Analysis of the efficiency of modern information technologies in e-learning and the use of interactive methods

Anatoliy Sigal[1], *Maria* Bakumenko[1*], and *Dmitriy* Titarenko[1]

[1]V.I. Vernadsky Crimean Federal University, Department of Business Informatics and Mathematical Simulation, Prospekt Vernadskogo 4, Simferopol, 295007, Russia

Abstract. Today, there is an urgent need to use distance technologies in education. The significant disadvantages of e-learning are students' low self-motivation, and the insufficient level of formed social communication skills. The above disadvantages can be largely overcome with interactive teaching methods and appropriate information technologies in the educational process. A correct approach in including interactive technologies in e-learning provides significant positive effects. One of the main challenges in using interactive technologies in e-learning is how to organize efficient remote dialogue and joint work of the participants. The paper analyzes information technologies recommended at various stages of organizing and designing interactive learning technologies. When working in groups, students can use online services such as Google Sheets, Google Docs, and Google Slides. These services greatly facilitate the work on a joint project and help the project team prepare for its successful presentation. Since many e-learning platforms cannot provide high-quality communication for participants, video conferencing services and social networks should supplement them. E-learning platforms should ensure that learners work effectively on common tasks using interactive learning technologies. We believe that every modern e-learning platform should contain a software module similar in functionality to Google Docs, Google Sheets, and Google Slides. It will make it possible to successfully implement all stages of organizing and designing interactive learning technologies. We can evaluate the efficiency of the forms of conducting classes using mathematical modeling, in particular, game-theoretic modeling. To assess the efficiency of the traditional and interactive forms of conducting classes, it is advisable to use an antagonistic (matrix) game and a cooperative game, correspondingly.

1 Introduction

In today's highly dynamic economy and during the COVID-19 global pandemic, there is an urgent need for the use of distance technologies in education, including higher education institutions. As noted in [1], "e-learning is essential in some instances … and, with the right

* Corresponding author: bakumenko_ma@mail.ru

approach, can produce a high level of knowledge (for example, a second university degree for employed and highly motivated people)" [1].

Interactive teaching methods have proven to be highly efficient in the educational process. However, the use of these methods in e-learning leads (in some cases) to additional challenges. We can overcome these challenges by using modern information technologies.

A significant number of scientific papers are devoted to various issues of applying interactive technologies in teaching, among which are the papers by T.I. Anisimova, L.A. Krasnova [2], O. Bezkopylnyi et al. [3], X. Li [4], S.L. Malchenko, D.V. Mykoliuk and A.E. Kiv [5], T.U. Matveeva, I.S. Osadchiy and M.N. Husnutdinova [6], M. Odinokaya et al. [7], K.T. Shakirjanova [8], M. Tadjibayeva and K. Solihova [9], etc.

Despite the significant interest of scientists in this issue, we believe that there are many aspects here for further research. One of them is the challenge of using interactive technologies in e-learning in higher education during the COVID-19 pandemic.

The purpose of this paper is to analyze the efficiency of modern information technologies in e-learning, which involves the use of interactive teaching methods.

2 Some disadvantages of e-learning

In some cases, e-learning is a necessity and, if well organized, can give a significant positive effect, both for students and higher education institutions, and provide a sufficiently high level of knowledge, skills and abilities of students, and a sufficiently high level of the quality of the educational process.

The paper [1] systematizes the advantages and disadvantages of e-learning for students, educational organizations, and employers. The significant disadvantages of e-learning are a decline in the quality of the educational process, students' low self-motivation, the process of the so called dehumanization, and an insufficient level of formed social skills. The importance of the formation of students' communicative competencies, in particular, is described in sufficient detail in [6].

We believe that these disadvantages can decrease by using interactive methods in the learning process. In its turn, the efficient use of interactive teaching methods (in the case of e-learning) is impossible without the use of appropriate information technologies and software.

