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EFFICIENCY OF E-LEARNING FOR MATHEMATICS STUDENTS DURING QUARANTINE

EFICIENCIA DEL E-LEARNING PARA ESTUDIANTES DE MATEMÁTICAS DURANTE LA CUARENTENA

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ABSTRACT

The paper examines the opportunities to use e-learning technologies to improve the efficiency of the learning process based on the example of implementing online training courses and mathematical disciplines on the Moodle platform. The study finds that the laws of grade distribution in mathematical disciplines significantly vary between traditional and online learning. In traditional training, the law of distribution can be considered close to normal, in e-learning, the law of distribution should be defined as bimodal. In other words, students in the academic group should be split into two subgroups based on the results of e-learning: one of students who started learning better and the other – of those who went the opposite way. Student's t-test demonstrates that the average grades of the two subgroups in e-learning differ with a 95% reliability. This indicates that the academic group should be viewed as consisting of two sets with dissimilar characteristics. Analysis of the efficiency of the implementation of e-learning demonstrates the promise of using this method in the study of mathematical disciplines. Further development of e-learning should focus on the development of individual and personalized approaches to training that promote the activization of the learning process for all students.

Keywords:

E-learning, independent work, personalized learning system, content level, interactive level, learning efficiency.

RESUMEN

El documento examina las oportunidades de utilizar tecnologías de aprendizaje electrónico para mejorar la eficiencia del proceso de aprendizaje basándose en el ejemplo de la implementación de cursos de formación en línea y disciplinas matemáticas en la plataforma Moodle. El estudio encuentra que las leyes de distribución de calificaciones en las disciplinas matemáticas varían significativamente entre el aprendizaje tradicional y en línea. En la formación tradicional, la ley de distribución puede considerarse cercana a la normal, en e-learning, la ley de distribución debe definirse como bimodal. En otras palabras, los estudiantes del grupo académico deben dividirse en dos subgrupos según los resultados del e-learning: uno de los estudiantes que comenzaron a aprender mejor y el otro, de los que tomaron el camino opuesto. La prueba t de Student demuestra que las calificaciones promedio de los dos subgrupos en e-learning difieren con una confiabilidad del 95%. Esto indica que el grupo académico debe ser visto como formado por dos conjuntos con características diferentes. El análisis de la eficiencia de la implementación del e-learning demuestra la promesa de utilizar este método en el estudio de las disciplinas matemáticas. Un mayor desarrollo del e-learning debe centrarse en el desarrollo de enfoques de formación individuales y personalizados que promuevan la activación del proceso de aprendizaje para todos los estudiantes.

Palabras clave:

E-learning, trabajo independiente, sistema de aprendizaje personalizado, nivel de contenido, nivel interactivo, eficiencia en el aprendizaje.

INTRODUCTION

In today's world, increasing importance is gained by electronic learning (e-learning) with the use of stationary personal computers, as well as its modification called mobile learning (m-learning), which consists of distance learning with the use of mobile phones, smartphones, pocket personal computers, and e-books, enabling the student to take part in the educational process without any temporal and spatial restrictions. The development of this form of training is a response to the needs of the time – the provision of equal access to quality education for all. The demand for this arose in the second half of the 20th century, which is associated with the transition of the economy of developed countries to the path of post-industrial development, the formation of the knowledge economy. Consequently, the use of innovative technologies in education is aimed at meeting the needs of both the individual and society as a whole.

However, the conditions required to realize this concept became possible to create only with the progress of computer technology, the development of the Internet, computerization, and the informatization of society. At present, e-learning is acquiring the features of a metaindustry (Bakuradze et al., 2022). One indicator of the spread of this form of education is the rapid growth of the volume of funds circulating in the global e-learning market (Bryantseva et al., 2019).

In the higher education system, the methods of traditional part-time learning are being gradually replaced by the tools of e-learning (Tolmachev et al., 2022). Even in the classroom sessions of full-time students, the various elements of e-learning are used to an increasing extent. These methods make the presentation of materials more illustrative and understandable and activate students' independent work, which is gaining more and more attention in course programs (Medeshova et al., 2022). For these reasons, the study of the advantages and drawbacks of e-learning in the system of higher education presents a topical task.

A comprehensive study of distance learning technologies and e-learning as the most ideal path for the implementation of distance learning has begun in the mid-20th century, at the time when it first emerged.

The concept of e-learning is broad (Artamonova et al., 2022). In the most general sense, it refers to training with the use of information technology (Fiofanova, 2021; Kapustina et al., 2022). Since the capabilities of information technologies in improving the quality of education are diverse (Alvarez, 2021; Sinyukov et al., 2021), depending on the sector of education and the way they are implemented, there are several directions for the improvement of e-learning (Judrups, 2015; Moreno et al., 2017).

