DOI: 10.37943/HOJH1901

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EXPERIMENTAL VERIFICATION OF THE EFFECTIVENESS OF TEACHING METHODS USING ADAPTIVE MATHEMATICS TEACHING

Abstract: The article presents theoretical and empirical results of the study of the advantages of adaptive learning. The practice of creating and organizing adaptive learning for students using the «Moodle» platform is considered, and the results of the application of the adaptive learning model in the preparation of first and second-year students in secondary vocational education are presented. The article presents the results of the input, intermediate, and control measures that the control and experimental groups took. The results are presented both in tabular form, indicating the individual achievements of students in points, and in the form of bar charts. Based on the data obtained, it is possible to quantify the progress in the study of the discipline of mathematics and to compare the individual achievements of students. Thanks to a detailed assessment of various aspects of the results of experimental tasks, it is possible to identify with high accuracy the strengths and weaknesses in the preparation of each of the students, to give individual recommendations for further training. The verification of the validity of the coincidences and differences in the characteristics of the control and experimental groups was carried out by using the Kramer–Welch statistical criterion, which demonstrated, on the one hand, the equality of the training levels of the control and experimental groups at the beginning of the pedagogical experiment under consideration, and on the other hand, the significance of the difference in the level of training at the end of the training process through the application of the proposed methodology.

Keywords: secondary education, mathematics, adapted personalized learning, pedagogical experiment, motivation, Kramer–Welch statistical criterion

Introduction

At the present stage of secondary vocational education, the main task of teachers is to comprehensively promote the formation and development of human individuality, and the main principle of teaching is attention to the inner world of students, their interests, and

Scientific Journal of Astana IT University
ISSN (P): 2707-9031 ISSN (E): 2707-904X
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needs. The problem of providing new approaches to the organization of pedagogical activity, which focuses on the development and realization of all the essential forces of the student, is brought to the fore. Teaching teams of secondary professional educational organizations are in search of more effective forms, approaches, and technologies for working with students. The authors conducted methodological work on the topic “The development of an adaptive personalized educational environment [1] through the integration of pedagogical technologies in mathematics lessons”.

American psychologist and behaviorist B. F. Skinner who is considered to be the founder of personalized (adaptive) learning, stated in his book “The Technology of Teaching” that one of the effective ways of teaching is dividing material into small parts and adapting learning tasks to the current level of students’ knowledge [2]. Elements of adaptive learning were reflected in the works of Hermann Astleitner and John M. Keller [3], B. Bloom [4], Volodymyr I. Bondar and Iryna M. Shaposhnikova [5], Lee J. Cronbach [6], Harold E. Pashler [7] and others. With the development of information technologies, the educational process has shifted online. Among the tools for implementation of adaptive learning in HEIs a learning management system is noted. One of such systems that gained popularity in universities due to its flexibility and free distribution is Moodle LMS. That makes the question of implementation of adaptivity elements in Moodle relevant and many researchers have paid attention to this topic in the recent decade among whom there are Gökhan Akçapınar [8], Valentina Caputi and Antonio Garrido [9], Aleksejs Jurenoks [10], Vladislav Kukartsev, Ekaterina Chzhan, Vadim Tynchenko, Oleslav Antamoshkin and Alena Stupina [11], Linawati, NMAE Dewi Wirastuti and G. Sukadarmika [12], S. Nikitopoulou, E. Kalabokis, Z. Asimakopoulos and A. Apergi [13], Herman Dwi Surjono [14] and others.

The ongoing processes in the field of education in the world and Kazakhstan at the present stage imply the demand for the training of highly qualified specialists of various profiles, who should not only receive the sum of certain knowledge but also be able to apply them in a specific practical situation. Some teachers use the concept of adaptive personalized learning as a learning technology based on the construction of an individual learning trajectory for the student, taking into account his current knowledge, abilities, motivation, and others. One of the varieties of differentiated learning is adaptive learning, which adapts to the educational needs of groups of students. Adaptive learning combines both the advantages of micro learning and the positive effect of training intervals (because the trajectory itself is based on the principles of micro learning). Micro learning is an approach in which a student receives new information in small portions, and then repeats it regularly. Micro learning is more common in the practice of adaptive learning. This is due to the following circumstances: – the opportunity to see the effect of learning. Due to the correct measurements at the beginning and the end of the training course, and sometimes in the middle, we can see what has changed in the knowledge of students. By adding a deferred knowledge check here, for example, after two or three months of the educational process with the use of new knowledge, you can understand how the information has kept up, and how actively it is being used. And if combined with the results of regular assessment of students, it turns out to be almost an ideal system.

