

DOI: 10.32517/0234-0453-2022-37-4-25-33

MATHEMATICS E-LEARNING IN THE CONDITIONS OF BILINGUALITY

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Abstract

The world is going through a period of the rapid development of electronic learning systems. In addition, the creation of a digital educational environment and the formation of scientific ideas about using such systems in the educational process are currently taking place. This is of particular importance when teaching small-numbered indigenous peoples living in bilingual and multilingual regions. The article aims to develop an approach to organizing mathematics e-learning for students in a bilingual environment using mechanisms for adapting educational content to specific linguistic features. The study used scientific literature analysis and empirical methods. We suggest that adaptive e-learning courses be a means of e-learning in mathematics. They enable students to pursue an individual educational route and ensure content adaptation according to students' language and the national peculiarities of their perception of learning materials. The result of the present study is an individual educational route created in an adaptive e-learning course in mathematics in a bilingual environment. In the future, the results of the research can become an element in the methodological system of personalized adaptive learning aimed at the preparation of a university student in a bilingual environment.

Keywords: adaptive learning, bilingualism, personalization, math learning.

For citation:

Vainshtein Yu. V., Noskov M. V., Shershneva V. A., Tanzy M. V. Mathematics e-learning in the conditions of bilinguality. *Informatics and Education*. 2022;37(4):25–33. DOI: 10.32517/0234-0453-2022-37-4-25-33

ЭЛЕКТРОННОЕ ОБУЧЕНИЕ МАТЕМАТИКЕ В УСЛОВИЯХ БИЛИНГВАЛЬНОСТИ

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Аннотация

Сегодня происходит активное развитие электронных образовательных систем, создание цифровой образовательной среды и становление научных представлений об их использовании в образовательном процессе. Это приобретает особую значимость при обучении малочисленных коренных народов, проживающих в билингвальных и мультилингвальных регионах. Целью статьи является развитие подхода к организации электронного обучения математике студентов в условиях билингвальности с применением механизмов адаптации образовательного контента к языковым особенностям. В исследовании использованы методы анализа научной литературы и эмпирические методы. В качестве средства электронного обучения математике предлагаются адаптивные электронные обучающие курсы, позволяющие студенту двигаться по индивидуальному образовательному маршруту и обеспечивающие адаптацию контента по языковому аспекту и национальным особенностям восприятия учебными материалами. В результате построен индивидуальный образовательный маршрут в адаптивном электронном обучающем курсе по математике в условиях билингвальности. В перспективе результаты работы могут стать звеном методической системы персонализированного адаптивного обучения подготовки студента вуза в условиях билингвальности.

Ключевые слова: адаптивное обучение, билингвизм, персонализация, обучение математике.

Для цитирования:

Вайнштейн Ю. В., Носков М. В., Шершнева В. А., Танзы М. В. Электронное обучение математике в условиях билингвальности. *Информатика и образование*. 2022;37(4):25–33. (На англ.) DOI: 10.32517/0234-0453-2022-37-4-25-33

1. Introduction

The national policy of the modern state sets the task of accelerating the introduction of digital technologies in all spheres of life, including education. Today there is an active development of electronic educational systems, the development of new adaptive and practice-oriented educational programs, the creation of a digital educational environment and the formation of scientific ideas about their use in the educational process. The introduction of digital technologies of big data processing and intelligent information technologies into education is one of the most significant processes defining the era of digitalization.

Currently, it can be seen that traditional educational technologies are being replaced by electronic technologies, the peculiarity of which is the focus on achieving personal educational results, taking into account the individual characteristics of students and monitoring their own progress. This opens up new opportunities for students, including when teaching small indigenous peoples living in bilingual and multilingual regions of the country. It should be noted that their educational process directly depends on the level of knowledge of the language in which the training is conducted. This situation is quite common not only in Russia (Tuva, Yakutia, Chuvashia, etc.), but also abroad (USA, Canada, etc.). For the full inclusion of such students in training, it is important to provide equal educational opportunities, providing along with the formation of subject competencies, the formation of foreign language competence (knowledge of the language in which the training is conducted) with the preservation of the national language. In our case, it is the organization of e-learning in the conditions of national-Russian bilingualism.