The greatest popularity of e-learning is observed in the system of higher vocational education. In the U.S., for example, more than 90% of universities and companies with more than 1,000 employees effectively employ the elements of e-learning, such as the resources of the internal information and communication network (Rogerson-Revell, 2015). International electronic educational systems are also being formed (Arthur-Nyarko et al., 2020). More and more universities in Russia are introducing their electronic services to organize distance learning for both part-time (Avdeev et al., 2021) and full-time students (Chick et al., 2020).

Furthermore, the expediency of the broad implementation of e-learning has been proven by the challenges faced by the education system due to the COVID-19 pandemic and strict self-isolation measures (Katić et al., 2021). In these conditions, the educational process would have been altogether impossible without the use of information technology. It can be argued that the worldwide experiment of training exclusively as part of e-learning allows for assessing the advantages and shortcomings of this educational technology compared to face-to-face learning (Litvinova et al., 2022). The latter is effectively implemented in the format of full-time education when the teacher acts not only as a mentor who imparts knowledge, but also as a coach, who helps the student to properly formulate their own goal for mastering a particular academic discipline, to find ways to meet it, and to ultimately achieve this goal (Aldosari et al., 2022). The quarantine experience provides a unique chance to compare the efficiency of different methods and techniques of teaching the same academic groups of students.

Thus, the purpose of this research is to determine the efficiency of e-learning in the study of mathematical disciplines by full-time students.

MATERIALS AND METHODS

Under the research goal, throughout the 2020/2021 academic year, we conducted continuous monitoring of the academic performance in mathematical disciplines demonstrated by 1st-year full-time university students specializing in mathematics. The same few academic groups were compared by the level of students' engagement in the use of e-learning tools, as well as by the efficiency of mastering the course during the autumn semester, when distance learning was implemented due to quarantine measures, and during the spring semester when face-to-face learning was utilized. To reduce the number of

variable factors, a comparison was conducted only for the academic groups that were taught by the same teacher in the autumn and spring semesters.

The independent work of both full-time and part-time students was organized by the considered university through an e-learning system represented by personalized learning systems (PLS). Using this internal network, each student gains full access to the open educational content in the academic discipline and can complete all interim and final control assignments prescribed by the working program of the discipline. This access is gained by going to a corresponding link and signing in with a login and password.

The platform used by the university to manage the processes of e-learning and communication between students and teachers is Moodle – a system of software products for managing education (Ettl et al., 2022). This system integrates the authoring, publication, and analysis of content in an environment designed for a large number of users. This allows the teacher to not only create and manage content of a great range but also to monitor students' activities and assess the quality of their learning (Gamage et al., 2022).

A PLS is an integral part of the educational process used to provide for learning activities both in the classroom and in the extracurricular independent work of students. The system of tools offered by Moodle can be utilized at three functional levels: the content level, the interactive level, and the level of online courses. The content level implies filling the course with learning materials at a level that is sufficient for its assimilation in distance learning by both full-time and part-time students. At the interactive level, Moodle is complemented by interactive tools for testing and grading assignments online, as well as elements of communication between participants, such as forums, chats and private messaging, and e-mail correspondence. At the online course level, the interactive level is supplemented by video recordings of lectures in various academic disciplines.

In the habitual form of full-time learning, the teacher presents theoretical material in class. For added demonstration during the lecture, the teacher provides presentations in the form of either Microsoft PowerPoint files or dynamic presentations created with Prezi Next.

The Moodle system is used by students in class during laboratory and practical lessons, during module control in the form of tests, as well as during the extracurricular time when working independently. Independent work assumes the following types of work:

- the study of theoretical fundamentals from the materials of lectures and compulsory and additional literature presented in the PLS;
- solving practical problems and tasks under laboratory works offered for independent completion;
- preparation for final assignments (the student independently systematizes the material studied within the topic);
- preparation for the exam (the student independently systematizes the material studied throughout the course);
- research and analytical work that culminates in writing a research paper.

The PLS becomes an indispensable aid in all the above types of work. Most online PLS courses created by teachers as educational and methodological support for mathematical disciplines for full-time students have an interactive level to them (Table 1).

