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The Role of Adaptive Personalized Technologies in the Learning Process:

Stepik as a Tool for Teaching Mathematics

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ABSTRACT

This article is devoted to the development of an adaptive personalized online course in mathematics for students, which was implemented on the Stepik platform. The authors discuss a non-linear approach to online learning that adapts to the needs of the student as they progress through the course content, which leads to an individual learner's experience based on prior knowledge. Within the framework of this article, the authors consider the experience of Aktobe Higher Polytechnic College in the task of implementing an adaptive personalized online course, and also offer specific methods and technologies. For this reason, the authors are exploring Stepik adaptive personalized learning software as an educational platform and designer of open online courses and interactive training lessons, using videos, tests, and various tasks with automatic verification and instant feedback.

KEYWORDS

Adaptive Personalization of Learning, Electronic Course in Mathematics, Integration of Elements, Mixed Learning Format

INTRODUCTION

Today, students are faced with a vast flow of information. The personal qualities of each individual, and accordingly, the degree of assimilation of the material is different. At the same time, various external factors can influence the learning process. The creation, and application, of an intelligent adaptive platform will solve the problems associated with the individualization of the education process.

Bloom (1984) describes a phenomenon known as two sigmas (two curves of the normal distribution of student results), where a student, trained individually, according to an individual program, showed results 98% higher than a control group trained by standard methods. Peng et al. (2019) discuss that, in 2012, adaptive personalized learning was implemented by the World School Council in London in several types of educational systems, such as adaptive hypermedia, intelligent

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learning systems, computerized adaptive tests, and computer pedagogical agents. The method has also been used by the University of Colorado since 2012.

The purpose of this study is to conduct an experiment with students using an adaptive personalized learning system and find out the impact of such methods on student learning achievement. The Adaptive Approach to College Mathematics Teaching is a methodological approach that allows the teaching of mathematics to be adapted to learning levels, thinking styles, and leading modalities to ensure a sustainable quality of learning outcomes. The results obtained allow teachers to gain a clear understanding of adaptive personalized learning and provide them with a tool to take into account and provide implementation for the individual characteristics and capabilities of students, as well as serve as a guide for future relevant research and practice.

The authors conducted experimental work on the development of an electronic personalized adaptive training course based on Stepik in the discipline of mathematics for students in the first year of study in the area of training information systems at Aktobe Higher Polytechnic College. To conduct this study, the following research questions will be considered:

1. What adaptive platforms are used in foreign and domestic education systems?
2. How does one effectively apply the adaptive personalized learning system Stepik in mathematics education?
3. How have student academic outcomes improved as a result of using this adaptive personalized learning platform?

LITERATURE REVIEW

Zotova et al. (2021) discuss the perception of adaptive learning as one of the key trends in the digital transformation of education, which was the result of a tectonic shift in the scientific analysis of adaptive learning problems in the mid-2000s. As a result, in 2003, about a hundred articles on the subject of "adaptive learning & education" were registered in the Scopus database. Then, in 2017, about 600 were already registered (note that in 1997 there were less than 20). Bond et al. (2018) discuss the beginning of the emergence of courses, in the mid-90s, in various disciplines, more often language, mathematics, and physics, in which certain mechanisms of adaptive learning were implemented. Morze et al. (2021) discuss the implementation of adaptive learning systems in the educational process of higher education in terms of scope, type of adaptive learning, functional purpose, integration with existing learning management systems, and the use of modern technologies.

The researchers argue that using the concept of blended learning facilitates the structuring of an e-learning course and determines how it can be adapted. The work of Watson (2008) has been used by many professors to show how blended learning with adaptive programs promotes constructive understanding and learning. Lynch and Dembo (2004) discuss that by analyzing the studied material, students understand and remember much more and; therefore, blended learning is more effective. Grover et al. (2015) discuss that one of the most important advantages of both distance learning and blended learning, is their independence from the social and personal factors of students. Such programs allow people to learn regardless of age, and physical and mental abilities, which makes education more accessible to everyone.

Molenaar et al. (2021) discuss the developmental perspective of self-regulated learning (i.e., how learners regulate their efforts, accuracy, and erudition), using adaptive learning technology, as well as instantaneous learning curves. Their result confirms that adaptive technology can improve self-regulated learning and improve learning efficiency. Papanicolaou et al. (2003) discuss an Internet-adaptive educational hypermedia system called INSPIRE designed to support personalized learning over the Internet and traditional classroom learning as a complementary resource. The proposed method includes adaptive and adaptable behavior based on the student's model and characteristics, such as the level of knowledge and learning style.

Chen et al. (2005) discuss the prospect of using an IRT-based personalized e-learning system (SPEL-ART) that takes into account both the complexity of the course material and the student's ability, to provide customized learning paths for students. Experimental results show that the proposed system can provide personalized learning and help students learn more effectively.

Han et al. (2021) discuss the prospect of using learning analytics to develop two dashboards for students and teachers. This allows the students to track their joint argumentation face to face, to process through adaptive feedback, and helps the instructor provide adaptive support at the right time.

International experience shows that adaptive learning is an approach that takes into account the individual abilities and needs of the student as much as possible. With the active development of information technologies in the field of education, electronic learning environments are increasingly being used, which makes it possible to implement the ideas of adaptive learning into practice.