3 Interactive teaching technologies in higher education

T.I. Anisimova and L.A. Krasnova define interactive learning as "dialogue teaching during which interaction between a student and a teacher, between students is carried out" [2]. M. Tadjibayeva and K. Solihova note that "interactive education is an education that is based on organizing students' interactions to acquire cognitive skills and specific moral qualities" [9].

According to T.I. Anisimova and L.A. Krasnova, "modern professional education … is focused not on the transfer of ready knowledge but on teaching to find this knowledge and to apply them in situations close to the professional conditions" [2].

The skills of self-guided work and information search acquired by students during interactive learning will be important for their successful career and professional activity in a constantly changing world. As rightly noted by Svitlana L. Malchenko, Davyd V. Mykoliuk, and Arnold E. Kiv, "the ability to learn will allow them to improve experience and knowledge, to analyze and to use the achievements of science and technics in the professional activity" [5].

As stated in [7], among the teaching technologies of higher education, interactive technologies are the most effective, since they work not only at the cognitive level but also at the emotional and behavioral levels.

As a rule, the interactive form of conducting classes (with the correct methodology) triggers only positive emotions in the students. Thus, for example, Maria Odinokaya et al. note that "students enjoy the interactive form of work, as it stimulates their desire to independently acquire knowledge, to critically interpret the information received" [7]. According to C.-H. Tu, "interactivity is the key to effective human learning and knowledge construction" [10].

Figure 1 shows the basic principles of interactive learning technologies presented in [9]. Table 1 compares traditional and interactive forms of giving classes (for those cases where both forms are applicable).

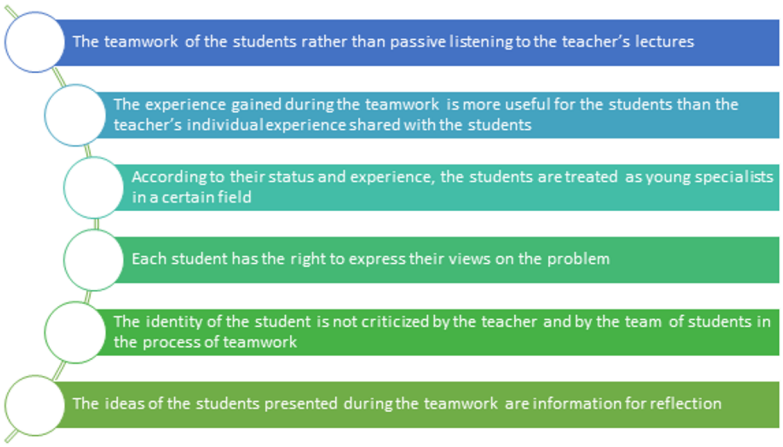

Fig. 1. The basic principles of interactive learning technologies. [a]

[a] formed by the authors based on [9]

We can note that "the interactive instructional model is a challenge to the teachers' leading position in the education" [4], and "teachers' function transits to organizer and advisor instead of authority" [4].

There are the following interactive forms of education:

- public presentation of the project;
- group discussion;
- creative task;
- analysis of specific situations;
- business game;
- role-playing game;
- interactive lecture;
- brainstorming;
- etc.

Table 1. Comparative analysis of traditional and interactive forms of giving classes. [b]

Characteristic	**Form of giving classes**	
	traditional	**interactive**
Key player of the learning session	the teacher	the teacher and the students are characterized by equal roles

Communication style	authoritarian	democratic
The nature of obtaining knowledge	the teacher transfers ready knowledge to the students	the teacher guides the students to independently search for the required information and assists in their work
The main goal of education	transfer of knowledge to the students	the development of students' ability for further learning, independent problem solving, creativity, cooperation, personal development

[b] formed by the authors based on [4]

Each of the above interactive forms of learning has certain advantages and disadvantages, to be taken into account when organizing the educational process. In practice, the choice of an interactive form of training depends on several factors: the direction of the education of students, the discipline studied, the theme of the lesson, the composition of the group, the level of students' training, etc. Within a course of study, it is advisable to combine various interactive forms of education.

