International Journal of Innovative Research and Scientific Studies, 8(3) 2025, pages: 2847-2856

IJIRSS
International Journal of Innovative Research & Scientific Studies

ISSN: 2617-6548

URL: www.ijirss.com

Integration of personalized adaptive learning elements into the electronic educational content of a college mathematics course on the Stepik platform

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Abstract

This study aims to evaluate the effectiveness of integrating elements of adaptive personalized learning into a college-level electronic mathematics course delivered via the Stepik platform for first-year students in technical fields. The research combined theoretical analysis of adaptive learning principles with experimental implementation. An electronic course was developed with integrated adaptive elements, and a pedagogical experiment was conducted with first-year college students, during which students' progress was monitored through automated settings in Stepik, and data were collected via diagnostic assessments, surveys, and observations. The findings demonstrate that the integration of adaptive personalization elements led to a noticeable improvement in students' mathematical competence, with an increase in the proportion of students achieving high and medium competence levels and a significant reduction in the number of students with a low competence level. The study concludes that incorporating adaptive personalized learning into electronic courses enhances the effectiveness of blended mathematics education, fosters student motivation, and supports the development of independent learning skills. The practical implications suggest that adaptive personalization strategies, implemented through platforms like Stepik, can effectively promote student-centered learning and improve educational outcomes in college mathematics courses.

Keywords: Adaptive personalization of learning, an electronic course in mathematics, a mixed learning format, integration of elements.

DOI: 10.53894/ijirss.v8i3.7090
Funding: This study received no specific financial support.
History: Received: 1 April 2025 / **Revised:** 7 May 2025 / **Accepted:** 9 May 2025 / **Published:** 16 May 2025

Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.
Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.
Publisher: Innovative Research Publishing

1. Introduction

One of the strategic directions of the state's development is education and science, on the development of which the pace of technical, technological, and economic progress, development, and the state of culture and spirituality in society depend crucially. At the present stage of the development of the education system, the task of its modernization to achieve a high quality of preparation for the life of the younger generation is at the forefront [1, 2].

Teaching students with different knowledge of the subject area, learning styles, interests, and preferences is not possible using a «one-size-fits-all» approach. To solve the problem and improve educational learning outcomes, the use of adaptive personalized learning is proposed [3].

An analysis of the current situation of the development of e-learning tools and methods shows that it is the «Adaptive personalization» scenario that is currently becoming a global trend in e-learning. In addition to adaptive approaches, recent studies emphasize the importance of ensuring academic honesty during online assessments through proctoring technologies [4] and enhancing digital literacy using virtual reality applications [5]. These innovations reflect the broader movement toward the digitalization and individualization of educational processes, highlighting the need for flexible, personalized learning environments.

The growing popularity of adaptive personalization among consumers (students) can be explained, on the one hand, by the reflection of the desire for an individual approach to personal needs, natural for human nature, on the other hand, due to technological advances, the growing need of people for even greater productivity and comfort of work to master new competencies [6].

The use of adaptive personalized teaching of mathematics is supported by the following system of didactic principles: accessibility, consistency, the connection of theory with practice, conscious activity, an individual approach, and cooperation. The main requirement for a teacher at present is the full use of the potential of each student. Therefore, one of the most important factors for the successful assimilation of the program material by each student is a combination of frontal and individual-group forms of work based on a systematic study of the characteristics of students. The teacher always has a task: not only to see in each lesson a common educational problem but also to determine ways to solve this problem for each student. This is the key to the successful implementation of an individual approach in the educational process.

It is also important to note that mathematics education in college often takes place under conditions where students in the same academic group have a heterogeneous starting level of mathematical literacy, a diverse level of learning mathematics, and, in fact, different value orientations and motivations. Accordingly, one of the important tasks facing the teacher at the stage of diagnosis is to motivate educational activity by creating a psychological attitude toward assimilation, orienting the student in the system of educational work, directing them to eliminate gaps, and aiming at the main supporting knowledge for the new material.

A personalized learning trajectory allows the learner to develop different skills at different speeds. At the same time, teachers carefully monitor the progress of the student and provide support to avoid falling behind the group. The development of educational technologies, in particular, Stepik, makes it possible to find new solutions to the problem of personalizing the teaching of mathematics.

Integration of adaptive personalization elements into electronic educational content seems to be one of the promising directions for the development of mixed mathematics education.

By the purpose of the study, the following research objectives were identified:

- To present the theoretical foundations and prerequisites for adaptive personalization as the main trend in the development of educational programs in modern conditions;
- Describe the experimental work with an electronic training course based on Stepik in the discipline of «Mathematics» for first-year students in technical fields of study in college education;
- To present the results of the evaluation of the effectiveness of the developed course in the formation of mathematical competence of students of the 1st year of study.