In their research, Kopeyev et al. (2020) and Shuinshina et al. (2019) discuss the strategic directions of development of Kazakhstan, such as improving education and science, and their modernization, aimed at achieving a high level of preparation of the younger generation for real life. Therefore, adaptive learning is a priority in Kazakhstan in the online education development program. Some specific platforms and services are designed to improve the level of knowledge of the student, taking into account their characteristics. These platforms allow teachers to provide students with materials of various kinds, as well as interact with them in real time. These also allow teachers to monitor the development of the learning process and know how each student copes with specific tasks.

The work of Toktarova (2022) has been used by many professors to show what adaptive platforms exist, such as 2U, Wiley, Canvas, LoudCloud, Blackboard, Knewton, Realize IT, Adaptcourseware, Anewspring, Geekie, and Smart Sparrow. Weber et al. (2001) discuss the popularity of the Geekie smart system in Brazil. This is a developed AI-based software platform that allows students to prepare for final exams at school. It includes materials (video tutorials, tests, practical tasks) developed by teachers. The idea of adapting the learning process has become most widespread in the USA. The work of Rigby (2016) has been used by many professors to show the existing platforms and online services used in different parts of the education system. McCusker et al. (2013) discuss the educational service (platform) Knewton, which has been personalizing learning since 2008. Knewton is a platform-based learning system on which programs and applications with adaptive functions are developed. The work of Bulger (2016) has been used by many professors to show how to use the MyLab & Mastering educational platform. The analytical system allows you to answer questions such as, 1) what the student knows; 2) why he made a mistake in the assignment; 3) what topics are important to him; 4) the forecast of success at this stage. Adaptive learning platforms are particularly useful when teaching natural sciences, in general and mathematics, in particular. They allow you to select educational material depending on the level of knowledge of the user.

Borba et al. (2016) discuss methods of teaching mathematics as one of the most studied areas of research in the field of education. The work of Hatfield (1987) has been used by many professors to analyze what computer applications in teaching have been used in mathematics education. Since then, many studies have been conducted in which the effectiveness of new technologies used for teaching mathematics has been analyzed.

Dick and Rallis (1991) discuss an article presented by Skinner, an influential and well-known neo-behaviorist, on programmed learning that seems to have had a major impact on education, in general and mathematics education, in particular, in 1958. An example is the Programmed Skinner Instruction (PI) which was designed to change student behavior. Skinner's fundamental approach was to define the desired behavior and then prepare situations in which successive approximations of the behavior would be reinforced. All students study the so-called "linear text," the teaching material used by Skinner. When students complete a text, it was assumed that they have learned the behavior required of them. The main characteristic of programmed learning is the "small steps" approach, which means dividing the task into small manageable blocks and giving immediate feedback to students based on the answer they give. A learning machine is a box designed to display the programmed instruction text one frame at a time. It is generally believed that it is the predecessor of a device called a “computer” intended for educational use. Skinner’s programmed instruction formed the basis of the movement for computer learning.

Kozík and Slivová (2014) discuss an attempt to create an adaptive platform Stepik in Russia in 2015, which would select educational material depending on the level of knowledge of the user and advise the most important for this stage of learning. All these applications have common functions, but some of them are more flexible and complete in specific aspects, such as their maintenance and administration of the learning process, the formation of reports on student success, assigning roles, etc.

Today, Stepik is a popular platform for creating online courses with adaptive recommendations. It allows you to create interactive training lessons with feedback and automatic verification. The Stepik educational platform acts as a virtual teacher for the selection of material for the successful development of the course. The founder of Stepik is Nikolay Vyakhkhi, who created the author’s courses in bioinformatics with the support of JetBrains and the Laboratory of Algorithmic Biology of St. Petersburg Academic University. In 2013, an online platform was created based on developments, and in September 2013, the first third-party training programs were released on it. Today, Stepik presents online courses from educational organizations (the Institute of Bioinformatics, Computer Science Center, Yandex Academy, BFU Kant, National Research University Higher School of Economics, European University, Samara University, Tomsk State University, Tomsk Polytechnic University, and other educational institutions), companies (JetBrains, Mail.ru Group, SKB Kontur, Samsung, and others), as well as individual authors. One of the most striking features of the Stepik platform is the training schedule, which is focused on structured learning objects. Negara et al. (2022) discuss that the platform, depending on the educational context, can explain the same fact to each student differently depending on their previous knowledge, learning goals, and language.

Thus, having studied the international experience in adaptive learning, we can conclude that adaptive learning provides a personalized learning process. And also, thanks to information technology, refers to systems that track the progress of students and use data to constantly change the content of learning to the behavior and needs of individual students.

METHODOLOGY

The authors of the study developed and provided the teachers of Aktobe Higher Polytechnic College with the Stepik platform for creating and posting educational materials, offered as a supplement to classes in a physical classroom. Our goal is to provide an adaptive online course that can integrate into the college’s e-learning environment and meet the modern requirements of online education. To test the theoretical propositions put forward, a pedagogical experiment was conducted with two groups of students: two study groups of 30 students in each group were taken as control and experimental groups. To select a group of students for the experiment, first, a test was conducted for first-year students to determine study groups. According to the results of testing in the experiment, two groups were selected that were close to each other in terms of knowledge, that is, the average level of development of mathematical critical thinking was the same in both groups. During the formation of the sample, a strategy was used - the involvement of real groups, that is, the use of real groups as experimental and control groups. Teachers are divided into experimental and control groups according to similar parameters: professional education, qualification category, and teaching experience. The experiment affected all the main components of the methodological system of personalized adaptive learning of mathematical functions, trigonometric functions, trigonometric equations, and inequalities, which are substantially the same for both the experimental and control groups. That is, educational content with uniform content, uniform control, and measurement materials and requirements for the assessment of students were used. But the training in the experimental group was carried out using adaptive personalized learning technology, and the training in the control group was carried out using electronic training courses that do not support flexible adaptation of educational content to the characteristics of students.