The use of interactive technologies in the learning process leads to the following positive effects [2; 3; 8]:

- activates the mental and cognitive activity of the students;
- leads to the mutual enrichment of the participants of the learning process (exchange of experience and knowledge);
- promotes the development of the students' skills of analysis and critical thinking;
- promotes the formation of conscious practical skills;
- increases motivation to learn (to study the discipline);
- creates a favorable atmosphere for learning;
- develops communication skills and abilities of the students;
- forms the skills of effective teamwork;
- contributes to the formation of skills of independent search for necessary information and determination of its relevance;
- thanks to reflection, forms the attitude of the students to their actions and provides an adequate correction of these actions;
- promotes tolerance and mutual understanding during teamwork;
- develops the ability to resolve conflicts;
- reduces the share of traditional classroom studies and increases the share of independent work of the students;
- develops the skills of mastering modern technical devices and information processing technologies;
- forms students' responsibility for making decisions;
- promotes the creative activity of students;
- develops originality of thinking, the ability to generate ideas;
- allows students to find and create personal opportunities.

4 Analysis of information technologies recommended at various stages of the organization and design of interactive learning technologies

There are three main stages of organizing and designing interactive technologies in learning:

1. Coordination of goals, dividing students into groups, briefing on solving the assigned tasks.
2. The work of the students in groups (teams) to complete the task.

3. Reflexive stage (students' understanding of their activities within the framework of collaboration).

One of the main challenges in using interactive technologies in e-learning is the organization of effective remote dialogue and joint work of the participants.

In e-learning, one can implement the first and third stages using educational platforms (for example, Moodle, Blackboard), video conferencing services (Zoom, Skype, Discord), and various social networks (Facebook).

In addition to the above information technologies, the second stage needs such online services as Google Sheets, Google Docs, and Google Slides. These services greatly facilitate the work on a joint project and help the project team prepare for its successful presentation. These free online services allow the participants of the educational process to jointly create documents and do not require any additional software to be installed on a personal computer. Generated documents are on the Google server, with the capability of export to a file. The participants can access the service from any device connected to the Internet.

Figure 2 shows information technologies recommended at various stages of organizing and designing interactive learning technologies.

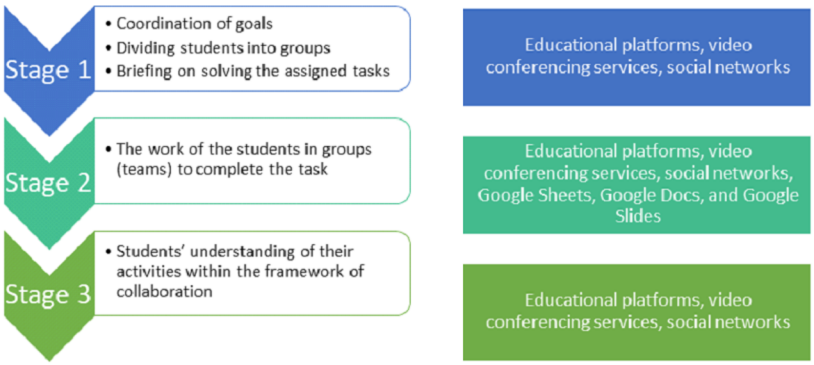

Fig. 2. Information technologies recommended at various stages of the organization and design of interactive learning technologies.

5 Comparison of information technologies used in e-learning

The organization of e-learning (including interactive technologies) is impossible without appropriate information technologies. As C.-H. Tu rightly notes, "online learning technology should move away from the use of computer technology as presentation and storage tools and advance to the next level by using them as interactive tools" [10].

There are many e-learning platforms developed and used (or Learning Management Systems), most of which are free of charge. According to the paper [11], there are several hundred software learning environments created.

As noted by M.A. Almaiah, A. Al-Khasawneh, and A. Althunibat, "e-learning systems can assist learning providers to manage, plan, deliver and track the learning and teaching process" [12].