Research methods:

- Theoretical – analysis of pedagogical works on the problem of research; analysis of methodological and educational literature; theoretical analysis of the main provisions of the proposed methodology, based on which the research hypothesis is put forward; theoretical justification of the system of work on testing the model of an electronic training course based on Stepik in the discipline «Mathematics» for first-year college students;
- Empirical – ascertaining, forming, controlling pedagogical experiment, questionnaire, testing, interview, observation; conversation, analysis of the results of experimental work.

The theoretical basis of the research is based on the works of Keefe [7], Jenkins and Keefe [8], Pane et al. [9], and Courcier [10] dedicated to the personalization of the learning process.

According to Keefe and Jenkins, the following elements are key to ensuring the proper implementation of personalized learning:

- The dual role of a teacher as a coach and an adviser;
- Diagnostics of the relevant characteristics of the student's learning;
- Collegiate school culture;
- Interactive learning environment;
- Flexible schedule and learning pace;
- The present assessment of training.

Ikumi Courcier studied teachers' understanding of personalized learning in English schools and found that due to ambiguity in terminology, teachers often confuse personalized learning with individual learning. In this regard, it is extremely important to distinguish the difference between these concepts. Although they pursue similar goals – to meet the needs and interests and realize the potential of an individual student who will continue to study throughout his life, they differ in the perception of students and/or teachers of their responsibilities. In particular, to achieve results in personalized learning, both teachers and students must be responsible for learning, while in individualized learning, teachers take the lead and guide individual students to achieve their goals.

Thus, learning is largely determined by the needs and interests of the student, as well as the context, and is based on a constant dialogue between the student and the adults in his life [11].

The practical significance of the research lies in the integration of the elements of personalization of learning into the electronic adaptive educational content of the mathematics course in college.

2. Materials and Methods

Already in the mid-50s, after the advent of computers, the first ideas of adaptive learning were formed. The first concepts of adaptive learning were proposed by the English cyberneticist G. Pask and American psychologists [12, 13]. The ideas they expressed are still relevant today. These scientists were unanimous in assessing the main reasons for the low efficiency of traditional education, making the following requirements for the educational process:

- «The educational process should have an operational (flexible) adaptation to the individual characteristics of students. One of the main reasons for the inefficiency of the modern education system is that a whole group of students is being taught at the same speed. The fact that this delays students who can advance faster is obvious to everyone. Less obvious is the harm that this causes to students who learn slowly. The sluggish under the traditional system quickly lag and become less and less able to move forward at the pace chosen by the teacher. With the help of properly designed programs, a slow student, having the opportunity to work at his own pace, will be able to rise to a level of development that we could not even dream of until now» [11].
- «No teaching method can be effective without the student's interest, and students always lose interest and start to get distracted when the teaching material is too simple for them, or when they lose faith in their strength because it is too difficult for them» [12].
- «An adaptive training program should provide the teacher and the student with a variation in the ways of presentation and assimilation of educational material; help in tracking the level of learning and, based on the results of feedback analysis, change the structure, parameters, and algorithms of training» [13].
- One of the leading provisions of the theory of activity for effective learning assumes «such an organization in which the student is involved in the operation of educational content, and only in this case it is absorbed consciously and firmly, at the same time, there is a process of developing the student's intelligence. The activity-based approach in teaching consists in the fact that the student should study, and the teacher should carry out motivational management of his teaching, i.e., cooperate with the student: motivate, coordinate, advise and control» [14].

In the 1970s, Cronbach and Snow [15] actively developed an approach based on the relationship between learning and students' abilities, called Aptitude Treatment Interaction (ATI). The authors of this approach believe that due to differences in cognitive nature, psychological characteristics, and differences in life experience, students may react completely differently to the same tasks, and also the same student may, due to different circumstances, react differently to the same type of task. Adaptive personalized learning technology adjusts learning accordingly. From the student's point of view, this means that he will have to make additional efforts in these areas. At the same time, adaptive learning encourages the student's success, which motivates them.

Currently, scientists abroad, such as Gaeta et al. [16], Walkington and Bernacki [17], Garrett et al. [18], Zhukova et al. [19], Teslina [20], Ivanov [21], and Tarkhov [22], as well as scientists in the country such as Savchenko and Omirbekova [23], Maulenov and Serbin [24], understand the meaning of adaptive learning differently. Based on the analysis and research of the relevant literature of the above authors, it is concluded that adaptive learning is a teaching method that uses computer algorithms, as well as artificial intelligence to organize the interaction with students and provide individual resources and educational activities to meet the unique needs of each student. Adaptive learning is not only the communication of new information but also teaching methods of independent work, self-control, mutual control, methods of research activity, the ability to extract knowledge, generalize and draw conclusions, and fix the main thing in a collapsed form. Thus, adaptive learning can not only fulfill the leadership role of teachers but also ensure that students will play the main roles.

Figure 1 shows a diagram of the adaptive learning methodology.