In this article, we show the main features of our adaptive online mathematics course (implemented in Stepik), as well as the conclusions drawn from this experience. First, we will present a description of the main features of our adaptive online mathematics course. We will then look at our results and student response to this initiative. To prove the reliability of the results obtained in the course of the formative experiment, we used the nonparametric Chi-square method, which is used to test the statistical hypothesis and allows us to formulate sufficiently reasonable conclusions only if the initial data used to calculate the statistics of the criterion are objective. A non-parametric statistical criterion $\chi 2$ has been identified for comparing the indicators obtained as a result of measurements in a connected sample. The possibility of using the criterion is illustrated by the example of determining the effectiveness of the proposed teaching methodology using the adaptive personalized platform Stepik in educational activities.

The created course is built from modules, each module contains separate lessons, which can be presented in the form of text, video lectures, or practical tasks. Makarov et al. (2020) discuss the formats in which practical tasks can be presented, such as tests, numerical tasks, puzzles, and more. Every registered user has the opportunity to publish the course. To create an open course, one can limit oneself to a free tariff.

Khalyapina and Kuznetsova (2020) discuss the benefits of this platform, for example:

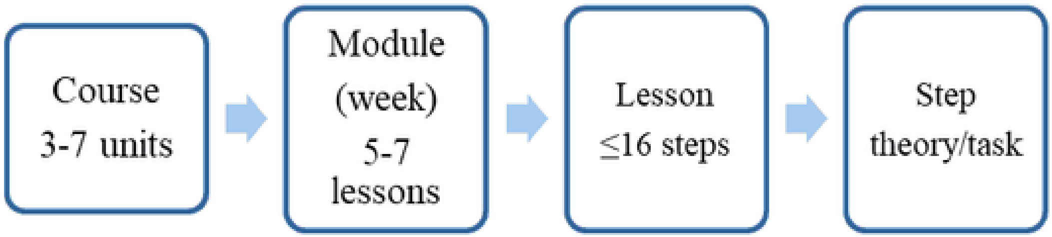
- No need to install additional modules or settings, the course is created online.
- Numerous opportunities for compiling statistical reports and analyzing academic performance.
- Using the Stepik free mobile app.
- The possibility of communication between users using comments under each lesson.
- Availability of a free tariff.
- The platform is initially more focused on hosting courses for programmers, respectively, it has more features, like inserting source code with syntax highlighting depending on the language; a module for automatic verification of the correctness of writing code for a task, and the correctness of its execution; API for integration with external verification/evaluation systems.
- Has a larger number of task types, for example, tests with multiple or single choices of answer options; programming tasks with automatic verification in different programming languages HTML, CSS, SQL, etc.; tasks integrated with IntelliJ IDE Educational Edition, aimed at execution in this IDE.

Stepik can be used for the following tasks:

- The creation of mass open courses for a wide audience. Such courses, as a rule, have the purpose of disseminating information about the subject of the course, the author, or the author organization.
- The creation of courses, and lessons for your audience on a narrow topic with a focus on the needs of a specific study group.
- Automation of the teacher’s work. One can create a test or a solution book with the ability to automatically check tasks.
- The creation of individual lessons as additional materials to support offline learning.
- Conducting exams. This can be an exam for an online course or an independent examination test.

In Stepik, all available information within the course (on a specific subject) is organized into separate modules. A course is a set of lessons on a general topic organized into modules (weeks). The course consists of modules, modules from lessons, and lessons from steps, as seen in Figure 1.

Figure 1. Course content



A lesson is a set of educational materials on one topic. The lesson consists of steps that can be tasks (more than 20 types) or theory (text, video). There can be up to 16 steps in one lesson. Lessons can exist on the platform and outside of courses and can also be included in several courses at once (for such an addition, use the lesson number — there is one in the address bar). One can add his own new and existing lessons to the course.

In our course, each module corresponds to a specific area of the subject. We organized it as follows:

First module: Functions, its properties, and a graph.
Second module: Trigonometric functions.
Third module: Trigonometric equations and inequalities.
Fourth module: Probability.

For mass courses, it is recommended to do three to seven modules and five to seven lessons in each module. The only limitation is that there can only be up to 16 steps in a lesson.

This curriculum is the same as the one that was distributed on the first day of classes, so there is no difference between the Stepik-oriented program and the program used during the full-time course.

The Solutions Forum is conceived as an online discussion space and a source of information and news in real-time. It is located under the task next to the comments and opens only after the conditions that the author set up when creating the task are met.

Information about the course is presented as a business card of the course. It is available even for unregistered students. The student decides to enroll in the course according to the description, so it is important to fill in the information as fully and clearly as possible.