According to the observation of German scientist Herman Ebbinghaus, micro learning can be much more effective, since according to his research, students forget more than 50% of new information 20 minutes after the end of the lesson. After nine hours, no more than 40% of what is learned remains in memory, and after a month this figure is reduced to 24% if the student does not repeat the information. Ebbinghaus recorded the results of his observations on a graph, which was called the “forgetting curve”. In 1991, the Ebbinghaus experiment was repeated by scientists from Germany. And in 2015, researchers from the Netherlands were able to reproduce the forgetting curve [15].

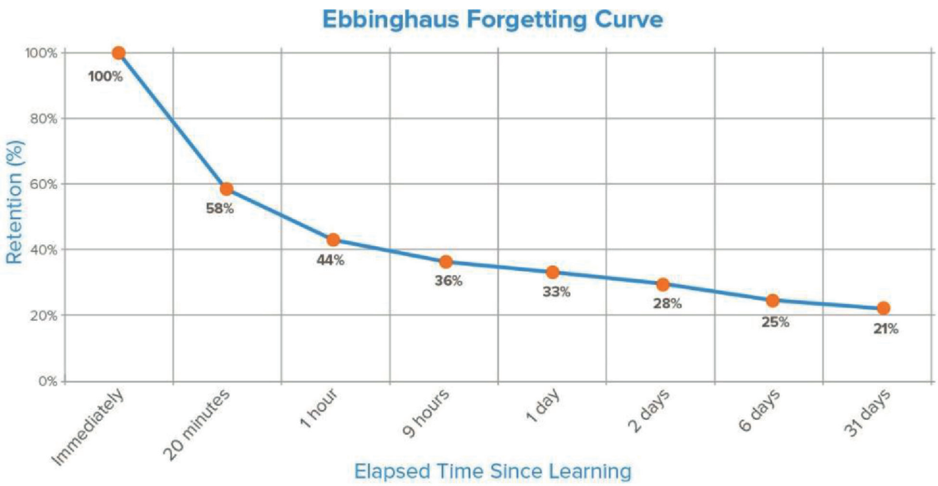

Figure 1. Ebbinghaus forgetting curve

Repetition of information at certain intervals helps to cope with forgetting. Such interval repetitions are the basis of micro-training.

Researchers mainly consider adaptive learning as part of the introduction of distance learning technologies into the college's educational process. Some of them point to the features of the introduction of adaptive learning, highlighting micro-learning [16] as a type of organization of the educational process in an electronically distributed college, while most colleges use LMS Moodle for various releases.

Materials and methods

The authors have developed and put into trial operation a model of the information educational environment of the college, which combines the capabilities of the distance learning system "Moodle" and the author's experience in the development and application of adaptive training courses. The project aims to develop an adaptive program that supports active individual training in various disciplines by combining the capabilities of adaptive learning systems. The configured technological environment and the educational model of the adaptive learning system make it possible to use most of the techniques used in traditional forms of learning. These include various versions of lectures with interactive feedback, practices, and seminars with the effect of "presence". To partially eliminate these problems, the possibility of placing courses in the form of SCORM packages in the LMS "Moodle" [17] was chosen, which can have their interactive scenarios, as well as algorithms for protecting materials. At the same time, it has become possible to replicate the best courses for almost any platform of the distance learning system.

In the second semester of 2022, experimental training was conducted for 1st and 2nd-year students of Aktobe Higher Polytechnic College for the specialty "Information Systems" using the described methodology and without it. As a didactic instrument of the experiment, the author's adaptive course "Mathematics" [18] was created, and placed in the form of a course in a distance learning environment (see fig.2).