Table 1. Content of the PLS for each mathematical discipline

Content level		Interactive level	
General information	Course program Working program Examination card example Scoring criteria Methodical literature Topics of research articles	Close-ended tests	Yes/no tests Multiple choice tests Matching tests
Classroom work	Lectures Practical classes Laboratory classes	Open-ended tests	Math test Short answer Identification of missing words Essay
Independent work	Assignments for independent work Multimedia presentations Training exercises	Communication	News forum Security Video conferences Submission block for completed assignments E-mail

Another advantage of PLS is the tools for monitoring students' attendance and their actions in the PLS, which provide the teacher with objective information about the elements of the course to which students pay attention. In addition, the PLS has an electronic grade book that automatically displays marks for the assignments stipulated by the working program, which allows students to monitor their progress.

Due to the introduction of quarantine restrictions, full-time students were trained in the distance mode during the first (spring) semester of 2020. Importantly, this form of

learning has certain differences from the distance learning of part-time students. Firstly, this concerns the planning of classes. Distance learning assumed free access to all the learning materials. For full-time students, classes were held on a fixed schedule in synchronous mode, which allowed students to get consultations immediately during the study of the material. Part of the lectures was held via videoconferencing, which created an opportunity for direct communication between students and the teacher. In addition, there were certain restrictions on the timing of the final control events.

Secondly, the e-learning process was more controllable. Students were tested in each practical class to assess their level of understanding of the topic, and online tests were administered as intermediary control. Thirdly, the availability of the electronic gradebook reflecting all the received marks enabled the student to monitor their performance in its dynamic and fix unsatisfactory grades, if present, in time, while the teacher gained the opportunity to control the mastery of each topic by students. Fourthly, full-time students in asynchronous e-learning could communicate with the teacher almost 24/7, while part-time students can only get consultations periodically and at a specific time. Fifthly, the role of the teacher changes. Traditionally, e-learning is focused primarily on the student, while the teacher provides the content. This is believed to be one of the major drawbacks of distance learning, as there is a gap in communication between the teacher and the student caused by geographical distance, and hence there may be a gap in understanding. Given this fact, special measures were adopted to make the e-learning of full-time students more active. One of these was e-conferences, in which various problems were discussed for students to later communicate their views on the considered problems in research papers. Such conferences, students' presentations of their papers, and discussions of scientific problems in a chat room with all students in the academic group play the same role as academic clubs.

The effectiveness of e-learning was assessed by the results of the semester interim and final testing, which in the fall and spring semesters were administered in the form of exams.

The grading was carried out on a 100-point scale under a cumulative system. According to this scale, the sum of 60 to 63 points corresponds to a "satisfactory" grade (E), 64 to 73 – a "satisfactory" grade (D), 74 to 81 – a "good" grade (C), 82 to 89 – a "good" grade (B), 90 to 100 – an "excellent" grade (A). The results of students' mastery of mathematical disciplines were compared within the same academic groups taught by the same teachers throughout the year.

RESULTS AND DISCUSSION

Table 2 shows the grades in advanced mathematics (fall semester) and probability theory and mathematical statistics (spring semester) for the 2020/2021 academic year.

Table 2. Distribution of the final grades of full-time students in the mathematical cycle of disciplines using e-learning and traditional learning.

Grade	Percentage of students from the total	
	e-learning	traditional learning
E	28%	16%
D	12%	28%
C	8%	24%
B	20%	16%
A	32%	16%

As demonstrated in Table 2, the distribution of grades in the fall and spring semesters differs significantly, although the quality of learning (the share of students with "good" and "excellent" grades) was almost the same – 60% and 56%, respectively. In the spring semester (traditional learning) the law of distribution can be considered close to normal. The average grade point is 76.4. This indicates that the distribution has a positive asymmetry. In contrast, in the fall semester (e-learning) the distribution law has two maxima, hence it should be defined as bimodal. This means that two populations of students can be identified within the academic group. For one population the average score is 89.7 and the asymmetry is negative, and for the second population the average score is 62.3 and the asymmetry is positive. The number of students belonging to the first population is approximately 60% of the group. This is the same as the percentage of quality determined by the results of both semesters. In the spring semester, however, there is no reason to single out this portion of the academic group as a separate population.

Let us now consider the statistical hypothesis of homogeneity of students' performance in the fall semester. Testing this statistical hypothesis using Student's t-test for independent samples shows that with 95% reliability, the mean scores of the two samples should be considered belonging to different general populations. In other words, the academic group of students should be seen as consisting of two populations differing in their characteristics. Hence, we can conclude that teaching according to the traditional face-to-face model, although passive, allows the teacher to exercise control over students who are not very conscientious about learning and whose level of self-organization is low. In the case of the e-learning model, the absence of such direct supervision leads to a deterioration in the performance of such students. Conversely,

the students who display diligence and activity during the training in direct personal interaction, due to the wider use of e-learning elements and the opportunity to plan their time more freely, used their time effectively in the conditions of distance learning technologies. It should also be added that a few students who belong to this population took free online Coursera courses in mathematical disciplines provided by the world's leading universities and received certificates during the quarantine events.