It is better to plan and create theoretical and practical course material in parallel. Follow the logic of learning. Think about how to structure the material better and create a unified learning plan where all modules, lessons, and steps are interconnected and correspond to common goals and objectives.

The authors created an introductory lesson where they talked about how to work with the Stepik platform and reflected on the features of their course. If the educator has any special features for the course or there are important points about tasks that everyone needs to know about, the educator can tell the students about them at the beginning of the course. An educator can make both a video instruction and a text step repeating everything said in it.

The first step of each lesson is best done in a text step with a description of what will be in the lesson. This can be a text with links to individual steps or a lesson table of contents. Educational materials on Stepik are served to the student in small portions called steps. This micro-learning approach will help the student spend a small amount of time on each approach. This is especially important for students who study in their free time. The steps on Stepik are divided into theoretical and practical.

Special attention should be paid to the first module of the course. It is during the first lessons of the course that students will decide whether they want to complete it. Any typos, inaccuracies in

Figure 2. Screenshot of the course description of the adaptive mathematics course

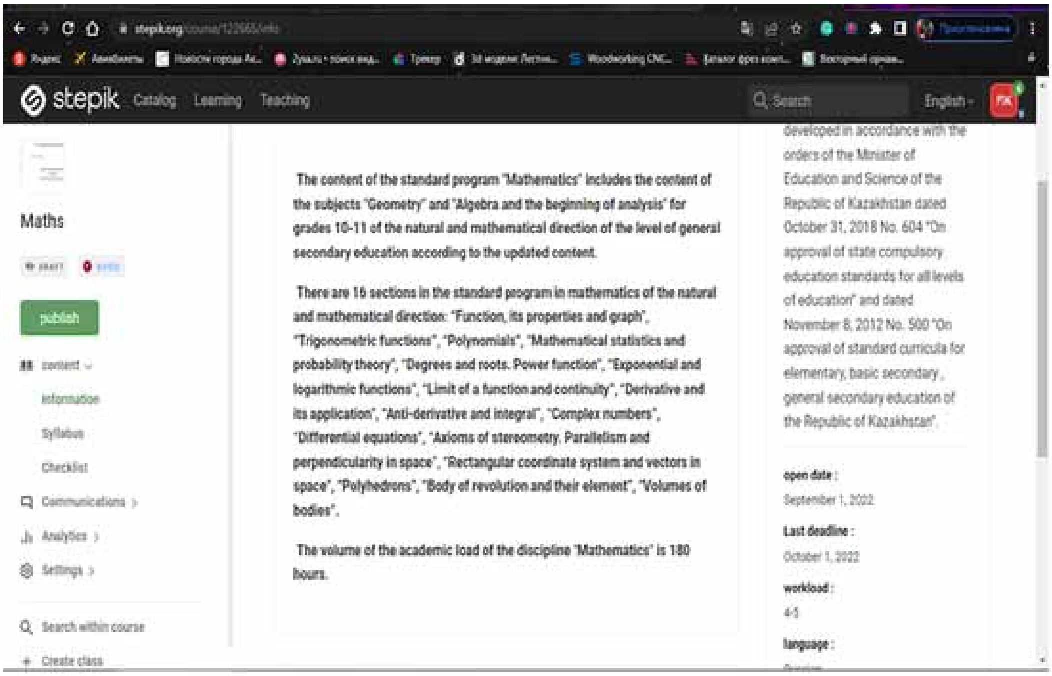
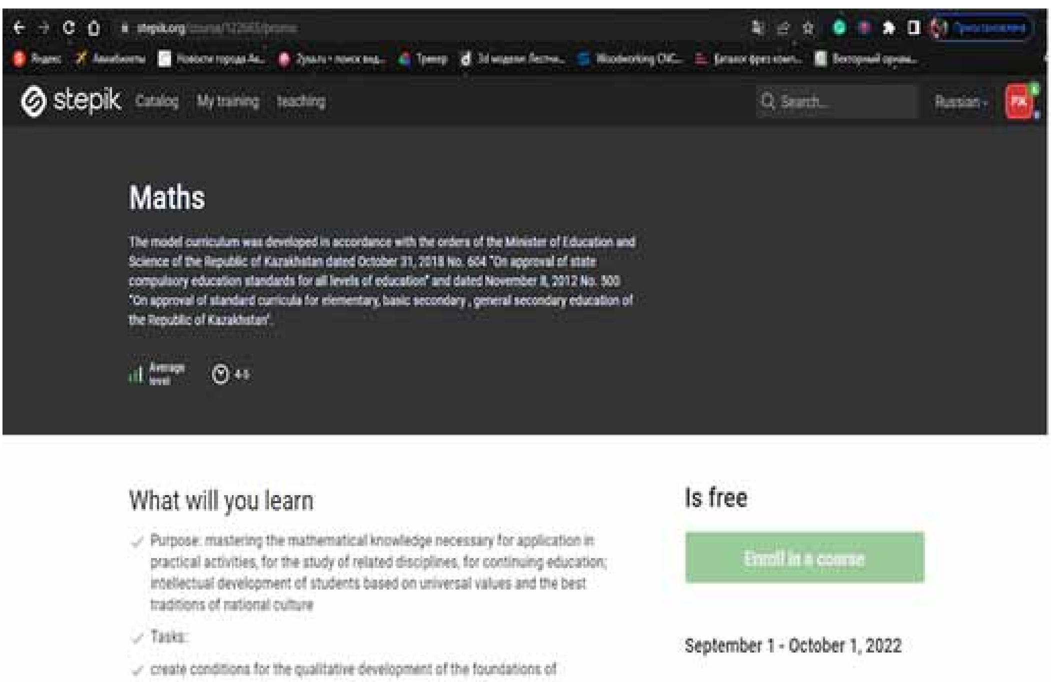


Figure 3. Screenshot of the introductory lesson of the adaptive mathematics course



assignments, and minor flaws in the first module can form a negative assessment of the course and significantly reduce the number of students who will continue further in the course.