Based on the analysis of research in the field of e-learning using modern digital and pedagogical technologies, we will highlight the following areas: conceptual foundations of digital transformation of education and the introduction of digital technologies [1, 2]; approaches, methods and algorithms for personalization of education [3–5]; programmable and adaptive learning [6–10]; development of e-learning courses and resources [11, 12]; construction of individual educational routes taking into account cognitive and personal characteristics [13–15]; formation of the “digital double” of the learner and prediction of the behavior of the learner [16, 17]; development of algorithms for the implementation of innovative educational strategies and adaptation mechanisms in learning systems and environments [17–20]; development of electronic bilingual environment [21–23]. These studies have made a serious contribution to the development of e-learning, which, of course, has increased its potential. At the same time, it should be noted that the directions mainly develop separately and are poorly integrated with each other. The situation of a total transition to online education that has arisen in connection with the spread of a new

coronavirus infection has stimulated the need for the development of methods of electronic subject learning. This actualizes the problem of developing complex innovative pedagogical and technological solutions that provide training in an electronic information and educational environment.

It is necessary to develop and implement such educational approaches, which, along with the pragmatic nature of the focus of e-learning on the formation of subject educational results and professional competencies, will be aimed at the development and self-development of the individual, including work with physical and psychophysical qualities. It is important to lay down such forms and methods of project and team work in an electronic environment that will allow developing organizational competencies. The development and integration of e-learning implementation models will radically restructure the educational process in accordance with the characteristics of a new generation of students brought up on the Internet and new forms of social communication.

It can be stated that adaptive learning is singled out by many researchers as a promising e-learning technology. Its main purpose is the organization of the educational process in an electronic environment, which ensures the variability of educational content taking into account the individual characteristics of the student [22].

At the same time, the use of adaptive learning for students in the educational process is accompanied by the construction of individual educational routes for them to master the discipline based on a wide range of individual characteristics, including cognitive and personal characteristics of students. The list of individual characteristics of students is very wide and may include levels of educational results, motivation, reflection, activity, styles of perception of educational content, etc. It should be noted that the choice of the characteristics to be taken into account is determined by the teaching methodology, and can also be dictated by the specifics of the subject area of the discipline, the field of professional activity and is associated with regional peculiarities.

In the educational process of the university, the study of mathematics plays a system-forming and key role, developing cognitive abilities, logical, analytical and creative thinking of students, which contributes to their further productive learning. Teaching mathematics is carried out in the initial courses of study and is the foundation for the preparation of a student of any educational direction in the higher education system.

The purpose of this work is to develop an approach to the organization of e-learning of mathematics for students in conditions of bilingualism with the use of mechanisms for adapting educational content to language features. As a means of e-learning mathematics, it is proposed to use adaptive e-learning courses that allow the student to move

along an individual educational route that provides personalization of the educational process.

2. Materials and methods

When forming the conceptual and terminological field of e-learning in mathematics in the conditions of bilingualism and identifying the features of its provision in the conditions of intensive development of digital technologies in the world and Russian educational system, the method of comparative analysis of psychological, pedagogical, scientific and methodological literature on the research problem was used.

Content analysis of the concepts of “e-learning”, “adaptive learning”, “individual educational route”, “bilingualism” and analysis of scientific literature reflecting the didactic potential of the electronic information and educational environment of the university allowed us to determine the possibilities of developing methods for constructing individual educational routes in adaptive e-learning courses and to determine the means of their technical implementation in LMS Moodle. As a pedagogical basis for the construction of adaptive e-learning courses in an electronic environment, a multi-paradigm approach is used, which is an open, consistent cluster of approaches to learning.

Empirical methods (questionnaires, testing, observation of students) were used to obtain feedback on the educational results being formed. These methods made it possible to obtain information about real changes in the educational results of e-learning mathematics in conditions of bilingualism, involvement in the educational process and activation of students’ activities in an electronic environment.

Within the framework of the agreement on network cooperation between the Institute of Space and Information Technologies of the Siberian Federal University and Tuvan State University of the Russian Federation, 104 bachelors of the first and the second year of the Faculty of Physics and Mathematics of Tuvan State University were involved in testing the hypothesis of the study: experimental (53 students) and control (51 students) groups. The experiment was carried out when teaching mathematical disciplines in 2019–2021. To process the results and evaluate the effectiveness of the implementation of the developed adaptive e-learning course in the educational process, a comparison of educational results in the control and experimental groups at the beginning and end of the discipline study using the Student’s t-test was carried out.