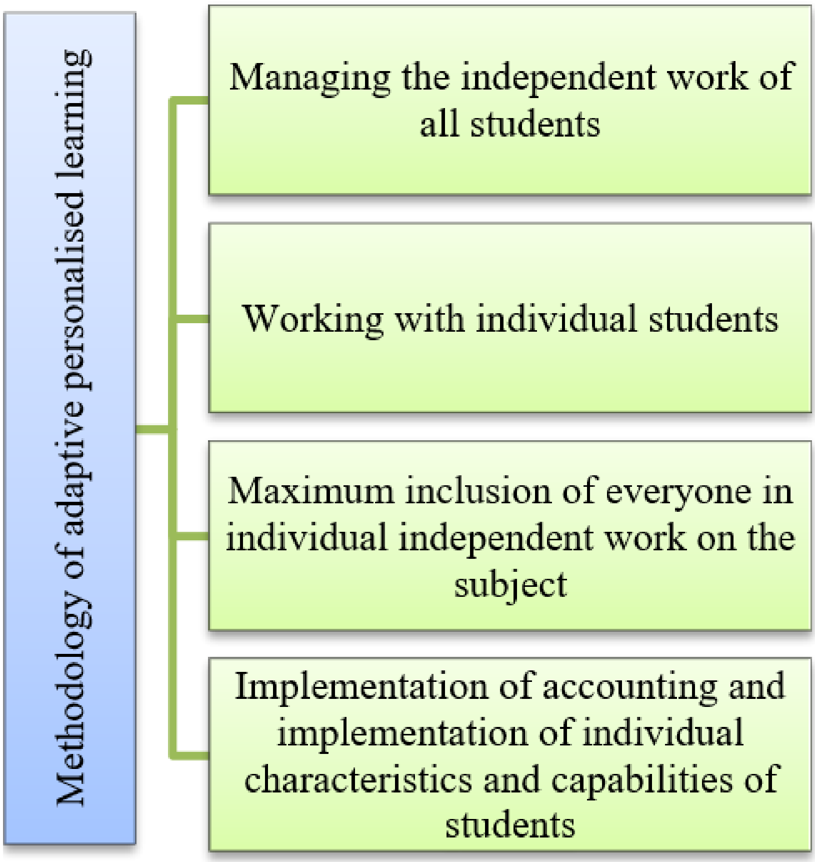

Figure 1.
The methodology of adaptive personalized learning.

While online platforms may have the disadvantage that students feel isolated and left to themselves, adaptive personalized learning overcomes this problem with life lessons. Participants can easily interact with the instructor, ask questions, and receive instant answers. The instant gratification gained from getting real-time answers and interacting with other students makes learning more enjoyable.

3. Results and Discussion

In recent years, theoretical and practical research in the field of adaptive learning has been gradually gaining momentum. Platforms using the adaptive learning model, such as LoudCloud, Blackboard, Knewton, RealizeIT, Geekie, Smart Sparrow, Stepik, and others. Zavyalova and Zubakov [25] studied the practice of adaptive learning based on the Stepik platform. The results show that adaptive learning based on the Stepik platform helps improve the learning effect.
Characteristic features of the adaptive personalized learning methodology:

- The division of educational material into separate, small, easily digestible parts, aimed at mastering each part;
- Verification of the part;
- Inclusion of a system of prescriptions for the sequential implementation of certain actions of assimilation of each part.

If the control tasks are completed correctly, the student receives a new portion of the material and performs the next step of training; if the answer is incorrect, the student receives help and additional explanations.

- Recording the results of control tasks that become available both to the students themselves (internal feedback) and to the teacher (external feedback).

To integrate the elements of adaptive personalization of learning into the electronic educational content of the mathematics course, the authors conducted a study based on the Department of Information Technology, a secondary vocational educational institution, «Of Aktobe Higher Polytechnic College». In this study, an attempt was made to integrate the following actual elements of personalized adaptive learning by including adaptive automated settings in Stepik:

- A collection of student data in real-time. The data is structured because there are ready-made ontologies and models inside the system, on which the collected information is superimposed.
- Educational analytics, that is, the generation of conclusions based on the evaluation of the learning strategy and the analysis of the collected data by methods of psychometrics and feedback tools.
- Personalization. Specific recommendations, individual tracks, and learning histories are created.
- The experimental work was carried out in four stages.
- At the first stage, the theoretical foundations and prerequisites of adaptive personalization were studied and analyzed as the main trend in the development of educational programs in modern conditions. Diagnostic methods were selected

to identify motivational, technological, content, cognitive, and reflexive criteria and indicators of the formation of mathematical competence.