An important part of online courses is the implementation of practical tasks. Tasks on Stepik are of varying degrees of complexity and include 1) test tasks; 2) answer input tasks; 3) complex tasks and 4) experimental tasks.

Most of the tasks on Stepik are checked automatically, but one may also encounter peer-reviewed tasks that can be manually checked by the teacher himself or other students. In addition to chats and forums, we have selected the following elements from various course materials that can be implemented in Stepik to include them in each thematic block (see, for example, Figure 4, Figure 5, and Figure 6).

The work of Burlacu (2021) has been used by many professors to show how didactic transformations such as remote labs, simulation labs, and video didactic content have transformed the distance education process in polytechnic education. According to UNESCO, a person remembers 10-15% of the material he hears and approximately 25% of the material he sees, up to 70% of information is absorbed with audiovisual perception. Consequently, the involvement of all the main senses leads to an increase in the degree of assimilation of the material in relation to traditional methods. Every teacher knows the use of video materials can have a beneficial effect on the lesson. Classes with the use of video material are the most intensive form of training. Educational video materials (training videos) today are a modern, effective form of presenting educational content in the context of personalized adaptive learning. Educational videos on the Stepik platform are a collection of videos that correspond to a lecture and practical course and allow one to organize various forms of work with students in an interactive format. Video materials contribute to a better understanding of the educational material, by increasing the density of information, the degree of perception, and emotional saturation. Figures 7 and 8 show the contents of the video lecture hosted on the Stepik platform.