3. The structure of the adaptive e-learning course in conditions of bilingualism

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as

the experimental conclusions that can be drawn. The Republic of Tuva is somewhat isolated from the rest of Russia and has a special national culture [24]. In the republic, the percentage of the population for whom the Tuvan language is their native language is significantly higher than in other national entities. This leads to the fact that many applicants speak Russian only at the level of understanding everyday issues. In some areas of Tuva, the Russian language is studied in conditions of almost complete isolation from the language and culture and the level of its knowledge (especially in remote areas) is determined only by contact with the teacher and the school. This leads to the emergence of language conservation and creates a special problem in the organization of training, when along with the formation of subject competencies, it is necessary to form Russian-language competence, since education is conducted in Russian at the university [23].

The authors propose to organize mathematics education in the conditions of Russian-Tuvan bilingualism with the use of adaptive e-learning courses. It is important to take into account the degree of proficiency in the Russian language of the student and to provide the joint formation of both mathematical and Russian-speaking competence in the process of creating the courses. At the same time, one of the educational tasks is to master the teaching materials and pass the certification in the discipline entirely in Russian.

Consider the construction of adaptive e-learning courses (AELC). As a software environment for their implementation, the authors selected the LMS Moodle distance learning system, which has the functionality of implementing educational content mechanisms through the accessibility settings of educational course elements. This is due to the fact that the construction of e-learning systems in higher education in Russia is carried out mainly on the basis of learning Management Systems (Learning Management System — LMS), including Blackboard and Moodle, which accumulate a large amount of data related to the educational activities of students. The development of approaches and technological solutions to the creation of adaptive e-learning courses and resources in LMS, the functionality of which includes personalization, analytics, consulting and evaluation of training based on available data sets, is becoming relevant. Note, however, that the organization of adaptive learning in LMS is a difficult pedagogical and instrumental-technical task. This is due to the fact that the methodology of using adaptive e-learning courses that provide students with an individual educational environment, the theoretical and practical material of which is focused on their individual characteristics, has not yet been sufficiently developed.

Adaptive e-learning courses are being created at the Institute of Space and Information Technologies of the Siberian Federal University of the Russian Federation, the adaptation of educational content in which is carried out depending on the level of assimilation of educational

material or the individual style of the student [13]. The adaptive e-learning course of the discipline is proposed to be understood as an educational resource presented in electronic and digital form, which includes a structure and subject content that allows for flexible adaptation for students depending on their individual characteristics.

When building AELC in LMS Moodle, it is proposed to represent it with a set of models: a model for the presentation of educational content, a user model, a model for the adaptation of educational content and a model of a competence framework (evaluation of learning outcomes) (fig. 1).

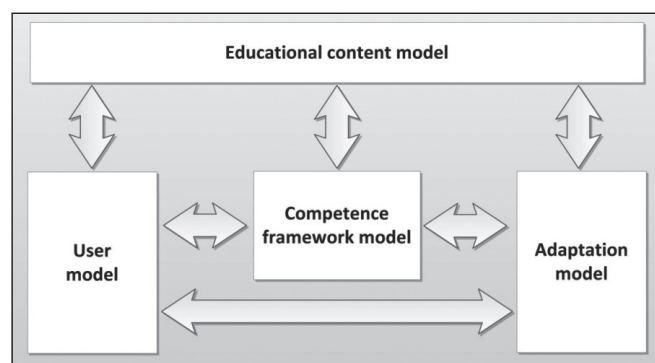


Fig. 1. The structure of the adaptive e-learning course

Let's take a closer look at the content of the models. In the model of presentation of educational content, it is proposed to use an approach based on the integration of logical-epistemological methods of the ratio of the volume and content of concepts by E. K. Voishvillo with the methods of taxonomic hierarchy based on the theory of graphs and hypergraphs [25]. All concepts of the course are arranged in the form of a hierarchical structure — a tree of concepts or a set of concept trees. The concept tree is used as a basis for allocating minimal portions of theoretical material — terms. By the term we mean a sequence of semantic facts and procedural rules having semantic completeness. That is, each term represents some fragment of the tree of discipline concepts. The criteria for including concepts in it are:

- volume restriction — each term contains no more than five concepts; if the concept is information-rich, it can be allocated to a separate term;
- completeness — when forming a term, the approach of embedding small structural units into large ones is implemented;
- verifiability — all concepts of the term allow the possibility of checking their assimilation.

Determining the sequence of studying terms allows you to correlate the concepts included in the term with their place in the overall structure of the discipline and contributes to the formation of its holistic perception.

Personalized educational content and control and measuring materials are generated for each term. The presentation of such content is carried out on the basis of hybridization of heterogeneous forms of digital storytelling: multimedia longreads, podcasts,

as well as complexes of educational step-by-step digital simulators. That is, as a result, the educational content of the adaptive course is a set of semantically related educational objects. This allows you to formalize the educational material and build logically justified sequences of its study, which is especially important when studying mathematical disciplines.