Figure 3 shows the main functions of e-learning systems.

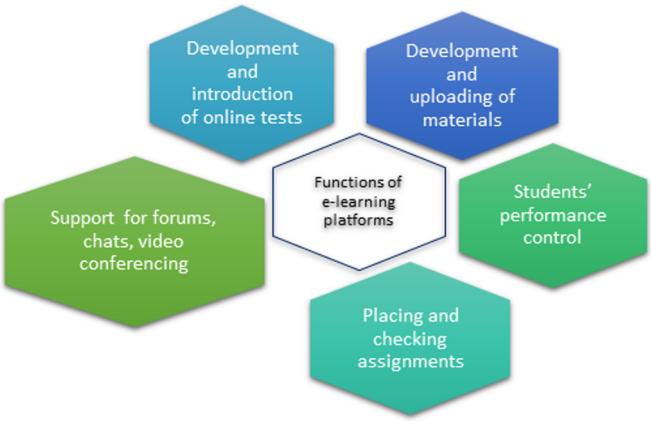

Fig. 3. The main functions of e-learning systems. [c]

[c] formed by the authors based on [11]

M. A. Almaiah, A. Al-Khasawneh and A. Althunibat highlight several challenges faced by the participants of e-learning [12]:

• change management issues (lack of awareness; lack of citizens interest; resistance to change);

• E-learning system technical issues (usability; ease of use; usefulness; access to e-services);

• financial support issues (projects delay; lack of financial support).

These scientists also identify several critical factors that affect the use of e-learning systems during the COVID-19 pandemic [12]:

• technological factors;

• E-learning system quality factors;

• culture factors;

• self-efficacy factors;

• trust factors.

The prime use of e-learning platforms is to provide a secure, reliable, and flexible e-learning environment. They also support forums, chat rooms, and e-libraries [13].

The most popular e-learning platforms are Moodle and Blackboard [11; 13]. The paper [13] compares 36 educational platforms according to the following groups of criteria: Learning Skills Tools, Communication Tools, Productivity Tools. The analysis showed that most e-learning systems have a similar set of functions. It is important to note that only 46% of all examined e-learning systems support chatting, and only 68% support forum communication [13].

The paper [11] compares ten e-learning systems (E-Stadi, ATutor, Blackboard, iSpring Online, TalentLMS, Inkling, Moodle, Sakai, Versal, WebTutor) according to the following criteria: Learning Tools, Support Tools, Technical Specifications. In terms of learning tools, the leaders are Moodle, Sakai, and Blackboard [11]. In terms of support tools, the analyzed platforms are at approximately the same level of development [11]. In terms of technical specifications, the leaders are four platforms of e-learning: ATutor, Blackboard, Moodle, and Sakai [11]. According to the research by I.A. Belous and A.Ya. Chupalov, the most developed e-learning platforms are Moodle, Sakai, and Blackboard [11].

The paper [14] reviews three e-learning platforms: Moodle, iSpring Learn, and Google Classroom. Comparison of the platforms uses the following characteristics: "the convenience of the interface, the mobility of the system..., the presence of a built-in course editor, the

presence of videoconference, the availability of the main features, the presence of additional features, support for... file extensions, the flexibility of the system, the availability of mobile applications, money costs...” [14]. S.A. Kovalenko, A.V. Barabanov, N.I. Grebennikova, and V.A. Malinovkin conclude that “the platforms considered do not provide the required functionality in full and in the proper quality” [14].

Since many e-learning platforms cannot provide high-quality communication for participants, video conferencing services and social networks should supplement them. The paper by S.V. Thakker, J. Parab, and S. Kaisare [15] is devoted to the challenges of using videoconferencing services in e-learning.

S.V. Thakker, J. Parab, and S. Kaisare analyzed seven video conferencing services: Zoom, Google Meet, Microsoft Teams, GoToWebinar, Zoho Meeting, Adobe Connect, GoToMeeting [15]. According to the study, the best solutions are Google Meet, Zoom, and Microsoft Teams [15].