- At the second stage, the theoretical concept of the study was clarified and corrected, and an experimental model of an electronic training course based on Stepik on the discipline «Mathematics» for 1-year college students and the corresponding didactic and methodological support of the educational process was developed.
- At the third stage, a training experiment was conducted, experimental verification of the e-learning course model due to automated feedback collection by Stepik means in an e-course on the discipline «Mathematics» for students of 1 year of study.
- At the fourth stage, theoretical understanding of the results of experimental work and their interpretation were carried out; the results of experimental work were formalized and conclusions were formulated; analysis, generalization, and systematization of the obtained data were carried out, the design of the study.

Figure 2 shows the stages of experimental work carried out.

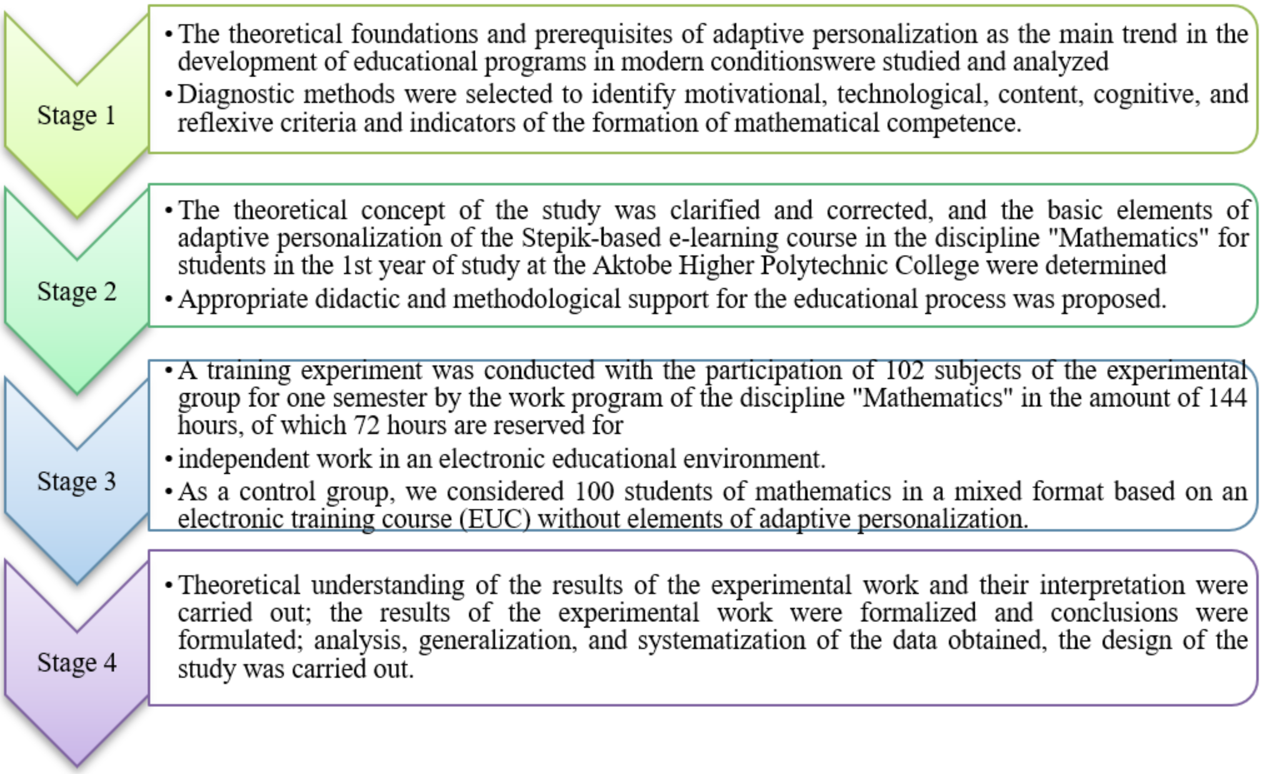

Figure 2.
Stages of experimental work

As part of the third stage, the task was defined the development of students' motivation for mathematical training in an electronic information and educational environment based on the Stepik learning management system, in which an electronic training course was developed for the organization of independent work of students. The expected result of the work was a steady motivation of students for mathematical training with the introduction of elements of adaptive personalization in the e-learning course.

An electronic training course with the use of adaptive personalization was developed at the Department of Information Technology in 2021-2022.

The structure of each module of the course and the individual route of its passage in the electronic course is nonlinear. The task system was developed taking into account the variability of achieving a certain level of knowledge in mathematics or according to the results of the student's previous tasks. Table 1 identifies three levels of assimilation of educational material during the course.

Table 1.
The scale of the system of assessment and accounting of educational achievements of students

Rating by a letter system	Points (% content)	Assessment according to the traditional system
A	95-100	Excellent
A-	90-94	
B+	85-89	Good
B-	75-84	
C+	60-74	Satisfactory
C-	0-59	Unsatisfactory

Depending on the result of the first task of the first section, the student gets access to the next task corresponding to his level of mastery of the material. For example, having scored over 75 points on the entrance test, the student gets access to tasks at the B+ and B- levels.