At the same time, the educational content focuses on the individual characteristics of students presented in the AELC user model, based on the development of approaches to building a trainee model in automated training systems. Its main purpose is the dynamic adjustment of parameters for the implementation of adaptive learning management in an electronic environment.

The range of adaptation parameters can be different depending on the discipline, on the goals of the educational process. All parameters of the user model are proposed to be divided into two groups: parameters designed to control the student's activity in an electronic environment, and parameters used in the adaptation of educational content. The first group of parameters includes the results of monitoring the student's learning process: his current position in the course; the time spent on studying each term and completing tasks; the number of effective logins to the system.

Based on the experience gained by the authors in the development and implementation of adaptive e-learning courses, the second group of parameters includes the language characteristics of the trainees, the learning style (individual characteristics of the perception of information of students), the level of motivation and the results of mastering each term. Various combinations of adaptation parameters were used in the process of testing AELC, which imposes certain conditions on the development of educational content: features and form of presentation of educational objects.

When teaching foreign students or students of small-numbered peoples of Russia in the conditions of bilingualism, the adaptation of content according to the linguistic aspect and national characteristics of the perception of educational materials by students becomes relevant. Interesting results were obtained when constructing the educational process using AELC for students of the Republic of Tuva with different levels of parallel proficiency in their native Tuvan and Russian languages. When developing educational content, the methodological technique "Variation of language communication techniques" was used, which is aimed at using two parallel working languages — Tuvan and Russian to create the best learning conditions for students in terms of accessibility and perception of the studied material [23]. Language adaptation can be applied to other indigenous peoples of Russia.

It is known that the perception of educational material is based on the perceptual modality, that is, the dominant channel of perception and processing of information: auditory, visual, kinesthetic or digital. The dominant channel of information perception is

unstable and can change during a person's life, but when considering it in such a short time interval as the study of a discipline, it can be considered a constant. In accordance with the type of perception identified in the learner, the appropriate training material is recommended in the AELC. For example, for auditory — the sound form of representation, visual — graphic-presentation, and for kinesthetic — spatial-dynamic. But at the same time, the possibilities of independent choice of content are open for the student. This approach makes it possible to choose the form of presentation of terms in order to facilitate the process of mastering the discipline material.

The level of motivation is determined on the basis of a questionnaire designed to measure the severity and type of motivation for learning activities, developed by T. O. Gordeeva, O. A. Sychev and E. N. Osin. Modification of the questionnaires in terms of instructions and questions was carried out regarding the context of teaching mathematics in an electronic environment. The control of the level of motivation of students when studying at the AELC is due to the problems associated with the difficulties of involving and retaining students in an electronic environment. For this purpose, the educational content of the AELC is accompanied by a developed gamification system, which acts as an effective means of increasing motivation and involving students in the educational process.

As the main parameter of the adaptation of educational content to the individual characteristics of the student, it is proposed to use the level of assimilation of the current material. In the case of unsatisfactory results of assimilation of each studied term, the material is automatically offered in a more accessible form of presentation, for example, using other examples and the level of detail.

The model of adaptation of educational content includes an algorithm for implementing an educational strategy that provides automatic navigation of the educational process in AELC by integrating and developing adaptive management methods, as well as algorithms and methods for constructing individual educational routes that take into account the individual characteristics of participants in the educational process in AELC. Each element of the educational content (thermo material, test, task, simulator) has certain settings due to the capabilities of the learning management system.

The adaptive electronic educational course implements two types of adaptation: current and evaluative-corrective. In the process of current adaptation, an individual educational route is automatically implemented for each student and a personal space of educational materials is formed, filled with content focused on the individual characteristics of the student and “adjusting” to his level of assimilation. Evaluative-corrective adaptation is aimed at evaluating and correcting the normative values of the parameters in the user's model, determined on the basis of expert evaluation.

The model of the competence framework (assessment of learning outcomes) in AELC is based on a modern approach of determining educational outcomes in the context of digital transformation of education, on methods of system analysis, multidimensional data analysis, expert assessments and pedagogical methods of assessing knowledge, skills, abilities and competencies in higher education.

At the same time, it is worth emphasizing that the advantages of organizing training with the use of AELC, along with the formation of subject educational results, would like to include the possibility of constant monitoring and implementation of feedback mechanisms, accessible and prompt communication of participants in the educational process (students and teachers), the formation and development of skills of independent and collective work, increased motivation and involvement of students in the educational process. We believe that the adaptive e-learning course has a good potential for adapting the educational environment to the individual characteristics of students and organizing subject-based learning in the electronic information and educational environment of the university.