Scientific Journal of Astana IT University
ISSN (P): 2707-9031 ISSN (E): 2707-904X
VOLUME 10, JUNE 2022

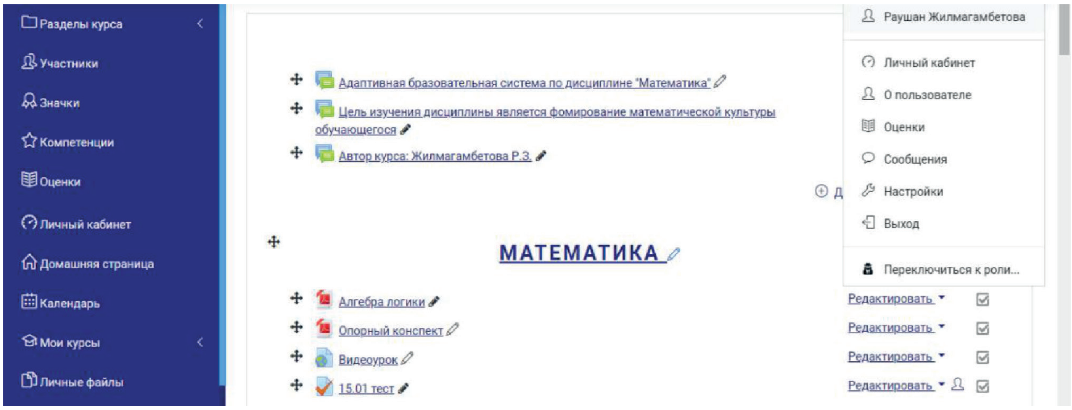

Figure 2 – Title screen of the adapted course

It is known that the typical task of data analysis in pedagogical research [19] is to establish coincidences or differences in the characteristics of the experimental and control groups. In this regard, we formulate statistical hypotheses:

– the hypothesis of the absence of differences between experimental training according to this method and traditional training (the so-called null hypothesis);

– the hypothesis of the significance of differences (the so-called alternative hypothesis).

If the obtained empirical value of the criterion turns out to be less than or equal to the critical one, then the null hypothesis is accepted – it is assumed that at a given level of significance, the characteristics of the experimental and control groups coincide. Otherwise, if the empirical value of the criterion turns out to be strictly greater than the critical one, then the null hypothesis is rejected and an alternative hypothesis is accepted – the characteristics of the experimental and control groups are considered different with the reliability of differences. Thus, if a = 0.05 and an alternative hypothesis is accepted, then the reliability of the differences is 0.95 or 95%.

Results and discussion

The experiment involved N=25 students of the experimental group (1st year) and M=30 people of the control group (2nd year). The control group studied the subject according to the classical methodology of secondary vocational education, that is, lecture material was read, and after that practical and seminar classes, and laboratory work was conducted. Students could use the course manuals, use the library, and additional materials. The experimental group of students was registered in the distance learning system and from the first lecture had the opportunity to access all the adaptive course material – tests, control tasks, interactive workshops, video clips. This allowed them to work independently with adaptive information, while seeing their achievements, controlling their level of assimilation on each topic, and lesson [20].

The initial state of the control and experimental groups was measured by testing at the beginning of training. For this purpose, the course "Mathematics" was used, which the students took in the 1st year. The difference in the groups was that the control group of students studied this subject relatively recently, and the experimental group took it more than a year ago.

The total number of test questions was 20. Those students who used the interface of the testing module for the first time received the opportunity of an additional attempt. To assess the success of passing the test, a dichotomous scale was used (passed/failed), that is, with a result of 75% or more correct answers, the result was recognized as successful.

Input control results (see fig.3):

1. The total number of tests (sample) was 20, the students of the experimental group successfully coped with the test – 16 out of 30 (53%), the control group – 10 out of 25 (40%).