Figure 3 shows a typical scenario for completing an e-course module. To ensure a successful learning process with the achievement of the best result, constructive interaction between teachers and students is necessary. At the same time, the need for interaction is important for both the student and the teacher to receive feedback, including individual consultations. Even with the use of correspondence or mixed forms of education, this type of work remains. The scenario below shows the distribution of the roles of the course participants: the educator, the teacher, and the system. Due to Stepik's ability to perform automatic checks of students' work, the process of transition from module to module on the level of students' knowledge occurs «seamlessly», with built-in system tools. Setting up «threshold» tasks according to the level of mastery of mathematics is carried out in the «access restrictions» properties of Stepik elements. Figure 4 shows an example of configuring the properties of elements in an electronic course.

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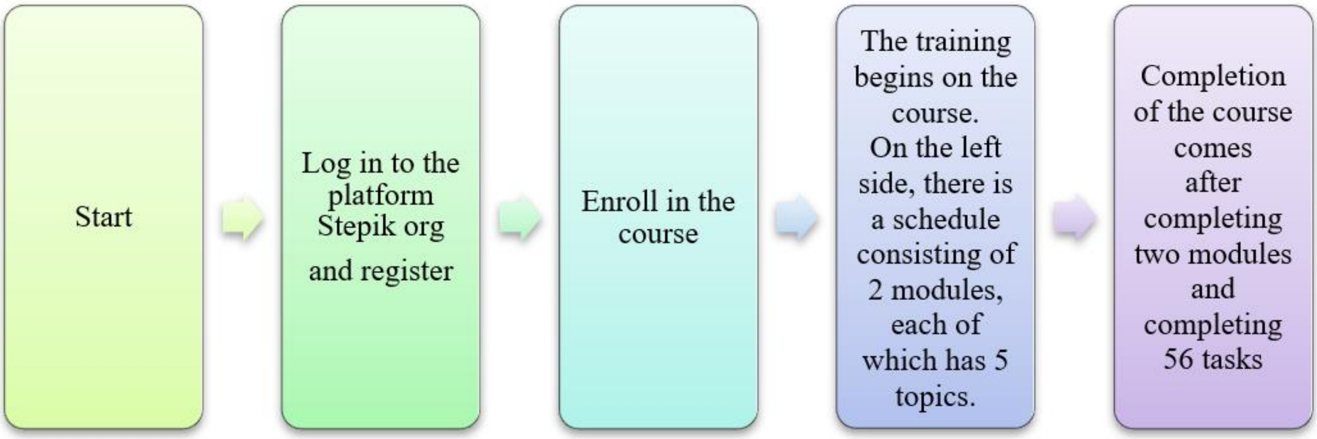
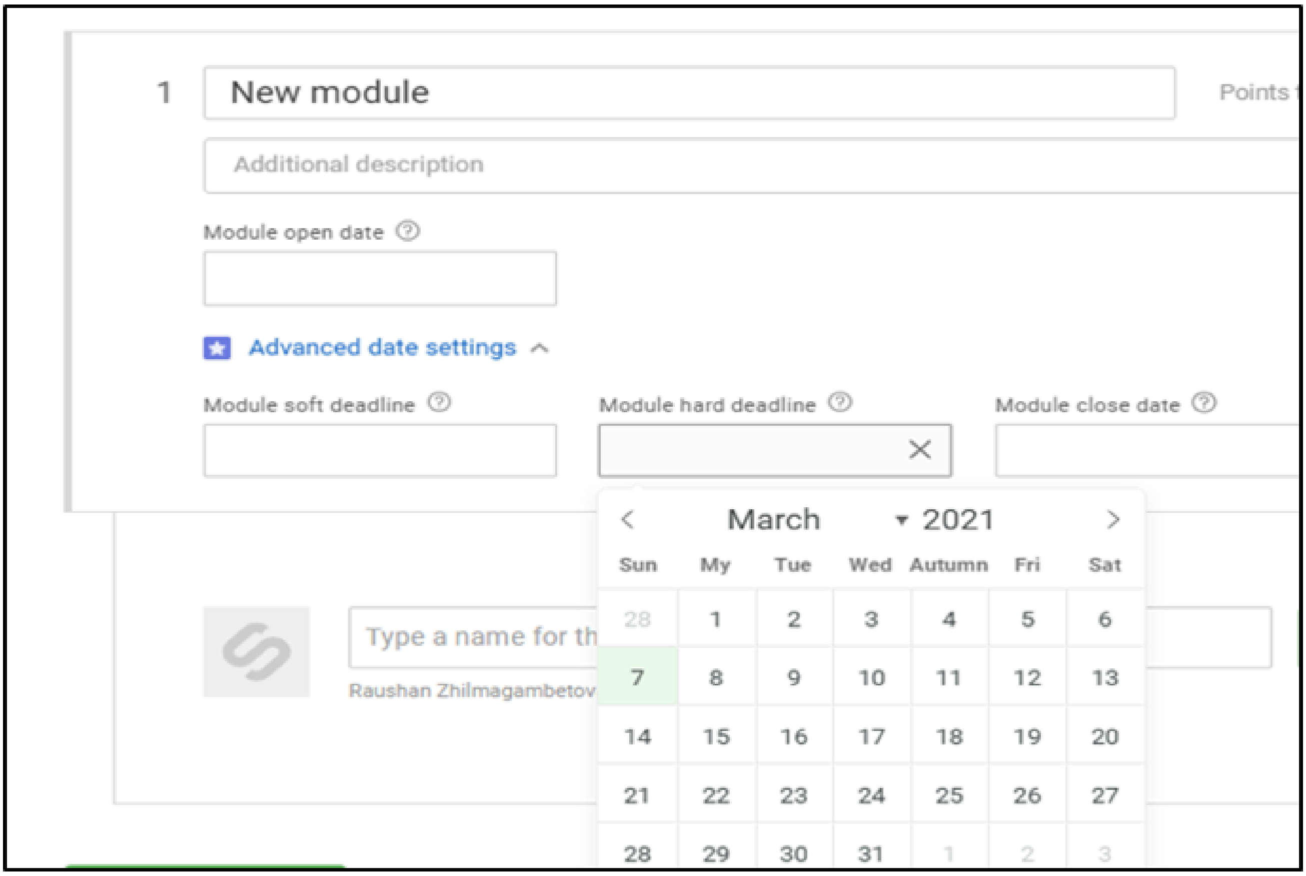