The papers by A. Krouska, C. Troussas, and M. Virvou [16], A.R. Nurutdinova, E.V. Dmitrieva [17], and others are devoted to various aspects of using social networks in the educational process.

According to A. Krouska, C. Troussas, and M. Virvou, the main advantage of social networks in education is the support of formal and non-formal learning and collaborative learning [16]. The study by A.R. Nurutdinova and E.V. Dmitrieva testify to the effectiveness of social networks in e-learning [17].

Google Docs, Google Sheets, and Google Slides are necessary and accessible tools while working on joint projects (tasks). These tools can facilitate complex and interrelated core collaboration processes [18].

We believe that e-learning platforms, in addition to the functions presented in Figure 3, should perform another important function – to ensure efficient work of students on joint projects (tasks) within interactive teaching methods. We believe that every modern e-learning platform should contain a software module similar in functionality to Google Docs, Google Sheets, and Google Slides. In this case, the e-learning system will make it possible to successfully implement all stages of organizing and designing interactive learning technologies.

6 Game-theoretic models for evaluating the efficiency of traditional and interactive forms of conducting classes

We believe that to assess the efficiency of the forms of conducting classes one can apply mathematical modeling, in particular, game-theoretic modeling. In the case of an individual student, the evaluation of the efficiency of the form of conducting classes equals the examination score of the student on a 5-point scale. Obviously, to evaluate the efficiency of different forms of conducting classes we should use different methods of mathematical modeling and, in particular, game-theoretic models of different classes. We believe that it is possible to use antagonistic (matrix) games to assess the efficiency of the traditional form of conducting classes (see, for example, [19]). However, to assess the efficiency of the interactive form of conducting classes, the use of antagonistic (matrix) games is not possible. To assess the efficiency of the interactive form of conducting classes, it seems appropriate to use cooperative games (see, for example, [19]). Let us examine in more detail the simplest game-theoretic model for evaluating the efficiency of the traditional form of conducting classes. This game-theoretic model is an antagonistic game defined by its payoff matrix, with each of the two players having three different pure strategies.

As you know, any antagonistic game, i.e. a zero-sum finite game of two players, is completely defined by its payoff matrix. The payoff matrix of the antagonistic game is the matrix $\mathbf{R} = \mathbf{R}_{k\times n} = (r_{ij})$ of the payoffs of the first player. Here k is the number of different pure

strategies of the first player, n is the number of different pure strategies of the second player. The value of the element r_{ij} specifies the value of the payoff of the first player in the situation $(i; j)$, i.e. the situation when the first player applied their pure strategy i, and the second player applied their pure strategy j, and, at the same time, the value of the loss of the second player in the situation $(i; j)$.

In the case of the simplest game-theoretic model for evaluating the efficiency of the traditional form of conducting classes, let us consider the teacher as the first player and the student as the second player. The payoff matrix of this antagonistic game has the following general form: $\mathbf{R} = \mathbf{R}_{3\times3} = (r_{ij})$, where the value of the element r_{ij} of the payoff matrix specifies the success of the learning outcome, where the success of the learning outcome is measured by the proportion, expressed as a percentage, of the educational material fully learned by the student, i is the level of the teacher's professionalism, j is the level of the student's abilities.

In the proposed simplest game-theoretic model for evaluating the efficiency of the traditional form of conducting classes, three $(k = 3)$ levels of the teacher's professionalism are possible:

1. $i = 1$ – low professionalism;
2. $i = 2$ – average professionalism;
3. $i = 3$ – high professionalism.

In the proposed simplest game-theoretic model for evaluating the efficiency of the traditional form of conducting classes, three $(n = 3)$ levels of the student's abilities are possible:

1. $j = 1$ – low level of abilities;
2. $j = 2$ – average level of abilities;
3. $j = 3$ – high level of abilities.