4. Results

When designing an adaptive training course in higher mathematics, educational content is a set of terms — microportions of educational material presented in several editions of the presentation, differing from each other in the degree of use of the Russian language. Edition of the educational material, designed for students with a low level of knowledge of the Russian language, is formed in parallel in Tuvan and Russian languages. This creates opportunities for students to adapt to learning in new conditions. The following edition of the material is designed for students with an average knowledge of the Russian language, i. e. Russian is spoken at the everyday level and contains statements and definitions in Russian and is accompanied by a translation into Tuvan, including a glossary of mathematical terms. The number of Russian-language fragments of each term increases from edition to edition and reaches a completely Russian-language version.

When structuring the subject area of mathematical disciplines with a volume of 30 credits (1080 hours), 168 terms of the AELC educational content were formed in three editions of the presentation, and 276 terms were included in the glossary of the subject area.

Let's consider the representation of the educational content of the term “Matrix”. For example, in the Russian version, the concept of a matrix is presented as follows.

A matrix is a rectangular table of any elements (numbers, letters, other objects), which consists of m rows and n columns.

For students who do not speak Russian, the concept is presented in Tuvan.

Table

Fragment of the Russian-Tuvan glossary AELC

The concept in Russian	The concept in the Tuvan language
A system of equations is a set of equations with unknowns, for which it is required to find the values of unknowns that satisfy all the equations simultaneously.	Деңнелгелер системазы — дээрге чаңгыс угда шупту деңнелгелерни хандырып турар билдинместерниң ужурутказын тыварын негеп турар билдинбестерлиг деңнелгелерниң ниитизи.
A matrix is a rectangular table of any elements (numbers, letters, other objects), which consists of m rows and n columns.	Матрица — дээрге кандыг бир чуулдерниң (саннар, ужуктер болгаш оон даа оске) доора болгаш узун дургаар одуруглардан тургустунган тодаргай таблица.
The determinant is a numerical characteristic of a square matrix.	Определитель — дээрге ийиги чаданың матрицазының саннар шынары.
The determinant of the 2nd order is a number equal to the difference between the products of the elements standing on the main diagonal and the products of the elements standing on the side diagonal.	Ийи дугаар порядоктуң определители дээрге кол диагональдың кежигуннериниң коудээшкининден болгаш побочный диагональдың кежигуннериниң коудээшкинин казып каан саны.
The rank of the matrix is equal to the number of non-zero rows after reducing the matrix to a stepwise form using elementary transformations over the rows and columns of the matrix.	Матрицаның рангызы дээрге доора болгаш узун дургаар одуругларның бодуунчуткен оскерлишкиннер соонда чадаланчак хевиринге кириген, тикке ден эвес доора одуругларның санны.
Vector — a directional segment indicating the beginning and end.	Вектор — дээрге эгезин болгаш тончусун айтыпкаан угланышкынның кезиндек.
Function — if each value of x is assigned one specific value of y according to some rule or law, then it is said that y is an unambiguous function of x and is denoted by $y = f(x)$.	Функция — дээрге кандыгла бир x бурузунге бир ле дурум езугаар чаңгыс y тодаратынып турар болза, ону y -тин чаңгыс уткалыг x -тен функциязы дээр, ынчангаш ону бижири $y = f(x)$.
The derivative of the function $f(x)$ at a point is called the limit of the ratio of the increment of the function to the increment of the argument. Denoted by $f'(x) = \lim_{\Delta x \rightarrow 0} \frac{\Delta f(x)}{\Delta x}$	$f(x)$ деп функциянын x, точкада производнаязы дээрге функция приращениезиниң аргументи приращениезинге хамаарылгазынын предели. Бижири: $f'(x) = \lim_{\Delta x \rightarrow 0} \frac{\Delta f(x)}{\Delta x}$

Матрица — дээрге кандыг бир чуулдерниң (саннар, ужуктер болгаш оон даа оске) доора болгаш узун дургаар одуруглардан тургустунган тодаргай таблица.

For students who have a poor command of the Russian language, the material contains statements and definitions in Russian, but is accompanied by a Russian-Tuvan glossary of mathematical terms, a fragment of which is presented in Table.