Figure 3.
Scenario of students passing the section of the electronic course in the discipline «Mathematics»

a)



b)

Figure 4.
Setting up individualization of training in an electronic course in the discipline «Mathematics»: a) a fragment of a module with restrictions; b) setting up the automated setting of dates and deadlines.

The purpose of the communicative stage of the experiment was to form the knowledge, skills, and competencies necessary for professional activity in first-year students when working with the electronic training course «A+ and A-, B+ and B-, C+ and C-». The organization of students' work in the process of studying mathematics in an e-learning environment has a special specificity, aimed at developing a set of mathematical knowledge, skills, and abilities, often associated with their future specialty. The expected result of the next stage of experimental work is the student's mastery of mathematics to form the mathematical culture of students at a level that meets the requirements of the current work program of the discipline «Mathematics». The purpose of the study at the reflexive stage of experimental work is to organize students' self-assessment of their achievements. The control stage of the experimental work was carried out to test the effectiveness of integrating elements of adaptive personalization of learning into electronic educational content in the discipline «Mathematics» for first-year students.

By the identified criteria and indicators of the formation of mathematical competence, the following levels are characterized: high A+ and A-, medium B+ and B-, and low C+ and C-.

The low level of formation of mathematical competence is characterized by an insufficient level of knowledge among students in the discipline «Mathematics», and a lack of motivation to study. The trainees have no desire to work independently in an electronic training course. Students with a low level of mathematical competence received from 0 to 75 points for completing all tasks.

The average level of mathematical competence formation presupposes a basic knowledge of the discipline «Mathematics» and mastering the basics of mathematical knowledge by students. Students are motivated and understand the importance of developing mathematical competence, but they lack theoretical and practical knowledge. Students with an average level of mathematical competence received from 75 to 89 points for completing all tasks.

The high level of mathematical competence formation is marked by the students' focus on achieving high results in the development of mathematical competence. There is a high level of motivation. Students received between 90 and 100 points for completing all tasks.

Comparative quantitative and qualitative analysis of the results of experimental work (Table 2) showed an increase in the level of formation of mathematical competence of 1st-year students, which indicates the effectiveness of the developed model.

Table 2.
The general level of formation of mathematical competence (FMC) of students at the ascertaining (AS) and formative (FS) stages of the experiment (in % of the total number of participants in the experiment)