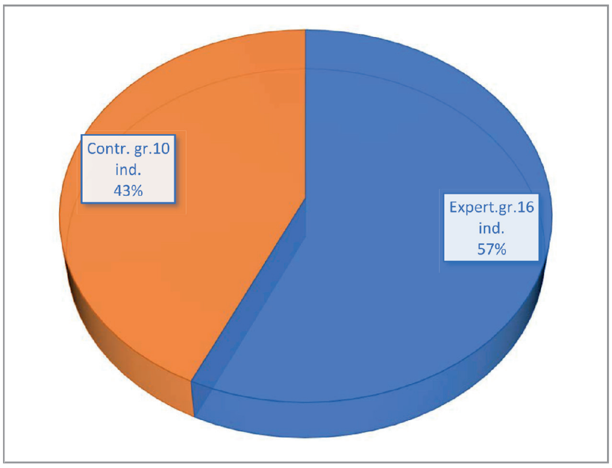

Figure 3. Comparison of the results of the input control of the control and experimental groups

The ratio in favor of the control group shows that the 2nd year students studied this subject was more than a year ago and the educational material was thoroughly forgotten.

During the experimental training of a group of 2nd-year students, the sample of answered control tests of the experimental group was 48, on average 14 attempts to pass control tests on lecture topics, that is, about 2 attempts on one topic. The results of the trial tests were not recorded, but statistical data on the number of attempts, time parameters for studying individual topics, and other statistics were collected using the Moodle distance learning system.

The students of the control group took the test in the same order as the students of the experimental group. According to the results of the tests, 4 students were unable to pass the test even on the second attempt.

At the end of the training, all students of the control and experimental groups passed the control on the test materials. The results of the control and experimental groups were summarized in Table 1, Figure 4 shows a graphical analysis of these results [21].

Table 1. Results of measurements of the level of knowledge in the control and experimental groups before and after the experiment on an ordinal scale

Level of knowledge	Control group before the experiment (ind.)	The experimental group before the start of the experiment (ind.)	The control group after the end of the experiment (ind.)	Experimental group after the end of the experiment (ind.)
Low	4	1	4	0
Average	10	14	7	6
High	16	10	19	19

Table 1 is constructed by introducing ranges of values for the number of correctly solved problems, getting into which was considered to correspond to the levels of knowledge. Note that with such a transition from the scale of relations to the ordinal scale, part of the information is lost – in the example under consideration, several different numbers of correctly solved problems correspond to the same level of knowledge. Consequently, it becomes more

Scientific Journal of Astana IT University
ISSN (P): 2707-9031 ISSN (E): 2707-904X
VOLUME 10, JUNE 2022

difficult to establish coincidences and differences in the characteristics of the studied objects. Therefore, it is recommended to use all available information, that is, if a scale of relations was used during measurements, then the data should be processed on this scale.

However, in many cases, in practice, measurements are made on an ordinal scale (for example, knowledge is evaluated in points), and the results of the experiment immediately have the form of a table like a table 2. Therefore, for the tasks of analyzing the results of measurements made in the scale of relations, we will assume that the experimental data have the form of table 1, and for the tasks of analyzing the results [22] of measurements made in the scale of order, we will assume that the experimental data have the form of table 2.

Table 2. Results of measurements of the level of knowledge in the control and experimental groups before and after the experiment on an ordinal scale

Level of knowledge	Control group before the experiment (ind.)%	The experimental group before the start of the experiment (ind.)%	The control group after the end of the experiment (ind.)%	Experimental group after the end of the experiment (ind.)%
Low	13	4	13	0
Average	33	56	23	24
High	53	40	63	76

Thus, descriptive statistics, firstly, allow us to present the results of a pedagogical experiment in a compact and informative form, which makes it possible to conduct a qualitative analysis of the objects under study. Secondly, several indicators of descriptive statistics are used in quantitative analysis.