The educational content of the AELC also contains mathematical objects that have an applied meaning and have a national, ethnic flavor. For example, when studying analytical geometry, we include in the AELC educational material related to the consideration as a mathematical model of the Tuvan yurt — a traditional dwelling in the conditions of nomadic life [26]. At the same time, the yurt presented in the exposition of the National Museum of the Republic of Tuva acts as a real ethnic source of research, which is a visual example of the formation of spatial thinking, motivation for learning, and also vividly demonstrates the natural beauty of geometry, Figure 2.

The AELC provides automated navigation between the editions of the material not only at the level of understanding of the Russian language, but also on

the basis of the level of assimilation of the educational material. Students are offered a revision of the educational material for study. Then an automated check of its assimilation is carried out and, depending on the results obtained, if problems are identified:

- with the assimilation of educational material that are of a linguistic nature, an edition of the educational material is automatically proposed with an increase in the volume of material in the Tuvan language and corresponding to its current level of proficiency in Russian;
- related to the lack of understanding of the material in the AELC, consulting assistance is provided, in the form of suggestive automatic prompts and explanatory examples on the training material, implemented through test simulators.

Adaptation mechanisms are implemented in the AELC by designing a database of rules for the selection of educational content and linking them to the relevant elements of the AELC, the access of trainees to which carries out their activation under specified conditions.

For example, a rule that automatically presents the term of educational content in a different version of the presentation, provided that the student has mastered



Fig. 2. Fragment of an adaptive e-learning course

the educational material and has shown a high level of proficiency in Russian, is set as follows:

```

IF
  [Parameter "Proficiency in Russian" := "High"
  AND
  Parameter "Level of assimilation of term I" :=
    = "High" (from 78% and above)]
THEN
  [Parameter "Availability of term i+1" := TRUE
  AND
  Parameter "Revision" := "Revision With"
  AND
  Parameter "Detail" := "Basic"].
  
```

Each term also includes elements of an adaptive e-learning course, such as simulator tasks that provide step-by-step solution of complex multi-step tasks and individual project tasks with mutual peer review of works.

The proposed approach has been tested in the educational process of bachelors of Tuvan State University.

The empirical basis of the study was the educational results and the results of a survey of bachelors of the Faculty of Physics and Mathematics of Tuvan State University of experimental and control groups who studied mathematical disciplines using an adaptive e-learning course that forms individual educational routes and without it.

The survey of the experimental group demonstrated a positive reaction of students to the introduction of AELC in the study of mathematical disciplines. For example, when assessing the adaptability of the AELC educational content, 50,9 % of respondents noted the option "high level of adaptability", 32.1 % considered "the level of adaptability rather high", 17 % considered the level of adaptability average, the options "low" or "rather low" students did not choose. 71.7 % of students

noted an increase in motivation to study the discipline in an adaptive electronic educational course, 24.5 % found it difficult to answer this question and only 3.8 % found the proposed approach rather uninteresting, no one spoke out for the complete lack of interest in adapting mathematical content. 84.9 % of students noted that studying the discipline in AELC contributes to a better assimilation of mathematics compared to traditional teaching, 1.9 % noted the insignificance of the proposed approach and 13.2 % found it difficult to answer this question.

To assess the effectiveness of the introduction of the developed adaptive e-learning course into the educational process, a comparison of educational results in the control (CG) and experimental group (EG) at the beginning and end of the study of the discipline using the Student's t-test was carried out. The null hypothesis that was tested was that the study groups do not differ in educational results regardless of the approach used in teaching. The experimental hypothesis was that EG students have higher educational results, that is, the differences between the results of the groups are statistically significant. At the beginning of the experiment, there were no statistically significant differences in the groups, since $t_{emp} = 0.8$ is less than $t_{cr} = 2.61$ at a significance level of 0.01. At the end of the experimental work, we obtained $t_{emp} = 3.1$. Since $t_{emp} > t_{cr}$, the experimental hypothesis is accepted with a 99 % probability that the compared groups differ significantly with higher educational results of the experimental group.

The dynamics of the formation of mathematical and Russian-speaking competence in the control and experimental groups when teaching mathematics is shown in Figure 3. The assessment of the level of competence formation of each student was carried