Figure 4. Screenshot of the first lesson of the adaptive mathematics course

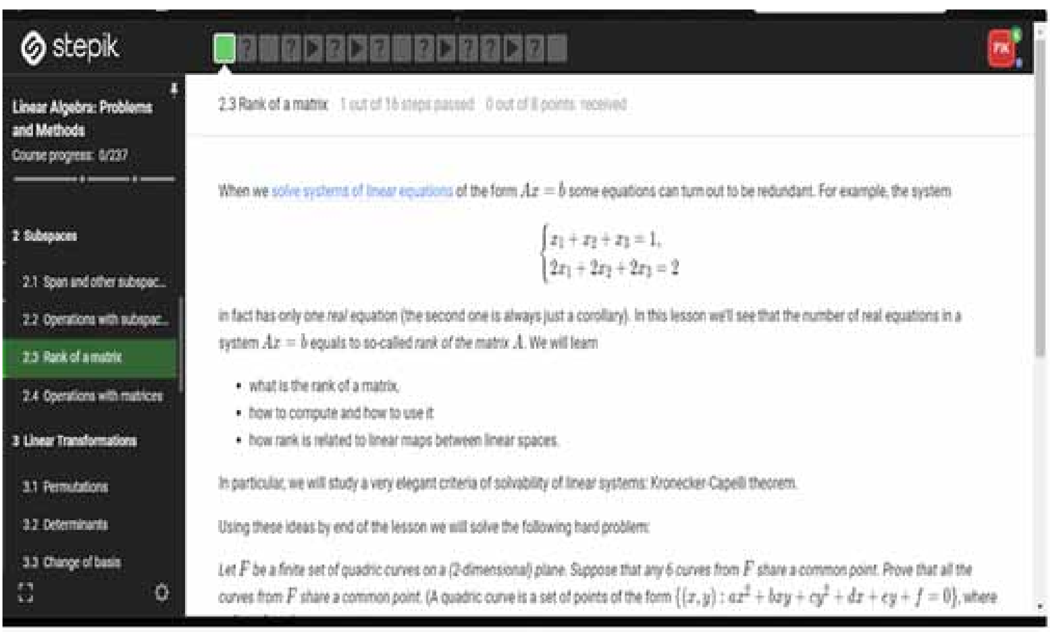


Figure 5. Screenshot of the practical task of the adaptive mathematics course

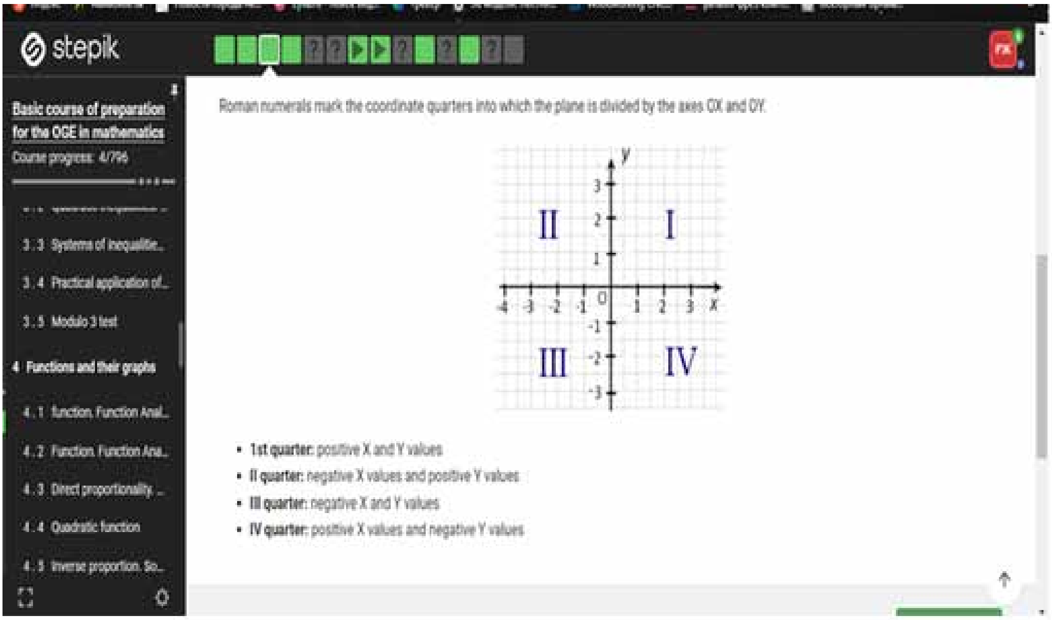


Figure 6. Screenshot of the practical task of the adaptive mathematics course

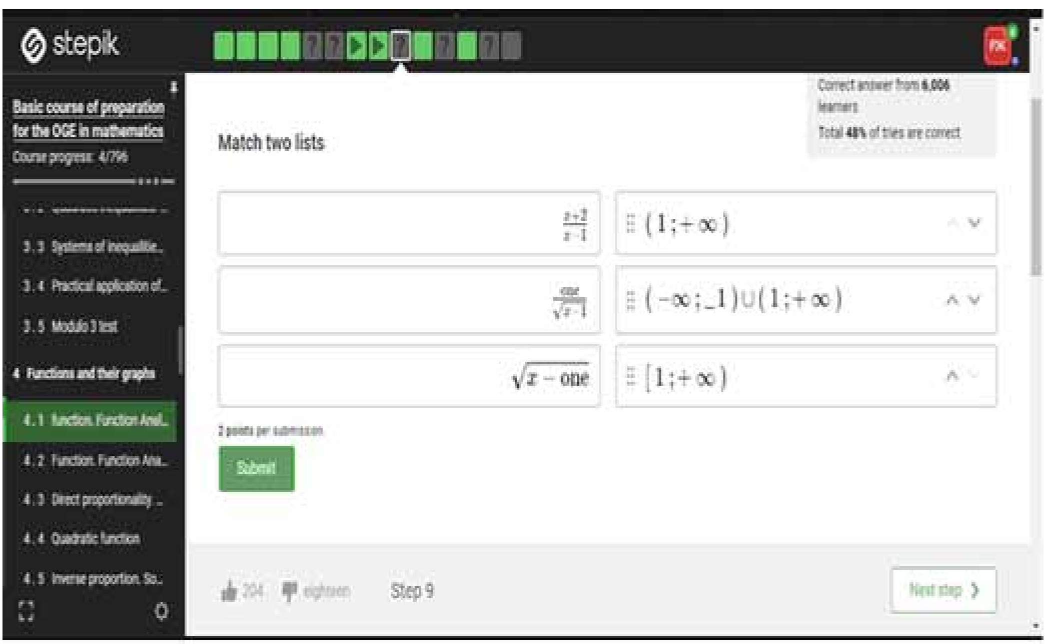


Figure 7. Screenshot of the video lecture of the adaptive mathematics course

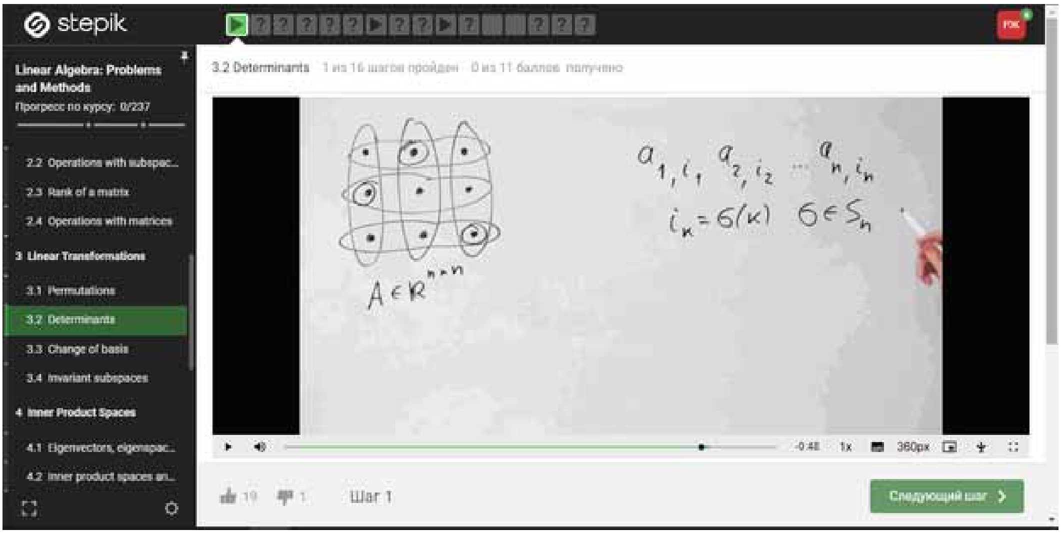
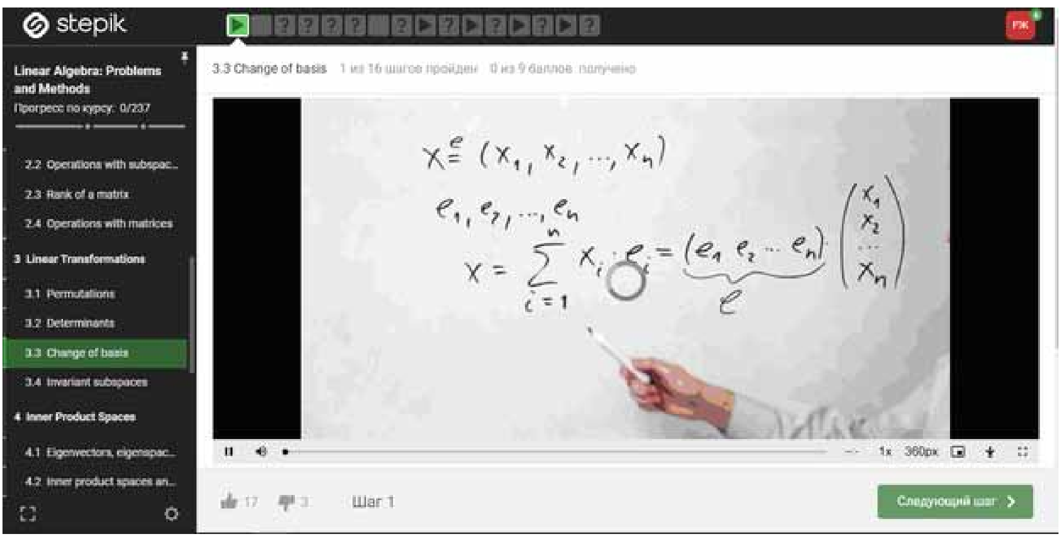


Figure 8. Screenshot of the video lecture of the adaptive mathematics course



FINDINGS/RESULTS

The discipline “Mathematics” implies the integration and generalization of such mathematical courses as algebra, number theory, mathematical logic, and geometry. As an input control for control and experimental groups, the average score of exam grades in mathematical disciplines studied at school was taken.

To assess the reliability of the coincidences and differences of the results obtained by the results of the input control in the control and experimental groups, we applied the nonparametric statistical criterion $\chi 2$.

The empirical values of the criterion for each of the cases are presented in the table (Table 1).

Table 1. Empirical values of the criterion χ2

Group	Experimental group No. 1 (E1)
Control group No. 1 (C1)	4,6865

The empirical values of the criterion turned out to be lower than the critical value of the criterion χ2, which for a significance level of 0.05 and a given number of degrees of freedom 3 is equal to 7.82. Thus, the characteristics of the compared samples coincide with the significance level of 0.05. Thus, the reliability of the differences in the characteristics of these groups of students according to the statistical criterion χ2 is 95%.

The proportion of students who scored from 1 to 3 points, which corresponds to the threshold level of mathematical competence, in the control group K1, is 37%, whereas in the experimental group E1is 6%, i.e. the percentage of students with a threshold level in the experimental group is insignificant, unlike the control group, where such students make up a third of the group. The proportion of students who scored from 4 to 6 points, which corresponds to the standard level of mathematical competence, in the control group is 49%, and in the experimental group is 61%. Thus, it can be concluded that the percentage of students with a standard level in the control and experimental groups is almost the same. The proportion of students who scored from 7 to 9 points, which corresponds to the reference level of mathematical competence, in the control group is 14%, and in the experimental group is 33%, i.e. the percentage of students with a reference level in the experimental group increased significantly and began to make up a third of the group.