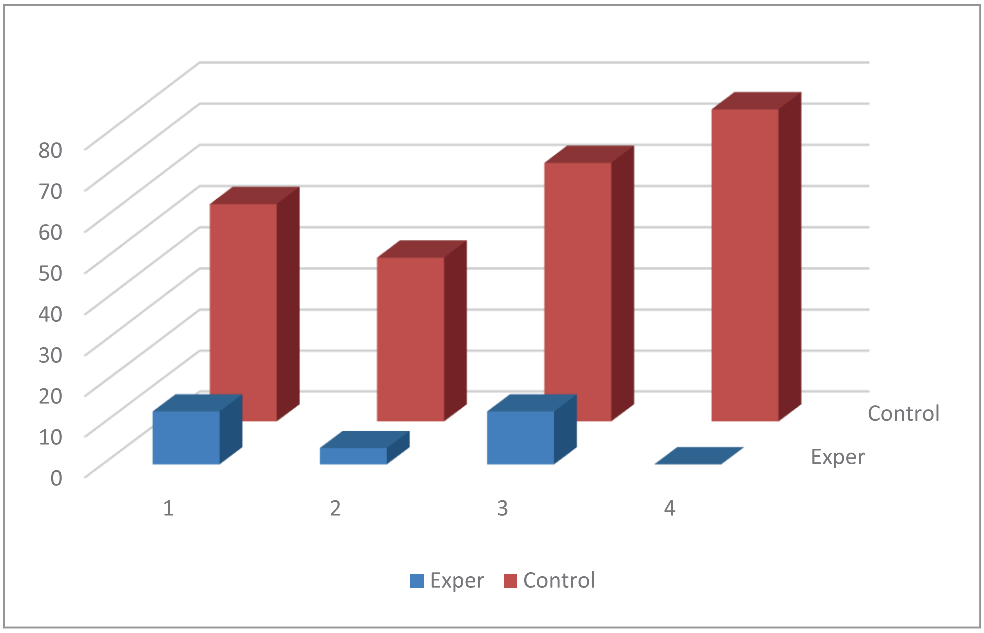

Figure 4. Comparison of the training levels of groups

Having completed the review of the indicators of descriptive statistics, we will proceed to the general methodology for determining the degree of reliability of coincidences and differences, and then describe its application first for data measured in the scale of relations, and then for data measured in the ordinal scale.

Table 3 below shows the visualization of the results of measuring the level of knowledge in the control and experimental groups before and after the experiment on the scale of relations.

Table 3. Results of measurements of the level of knowledge in the control and experimental groups before and after the experiment on the scale of relations

Control group (the number of correctly solved problems before the experiment)	The experimental group (the number of correctly solved problems before the start of the experiment)	Control group (the number of correctly solved tasks after the end of the experiment)	The experimental group (the number of correctly solved problems after the end of the experiment)
16	12	18	15
18	12	20	16
13	11	14	14
14	15	16	19
15	14	16	17
19	20	20	20
20	18	20	20
17	19	18	20
13	13	15	16
11	9	13	13
20	11	20	14
19	15	20	18
13	14	13	19
14	16	15	18
16	18	16	20
9	11	10	15
18	20	19	20
7	17	10	19
12	11	13	16
16	12	17	18
7	13	10	15
13	19	14	20
5	20	10	20
18	17	19	19
19	15	20	18
17	-	18	-
20	-	20	-
15	-	16	-
17	-	18	-
18	-	19	-

The level of knowledge testing consisting of 20 questions was used as an input control task. The task of determining the initial level of knowledge and skills in mathematics was evaluated according to a twenty-point system, and the overall test results were taken into account. The results of the input testing are recorded. Students of the experimental group, who will be trained according to the experimental curriculum, are given individual recommendations for improving skills and abilities. Further training is conducted by analyzing with students the step-by-step study of the materials of the experimental educational and methodological complex. Students can freely contact the teacher for advice. Students also have access to an adapted learning platform, fully implemented by an experienced expert developer of the module.

The measurement carried out by the authors is to determine the level of knowledge by conducting a test that includes 20 tasks. Let's assume that the characteristic of a student (feature) is the number of correctly solved tasks. The results of measurements of the level of knowledge in the control and experimental groups before and after the experiment are shown in Table

Scientific Journal of Astana IT University
ISSN (P): 2707-9031 ISSN (E): 2707-904X
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1, the rows of which correspond to the members of the groups (individual students). For example, the first student of the control group correctly solved 15 tasks before the experiment began, and the third participant of the experimental group correctly solved 12 tasks after the experiment ended, etc. The results of the experiment can also be obtained in an ordinal scale (or transferred from the scale of relations to an ordinal scale), so let's consider the representation of data in an ordinal scale.

We will check the validity of the coincidences and differences in the characteristics of the control and experimental groups. To decide which of the hypotheses (null or alternative) should be accepted, we use the Kramer-Welch statistical criterion, since experimental data are measured on a scale of relations. The Kramer–Welch criterion is designed to test the hypothesis that the mathematical expectations of two samples are equal. The significance level is assumed to be equal to 0.05, which is acceptable for pedagogical research.