Without loss of generality, we can assume that the values of the elements r_{ij} of the payoff matrix $\mathbf{R} = \mathbf{R}_{3\times3} = (r_{ij})$ of the antagonistic game, which characterizes the assessment of the efficiency of the traditional form of conducting classes, i.e. the simplest game-theoretic model for assessing the efficiency of the traditional form of conducting classes, satisfy the following properties:

1. $0 \le r_{ij} \le 100, \ \forall \ i, \ \forall \ j;$
2. $r_{11} < r_{12} < r_{13};$
3. $r_{21} < r_{22} < r_{23};$
4. $r_{31} < r_{32} < r_{33};$
5. $r_{11} < r_{21} < r_{31};$
6. $r_{12} < r_{22} < r_{32};$
7. $r_{13} < r_{23} < r_{33};$
8. r_{11} sets the minimum possible value of the efficiency of conducting classes: $\min\{r_{11}; \ldots; r_{33}\} = r_{11};$
9. r_{33} sets the maximum possible value of the efficiency of conducting classes: $\max\{r_{11}; \ldots; r_{33}\} = r_{33}.$

It is quite natural to assume that the examination score k_{ij} of any student on a 5-point scale is characterized not by a single number, but by some random integer K_{ij}, which can take on different possible values (with corresponding probabilities $l = 4$): 2 ("unsatisfactory"), 3 ("satisfactory"), 4 ("good"), 5 ("excellent"). Note that, for convenience, we can assume that, to the first approximation, the most probable value $\check{k}_{ij}$ of the student's examination score on a 5-point scale (the modal value $\mathbf{Mo}(K_{ij})$ of the random variable K_{ij}) linearly depends on the value of the element r_{ij} of the payoff matrix

$\mathbf{R}=\mathbf{R}_{3\times3}=(r_{ij})$, i.e. on the value of the success of the student's learning outcome measured on a 100 percent scale:

$$\check{k}_{ij}=\mathbf{Mo}(K_{ij})=2+\langle(100\cdot i+100\cdot j+4\cdot r_{ij})/400\rangle,$$

where $\langle x\rangle$ is the nearest integer to x. In addition, the above equation allows us to estimate, to the first approximation, the numerical value of the modal (most probable) possible value $\mathbf{Mo}(K_{ij})$ of the random variable K_{ij}.

Let us give examples how to calculate possible modal values of the random variable K_{ij}.

1. If $i=1,\ j=1,\ r_{11}=0,$ then $\check{k}_{11}=\mathbf{Mo}(K_{11})=2+\langle(100\cdot1+100\cdot1+4\cdot0)/400\rangle=$ $=2+\langle200/400\rangle=2+\langle0{,}5\rangle$, therefore, $\check{k}_{11}=\mathbf{Mo}(K_{11})=2$ or $\check{k}_{11}=\mathbf{Mo}(K_{11})=3$.
2. If $i=1,\ j=1,\ r_{11}=10,$ then $\check{k}_{11}=\mathbf{Mo}(K_{11})=2+\langle(100\cdot1+100\cdot1+4\cdot10)/400\rangle=$ $=2+\langle240/400\rangle=2+\langle0{,}6\rangle=2+1=3$.
3. If $i=1,\ j=2,\ r_{12}=20,$ then $\check{k}_{12}=\mathbf{Mo}(K_{12})=2+\langle(100\cdot1+100\cdot2+4\cdot20)/400\rangle=$ $=2+\langle380/400\rangle=2+\langle0{,}95\rangle=2+1=3$.
4. If $i=2,\ j=2,\ r_{22}=60,$ then $\check{k}_{22}=\mathbf{Mo}(K_{22})=2+\langle(100\cdot2+100\cdot2+4\cdot60)/400\rangle=$ $=2+\langle640/400\rangle=2+\langle1{,}6\rangle=2+2=4$.
5. If $i=3,\ j=3,\ r_{33}=100,$ then $\check{k}_{33}=\mathbf{Mo}(K_{33})=2+\langle(100\cdot3+100\cdot3+4\cdot100)/400\rangle=$ $=2+\langle1000/400\rangle=2+\langle2{,}5\rangle$, therefore, $\check{k}_{33}=\mathbf{Mo}(K)=4$ or $\check{k}_{33}=\mathbf{Mo}(K)=5$.