The test results are measured on a scale of relationships. To assess the reliability of the differences in the data obtained by the results of the test in the control and experimental groups, we applied the nonparametric statistical Wilcoxon-Mann-Whitney criterion (Mirzayanov et al., 2020). The empirical value of the Mann-Whitney criterion for each of the tested cases is calculated by the formula:

$$U = \sum_{i=1}^{N} a_i \qquad (1)$$

The obtained values are shown in the table (Table 2).

The empirical values of the criterion for each pair of groups are presented in the table (Table 3).

The empirical values of the Wilcoxon criterion were higher than the critical value of the criterion, which for the significance level of 0.05 is equal to 1.96. Thus, the reliability of differences in the characteristics of the experimental and control groups of students according to the statistical criterion of Wilcoxon Mann-Whitney is 95%.

Table 2. Empirical values of the Mann-Whitney criterion

Group	E1
C1	952

Table 3. Empirical values of the Wilcoxon criterion

Group	E1
C1	2,541358

The proportion of students who received an "unsatisfactory" grade for the test in the control group K1 is 16%, while in the experimental group E1 it is only 6%. The proportion of students who received a grade of "satisfactory," which corresponds to the threshold level of mathematical competence, in the control group is 37%, while in the experimental group it is only 12%, i.e. the percentage of students with a threshold level in the experimental group is insignificant, unlike the control group, where such students make up a third of the group. The proportion of students who received a grade of "good," which corresponds to the standard level, in the control group is 37%, and in the experimental group is 48%. Thus, it can be concluded that the percentage of students with a standard level in the control and experimental groups is almost the same. The proportion of students who received an excellent grade, which corresponds to the reference level, in the control group is 9%, and in the experimental group is 33%, i.e. the percentage of students with a reference level in the experimental group has increased significantly and began to make up a third of the group.