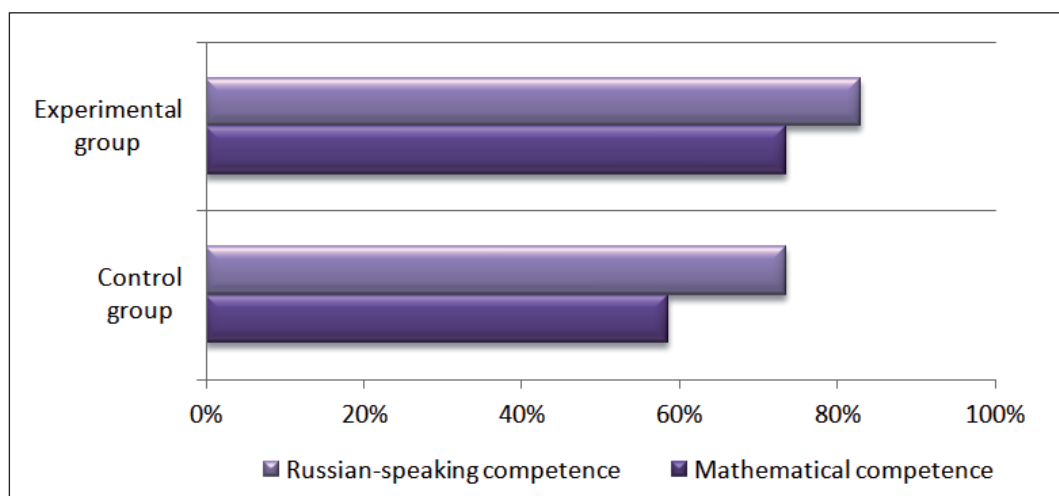


Fig. 3. The dynamics of the formation of mathematical and Russian-speaking competence

out on a 100-point scale. The histogram shows the average values of the formation of each competence in the control and experimental groups at the end of the experiment, translated into percentage components.

The use of adaptive e-learning courses in the educational process, which ensure the adaptation of educational content when teaching mathematics in the conditions of Russian-Tuvan bilingualism, allowed the formation of Russian-speaking competence along with mathematical competence. In the future, it is planned to optimize the adaptation mechanisms of the AELC by including in the database of rules for the selection of content the conditions for taking into account the activity of students in the electronic information and educational environment.

5. Conclusions

Authors should discuss the results and how they can be interpreted from the perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.

A feature of the presented work is the construction of an individual educational route in an adaptive e-learning course in mathematics in the conditions of bilingualism. The experimental results obtained in the work can be interpreted as confirming the effectiveness of teaching using an adaptive e-learning course that forms individual educational routes and an individual space of teaching materials of mathematical disciplines for students of the Republic of Tuva.

We see further development of adaptive learning in an electronic environment in the design and construction of educational process management models that ensure the intensification of educational processes in an electronic environment in the context of the implementation of various forms of e-learning and distance learning technologies (blended learning, web-enabled learning, training in mass open online courses,

etc.). The approach proposed in the article is significant for the development of educational approaches in the conditions of the epidemiological situation caused by the pandemic and the total transition to the use of exclusively e-learning, and can also contribute to the creation of a scientific base for further research in the field of digitalization of education. And there is no doubt that the results of the work can become a link in the methodological system of personalized adaptive training of a university student in conditions of bilingualism.

References

1. Uvarov A. Yu., Dvoreckaya I. V., Frumin I. D., Gejbl E., Karlov I. A., Merzalova T. A., Sergomanov P. A., Zaslavsky I. M. Difficulties and prospects of digital transformation of education. Moscow, NIU VShE; 2019. (In Russian.) DOI: 10.17323/978-5-7598-1990-5
2. Elliott S. W. Computers and the future of skill demand. Paris, OECD Publishing, France; 2017.
3. Andryushkova O., Grigoriev S. The influence online learning quality criteria selection on negentropy. *IEELM-DTE 2020 — Proceedings of the 4th International Conference on Informatization of Education and E-Learning Methodology: Digital Technologies in Education*. Krasnoyarsk; 2020;(2770):127–139.
4. Peng H., Ma S., Spector J. M. Personalized adaptive learning: An emerging pedagogical approach enabled by a smart learning environment. *Smart Learning Environments*. 2019;6(9). DOI: 10.1186/s40561-019-0089-y
5. Fisher J., White J. Takeaways from the 2017 blended and personalized learning conference. Available at: <https://www.gettingsmart.com/2017/10/17/takeaways-from-the-2017-blended-and-personalized-learning-conference/>
6. Komleva N.V., Vilyavin D.A. Digital platform for creating personalized adaptive online courses. *Open Education*. 2020;24(2):65–72. DOI: 10.21686/1818-4243-2020-2-65-72
7. Skinner B.F. Teaching machines. *Science*. 1958;(128(3330)):969–977. DOI: 10.1126/science.128.3330.969
8. Brusilovsky P. Adaptive and intelligent technologies for web-based education. *Künstliche Intelligenz*. 1999;13(4):19–25. Available at: <http://www2.sis.pitt.edu/~peterb/papers/KI-review.pdf>
9. Rizvi S. et al. Culturally adaptive learning design: A mixed-methods study of cross-cultural learning design preferences in MOOCs. *Open World Learning*. Routledge. 2022:103–115. DOI:10.4324/9781003177098-9