However, if the number x is a half-integer, then it has two different nearest integers $\langle x\rangle$, and in all other cases, the number x, not being a half-integer, has a single nearest integer $\langle x\rangle$. Thus, an integer random variable K_{ij}, which characterizes the student's examination score on a 5-point scale, can be either a bimodal random variable, i.e. a random variable that has two modal values different in their numerical values, or a unimodal random variable, i.e. a random variable that has a single modal value.

Taking into account the above properties of the elements r_{ij} of the payoff matrix $\mathbf{R}=\mathbf{R}_{3\times3}=(r_{ij})$ of the antagonistic game, which characterizes the assessment of the efficiency of the traditional form of conducting classes, the values of the most probable examination score $\check{k}_{ij}$ of the student on a 5-point scale satisfy the following properties:

1. $2\le\check{k}_{ij}\le5,\ \forall\ i,\ \forall\ j$;
2. $\check{k}_{11}<\check{k}_{12}<\check{k}_{13}$;
3. $\check{k}_{21}<\check{k}_{22}<\check{k}_{23}$;
4. $\check{k}_{31}<\check{k}_{32}<\check{k}_{33}$;
5. $\check{k}_{11}<\check{k}_{21}<\check{k}_{31}$;
6. $\check{k}_{12}<\check{k}_{22}<\check{k}_{32}$;
7. $\check{k}_{13}<\check{k}_{23}<\check{k}_{33}$;
8. $\check{k}_{11}$ sets the minimum possible value of the efficiency of conducting classes: $\min\{\check{k}_{11};\ldots;\check{k}_{33}\}=\check{k}_{11}$;
9. $\check{k}_{33}$ sets the maximum possible value of the efficiency of conducting classes: $\max\{\check{k}_{11};\ldots;\check{k}_{33}\}=\check{k}_{33}$.

In the case of a number (for example, a group) of students, to assess the efficiency of the traditional form of conducting classes, we can use the average examination score $\check{k}_{\text{av.}}$ of the students on a 5-point scale. At the same time, the value of the average examination score $\check{k}_{\text{av.}}$ of the students on a 5-point scale can be expressed through the value of the worth V^* of the antagonistic game given by the corresponding payoff matrix $\mathbf{R}=\mathbf{R}_{3\times3}=(r_{ij})$, according to the following equation:

$$\check{k}_{\text{av.}} = 2 + \langle (100 \cdot i + 100 \cdot j + 4 \cdot V^*) / 400 \rangle.$$

7 Conclusions

Today, there is an urgent need to use distance technologies in education. The significant disadvantages of e-learning are students' low self-motivation, and the insufficient level of formed social communication skills. The above disadvantages can be largely overcome with interactive teaching methods and appropriate information technologies in the educational process.

One of the main challenges in using interactive technologies in e-learning is the organization of effective remote dialogue and joint work of the participants. These challenges can be solved using modern information technologies, access to many of which is free: educational platforms, video conferencing services, social networks, Google Sheets, Google Docs, and Google Slides.

Since many e-learning platforms cannot provide high-quality communication for participants, video conferencing services and social networks should supplement them. In modern e-learning platforms, it is advisable to create a module similar in functionality to Google Docs, Google Sheets, and Google Slides. It will make it possible to successfully implement all stages of organizing and designing interactive learning technologies.

We can evaluate the efficiency of the forms of conducting classes using mathematical modeling, in particular, game-theoretic modeling. To assess the efficiency of the traditional and interactive forms of conducting classes, it is advisable to use an antagonistic (matrix) game and a cooperative game, correspondingly.

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