университеттің алдына қойылған міндеттерді шешуге мүмкіндік беретіні көрсетілген. Дуалды білім беру жүйесі қазіргі нарықтық жағдайында әртүрлі қызмет салаларындағы кәсіпорындарға сұранысқа ие жоғары білікті мамандарды оқытуға мүмкіндік беретін тиімді және икемді механизм болып табылады.

Түйінді сөздер: дуальды оқыту, дуальды оқытулың моделі, оқыту процесі, кәсіптік білім беру, өндірістік кәсіпорындар

РЕАЛИЗАЦИЯ ДУАЛЬНОГО ОБУЧЕНИЯ В ПЕДАГОГИЧЕСКОМ ВУЗЕ

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