10. Dolasinski M. J., Reynolds J. Microlearning: A new learning model. *Journal of Hospitality & Tourism Research*. 2020;44(3):551–561. DOI: 10.1177/1096348020901579

11. Šimko M., Bielikova M. Lightweight domain modeling for adaptive web-based educational system. *Journal of Intelligent Information Systems*. 2019;(52):165–190. DOI: 10.1007/s10844-018-0518-3

12. Bray B., McClaskey K. Make learning personal: The what, who, WOW, where, and why. Thousand Oaks, California, Corwin Press; 2014.

13. Tayebinik M., Puteh M. Blended learning or e-learning? *International Magazine on Advances in Computer Science and Telecommunications*. 2012;3(1):103–110. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2282881

14. Vainshtein Yu. V., Shershneva V. A., Esin R. V., Noskov M. V. Individualisation of education in terms of e-learning: Experience and prospects. *Journal of Siberian Federal University. Humanities and Social Sciences*. 2019;12(9):1753–1770. DOI: 10.17516/1997-1370-0481

15. Nazarova V. Y., Ostapenko M. S. Individual educational paths. *E3S Web of Conferences*. 2021;(266(2)):05001. DOI: 10.1051/e3sconf/202126605001

16. El-Sabagh H. A. Adaptive e-learning environment based on learning styles and its impact on development students' engagement. *International Journal of Educational Technology in Higher Education*. 2021;18(1):1–24. DOI: 10.1186/s41239-021-00289-4

17. Ilyin V. D. The model of the cooperative problem solver based on digital twins. *Systems and Means of Informatics*. 2019;29(2):172–179. DOI: 10.14357/08696527190215

18. Zaharova I. G. Machine learning methods of providing informational management support for students' professional development. *Education and Science Journal*. 2018;20(9):91–114. DOI: 10.17853/1994-5639-2018-9-91-114

19. Tsibulskii G. M., Vainshteyn Yu. V., Esin R. V. Developing adaptive e-learning courses in the LMS Moodle. Krasnoyarsk; 2018.

20. Dagger D., Wade V., Conlan O. Personalisation for all: Making adaptive course composition easy. *Educational Technology and Society*. 2005;8(3):9–25. Available at: <https://www.jstor.org/stable/jeductechsoci.8.3.9>

21. Taryma A. K., Shershneva V. A., Vainshtein Y. V. Development of professional ICT competence for future teachers of the Tuva republic under the conditions of bilingualism. *Perspectives of Science and Education*. 2019;40(4):27–90. DOI: 10.32744/pse.2019.4.7

22. Vainshtein J., Noskov M., Shershneva V., Tanzy M. Adaptation of educational content when learning mathematics in bilingual condition. *IEELM-DTE 2020 — Proceedings of the 4th International Conference on Informatization of Education and E-Learning Methodology: Digital Technologies in Education*. Krasnoyarsk; 2020;(2770):65–71. Available at: <http://ceur-ws.org/Vol-2770/paper9.pdf>

23. Shershneva V., Vainshtein Y., Kochetkova T. Adaptive system of web-based teaching. *Program Systems: Theory and Applications*. 2018;9(4):179–197. DOI:10.25209/2079-3316-2018-9-4-159-177

24. Lamajaa Ch. K. Tuvinology: the new horizons. M., Librocom Publishers; 2013.

25. Vainshtein J., Esin R., Tsibulsky G. Constructing domain model based on logical and epistemological analysis.

IEELM-DTE 2020 — Proceedings of the 4th International Conference on Informatization of Education and E-Learning Methodology: Digital Technologies in Education. Krasnoyarsk; 2020;(2770):140–146. Available at: <http://ceur-ws.org/Vol-2770/paper18.pdf>

26. Tanzy M. V., Saaya S. K., Shershneva V. A., Vainshtein Y. V., Ondar C. M. The yurt as a geometric model in teaching mathematics. *The New Research of Tuva*. 2020;(4):80–91. DOI: 10.25178/nit.2020.4.6

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Поступила в редакцию / Received: 01.07.2022.

Поступила после рецензирования / Revised: 15.07.2022.

Принята к печати / Accepted: 02.08.2022.