In discussing the results of the study it is reasonable to distinguish between the technical and personal aspects of the problem. According to our observations, the level of technical literacy of modern students is high and almost identical within each academic group. Likewise, each student has enough technical ability to access the online courses that are posted on the PLS and the Internet and has some experience with online learning. However, the findings show that, on average, only one-third of all students are capable of self-organization and interested in their learning outcomes to the point where they are willing to spend extra time to thoroughly study each topic. These are the students who improve their performance during distance learning. This can explain the appearance of the maximum "A" grade by the results of e-learning. Similar conclusions are also drawn by other authors, who investigated the relationship between students' personal qualities and the effectiveness of their learning online (Arthur-Nyarko et al., 2020) or in a blended system (Judrups, 2015).

The students for whom e-learning proves not only acceptable but more efficient than learning in the classroom should be classified as people with an internal locus of control. However, some students appear to be psychologically unprepared to study exclusively in the e-learning mode, as required by the conditions of self-isolation during quarantine. This could explain the appearance of another maximum (grade "E") (Table 2). Such students have an inherent external locus of control, and this is what negatively affects their academic performance. A student's performance in mastering the learning material in e-learning is almost independent of whether or not they have had the experience of such learning and is determined instead by their personal qualities. Other researchers have come to similar conclusions (Aldosari et al., 2022). The problem of the locus of control in a studying person attracts the increasing attention of researchers precisely because of the rise of e-learning. Some experts (Rogerson-Revell, 2015) even propose to pre-test students on their ability to study online.

The conducted pedagogical experiment thus proves the efficiency of e-learning for students who study with interest, strive for knowledge, can show initiative, and, importantly, do not hesitate to ask the teacher for advice when needed. PLS are a great support in the organization of e-learning. Unlike an e-textbook or e-learning textbook, a PLS provides for interaction between students and teachers and students with each other not only as per the regular class schedule but at any other time, if necessary. However, for inactive students, much of the difficulty of e-learning comes from the lack of the teacher's tutelage, even at the content level. Whereas in the classroom the instructor draws the attention of such a student by asking them a question or calling them to the board, online this is not possible. This poses a problem not only for the student, but also for the faculty member, who has to find means to get these students interested in the learning process itself, as well as to proactively provide students with detailed information about the rules they must follow during e-learning, about their responsibilities and how the learning system is built, and by what criteria their performance is evaluated. The student's personality traits cannot be changed, but certain behaviors related to academic performance can be corrected, and therein lies one of the challenges of e-learning that the educator must address.

Passive learning, when the student simply listens to the lecture, has already been proven ineffective. As a rule, lectures are read to a large audience of students and are designed for those at the average level. The same applies to practical in-person classes. Thus, for capable students who are learning-oriented, this process is of little efficiency, because even if they get distracted during class, they manage to absorb the new material. Therefore, the result of passive learning turns out to be average, as academic performance is averaged within the academic group (in the everyday sense rather than the mathematical one). To activate the work of all students in today's educational process, even during classroom sessions, certain types of activation are used, such as watching short videos, gamification of learning, case study technologies, and so on. The same technique, but to an even greater extent, teachers can apply in the process of e-learning online.

CONCLUSIONS

The modern information society is distinguished by the rapid development of innovative educational technologies. The need for changes in the system of formation of educational and methodological support and the organization of the learning process calls for further proliferation of interactive learning. The application of e-learning as a technology of distance learning greatly improves the quality of training and strengthens the practical orientation of academic disciplines of the mathematical cycle.

The experience of active implementation of e-learning courses in the context of quarantine measures ordered in relation to the COVID-19 pandemic allowed us to evaluate the efficiency of e-learning and to identify the individual factors affecting the quality of its further use.

The conducted research proves e-learning to be an efficient method of training students and points to the expediency of applying it in the study of mathematical disciplines as widely as possible. The extensive use of e-learning contributes not only to the effective assimilation of knowledge and the development of skills and abilities to apply it but also to the formation of students' responsibility for meeting the requirements of the educational process, the ability to independently determine the tasks of their education and to overcome the obstacles to their solution.

To a major extent, this effect is provided by the use of PLS on the Moodle platform. This specific platform allows adjusting the existing classroom courses to independent work, which provides a variety of opportunities for students' self-education.

However, in its current form, e-learning is more applicable in teaching students with an active approach to their education. Further development of e-learning we believe lies in promoting the methods of development of information and communication technologies that help intensify the learning process. This improvement will make e-learning useful for the entire student community.

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