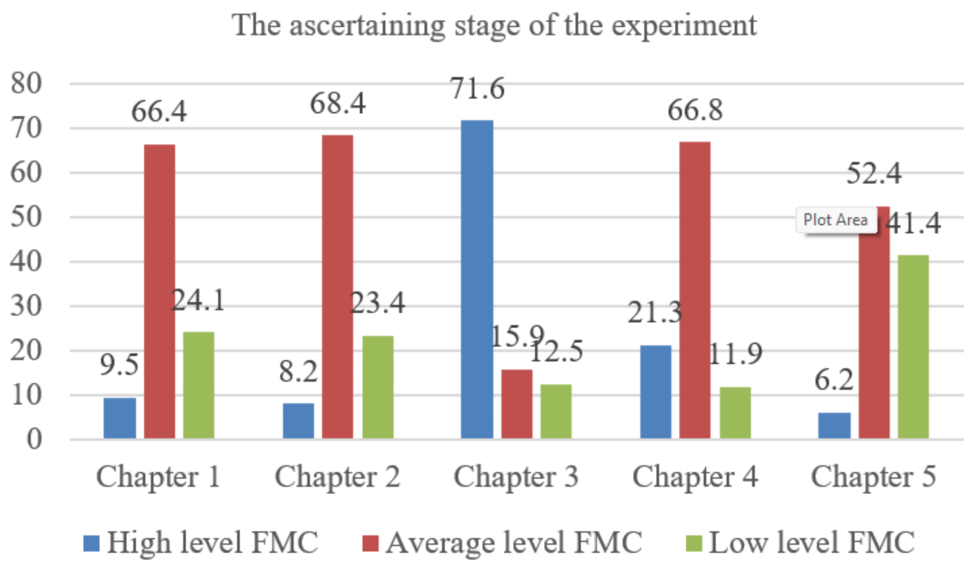
Category	Ascertaining stage (AS)			Formative Stage (FS)		
	High level FMC	Average level FMC	Low level FMC	High level FMC	Average level FMC	Low level FMC
Chapter 1	9.5	66.4	24.1	11.4	74.4	14.2
Chapter 2	8.2	68.4	23.4	10.1	72.4	17.5
Chapter 3	71.6	15.9	12.5	76.8	18.9	4.3
Chapter 4	21.3	66.8	11.9	27.0	69.4	3.6
Chapter 5	6.2	52.4	41.4	13.5	63.7	22.8

According to the 1st section of the electronic educational complex, 9.5% of respondents showed a high level of FMC at the AS experiment, and 11.4% of respondents at the FS (Figure 5). The average level of FMC is 66.4% of the subjects, respectively, and the growth of FMC is 74.4% of students. At a low level of FMC, 24.1% of respondents were registered at the AS and 14.2% of students, respectively, at the FS of the experiment.

According to section 2 of the electronic educational complex, a high level of FMC was noted in 8.2% of the subjects at the AS experiment; the level of FMC increased slightly to 10.1% of the respondents at the FS. The average level was 68.4% of the subjects, respectively, and the forming experiment showed an FMC of 72.4% of students. At a low level, 23.4% of respondents were registered at the AS and 17.5% of students, respectively, at the FS. According to section 3, 71.6% of students had a high level, followed by 76.8% of respondents. The average level at the AS is 15.9% of the subjects, respectively, and 18.9% of bachelors at the FS. At a low level, 12.5% of respondents were registered at the AS and 4.3% of students, respectively, at the FS.

According to section 4, the high level of FMC was 21.3% of respondents on the AS and showed 27.0% of respondents on the FS. The average level on the AS is 66.8% of the subjects, respectively, followed by 69.4% of the respondents on the FS. 11.9% of respondents on AS and 3.6% of respondents on FS were recorded at a low level.

According to section 5, the high level was 6.2% of the subjects on AS, and on FS - 13.5% of the respondents. The average level in the Experimental Group is 52.4% of the subjects; respectively, 63.7% of the students are in the FS. 41.4% of respondents in the AS and 22.8% of students in the FS were recorded at a low level.



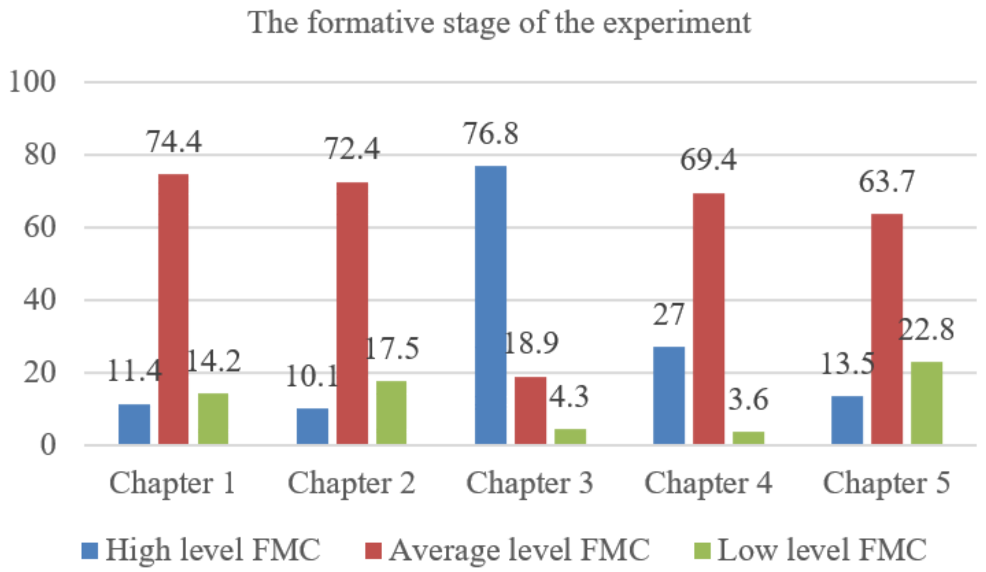


Figure 5.
Results of the stages of the experiment

Positive changes took place at the formative stage of the experiment (Figure 6). The number of students with high and medium levels of mathematical competence has increased. The number of respondents who revealed a low level of mathematical competence formation during the statement during the formative stage has decreased somewhat.