DISCUSSION

To verify the formulated statement, a pedagogical experiment was conducted, which consisted of a formative stage. In total, about 60 students participated in it. The aim was to test the effectiveness of the adaptive personalized methodology and to study the level of formation of mathematical competence among students. This stage of the experiment consisted in teaching the elective discipline "Mathematics" to first-year students studying in the area of "Information Technology," in the amount of 38 classroom hours. At the formative stage of the experiment, statistical processing of the results of questionnaires, control works, and tests was carried out, and the results obtained in the control and experimental groups were compared.

The analysis of the survey results allows us to conclude that during the study of the discipline "Mathematics," with the help of adaptive personalized technology, students' interest in studying mathematics increases, and there is a need to study mathematics.

Based on the results of a survey conducted at the beginning of the first year of the course (before studying the discipline "Mathematics"), it can be concluded that the majority of students have a reflexive component of mathematical competence formed at a standard level. The results of repeated questioning after studying the discipline "Mathematics" show that the number of students with a standard level of formation of the reflexive component has increased, while the number of choices of the answer "I find it difficult to answer" has decreased, which indicates the formation of self-esteem skills within the course "Mathematics."

CONCLUSION

The results of the control work and the test give approximately the same distribution of students in percentage terms by levels of mathematical competence formation. Thus, students who have reached the standard level make up about half of both the control and experimental groups. In the control group, one-third of the group has a threshold level and only a few students have a reference level. In the experimental group, one-third of the group has a reference level and only a few students have a threshold level. Thus, the effectiveness of the methodology using adaptive personalized technology of teaching mathematics systems in the framework of the formation of mathematical competence has been tested.

From a didactic point of view, Stepik is a convenient adaptive platform for teachers. It is possible to create different types of educational material on Stepik, such as online exams, small lessons with assignments, courses for individual groups of students, or massive open online courses. It is a great way for teachers to organize, manage, and provide educational materials. The use of multimedia tools to create attractive classes makes the learning process more convenient for students. As a result, these events increase students' interest in studying mathematics. Teachers can expand the curriculum of their full-time courses. Some of the teaching material that has been taught full-time in the classroom can now be offered online. Additionally, in the classroom, teachers will be able to spend more time analyzing interesting and additional topics, as well as bringing students to the same level of training, checking homework and conducting tests automatically, helping failing students catch up with classmates, and sharing knowledge with hundreds of thousands of people.

Stepik also facilitates interaction with students in real-time, and also allows teachers to receive student opinions and suggestions. As a learning community, Stepik allows students to share their knowledge and difficulties so that they can help each other through forums and chats. Teachers may notice which parts of the subject students are finding more difficult to understand and the concepts can be developed in the classroom.

At the beginning of the academic year, students were a little reluctant to participate in this class, probably because they were not used to solving new problems. Then, they gradually increased the number of site visits. We noticed that when we uploaded the practice tasks, they began to study other elements previously uploaded to the platform; then they started conducting tests and even offered us some improvements. This is a key point, as it is very important that students feel involved in their learning process. We can also note that the number of visits to the platform increased over time, which indicates that students have an interest in such e-learning methods.

We appreciated the improvement in academic results obtained as a result of using this adaptive e-learning platform. Students who used Stepik regularly during the semester received higher scores than students who did not. Thus, the impact of these adaptive web applications on students becomes obvious. Moreover, the students informed us that, in their general opinion, Stepik helps them to strengthen their abilities and knowledge. These results encourage us to continue improving our adaptive course on the Stroika platform.

Thus, the adaptive learning system initiates the activity of students, promotes motivation, ensures optimal adaptation to the individual characteristics of students, and allows for regular effective monitoring. All these factors contribute to improving the overall quality of education and the level of competence of students.

RECOMMENDATIONS

It is recommended to develop educational programs in pedagogical subject areas based on a proven adaptive personalized model. The training material is automatically presented to the student with a level of detail that best corresponds to his characteristics or according to the results of identifying the dominant channel of information perception. Taking into account the recommendations, students can independently decide on the choice of content, using their strengths and, if desired, developing weaknesses, which creates additional opportunities for them in the educational process.

LIMITATIONS

Several limitations can be noted. Firstly, two study groups of students (30 people in each group) of Aktobe Higher Polytechnic College in Kazakhstan were taken as control and experimental groups. Secondly, to assess the reliability of the coincidences and differences in the data obtained from the results of the input control in the control and experimental groups, we applied a nonparametric statistical criterion $\chi 2$. Thirdly, the experiment consisted in teaching the elective discipline “Mathematics” to first-year students studying in the area of “Information Technology,” in the amount of 38 classroom hours. Fourth, at the time of this study, some students were unable to attend because they were still in the COVID-19 state. Thus, the number of data samples in this study was not as expected, which could affect the internal reliability of the conclusions made.

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