The empirical value of this criterion is calculated based on information about the volumes of N and M samples x and y, sample averages x and y, and sample variances D_x and D_y of the compared samples according to the following formula:

$$\mathrm{T}_{emp} = \frac{\sqrt{M \cdot N}|\bar{x}-\bar{y}|}{\sqrt{M \cdot D_x + N \cdot D_y}} \tag{1}$$

where, M and N – are the numbers of control and experimental groups, respectively,

$\bar{x}$ and $\bar{y}$ – the average value of the assessment in the control and experimental groups, respectively, was calculated by the formulas

$$\bar{x} = \frac{1}{M}\sum_{i=1}^{M} x_i \quad \text{and} \quad \bar{y} = \frac{1}{N}\sum_{i=1}^{N} y_i. \tag{2, 3}$$

D_x and D_y – sample variances of estimates in the control and experimental groups, respectively, calculated by the formulas

$$D_x = \frac{1}{M-1}\sum_{i=1}^{M}(x_i - \bar{x}) \tag{4}$$

and

$$D_y = \frac{1}{N-1}\sum_{i=1}^{N}(y_i - \bar{y}) \tag{5}$$

Here are the calculation results for the data obtained during the input control. $M = 25$, $N = 25$, $\overline{x_{ex}} = 2{,}285$, $\overline{y_{ex}} = 2{,}305$, $D_x = 1{,}322$ and $D_y = 1{,}383$.

$$T_{emp} = \frac{\sqrt{25 \cdot 25}|2{,}285 - 2{,}305|}{\sqrt{25 \cdot 1{,}322 + 25 \cdot 1{,}383}} = 0{,}085.$$

The algorithm for determining the reliability of coincidences and differences in the characteristics of the compared samples for experimental data measured in the ratio scale using the Kramer Welch criterion is as follows:

1. Calculate the T_{emp} empirical value of the Kramer–Welch criterion for the compared samples using the formula (1).

2. Compare this value with the critical value $\mathrm{T}_{0.05} = 1{,}96$: if $\mathrm{T}_{emp} \leq 1{,}96$, then to conclude: "the characteristics of the compared samples coincide at a significance level of 0.05"; if $\mathrm{T}_{emp} > 1{,}96$, then to conclude "the reliability of the differences in the characteristics of the compared samples is 95%."

As an example, we apply the algorithm for the data from Table 1.

To do this, let's first compare the numbers of correctly solved problems in the control and experimental groups before the experiment. We calculate the value by the formula (1)

$T_{emp} = 0{,}085 < 1{,}96$. Therefore, the hypothesis about the coincidence of the characteristics of the control and experimental groups before the experiment is accepted at a significance level of 0.05. Now let's compare the characteristics of the control and experimental groups after the end of the experiment. We calculate the value by the formula (1) $T_{emp} = 2{,}36 > 1{,}96$. Consequently, the reliability of the differences in the characteristics of the control and experimental groups after the end of the experiment is 95%.

So, the initial (before the start of the experiment) states of the experimental and control groups coincide, and the final (after the end of the experiment) – differ. Therefore, it can be concluded that the effect of changes is due to the use of experimental teaching methods.

Conclusions

Based on the results of the pedagogical experiment, the following conclusions can be drawn:

1. The methodology of teaching the discipline "Mathematics" based on the created adaptive course in the distance learning environment is in principle applicable to the teaching of any other discipline.
2. The results of experimental training using this method revealed a statistically significant difference in the characteristics of the control and experimental groups at each level of training.
3. The conducted survey of students confirmed the positive attitude of students to adaptive forms of learning.
4. The analysis of the scientific activity of students confirmed the increase in the interest of students of the experimental group in scientific work.

Thus, the conducted pedagogical experiment on the use of teaching methods of the adaptive course "Mathematics" showed that the forms of micro-education have a positive effect on all aspects of educational activity, increase students' motivation, and a positive attitude to knowledge acquisition, interest in scientific activity. At the same time, an independent methodology for determining the levels of learning demonstrated a statistically significant increase in this indicator in the experimental group.

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