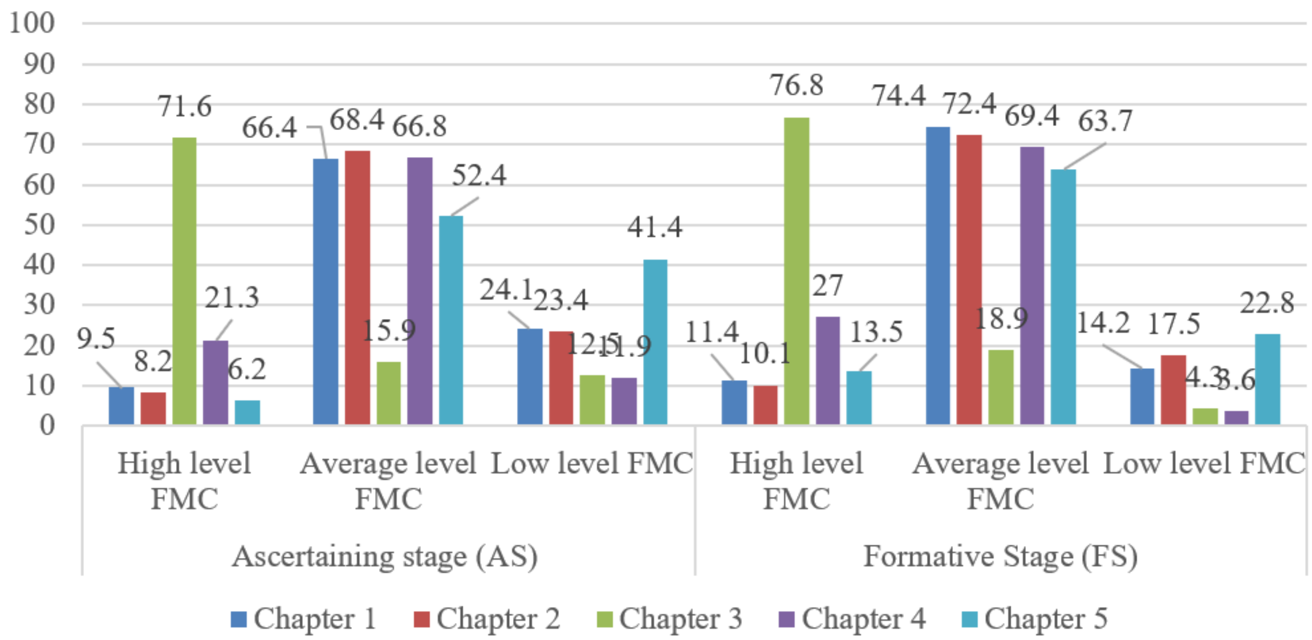


Figure 6.
The final diagram of the formation of mathematical competence of students.

Thus, the effectiveness of integrating elements of adaptive personalization of learning into the electronic educational content of the college mathematics course has been confirmed. At the end of the experiment, the number of respondents with a high level of mathematical competence increased, students showed motivation to work in an electronic information educational system, and a desire to improve and increase their level of mathematical competence due to the knowledge and skills acquired during the experiment.

4. Conclusion

The introduction of elements of adaptive personalization in the electronic course of the discipline requires teachers to make significant efforts to study the individual needs, characteristics, goals, and motivational attitudes of students. A detailed analysis of the data obtained allows for achieving high efficiency in methodological work aimed at developing an adaptive product. The conducted research confirms the positive impact of adaptive personalization on the formation of students' mathematical competence in the format of mixed mathematics education. Modern education management systems, in particular, the one used in the Stepik experiment, make it possible to effectively integrate adaptive automated settings into electronic content, providing greater flexibility and a student-centered educational environment.

The improvement of electronic educational resources in the aspect of adaptability to individual characteristics of students contributes to the increase of their internal motivation, satisfaction with academic performance, the development of academic autonomy, and optimization of the educational process through careful selection of priority «nodes» in the course content, which ultimately ensures the effective formation of mathematical competence. Personalized adaptive teaching of mathematics seems to be a promising area of research into innovative methods of teaching mathematics using information and communication technologies. The authors plan to continue the study of the introduction of personalized models of e-learning courses in mathematics as part of the implementation of various programs of the disciplines of the cycle «Mathematics».

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