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Business Games as a Teaching Strategy for Delivering a Practice-Oriented Course in Mathematics at Agricultural University

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***Abstract*—The development of markets for scientific and technological initiatives in modern Russia requires the transformation of educational processes. Highly qualified specialists with "hard skills" and "soft skills" are more in demand. The application of practice-oriented approaches to educational activities ensures the development of these competencies. Mathematics studies are not limited by a specific discipline. Some aspects of mathematics are involved in other profession-related disciplines, too. The practical activities of undergraduates at agricultural universities include a lot of experimental work and analysis of the results. The teachers can simulate this situation in the educational process with the help of business games, which allows the increase of students' proactive behavior and motivation in the educational process and identification of the talented youth. With the purpose of improvement of the effectiveness of the educational process, several disciplines should be joined together in the business game. For agricultural universities, the most acceptable example of discipline convergence is a combination of mathematics, genetics and biology. The authors found out that the use of business games in the educational process has improved the quality of knowledge of students in the disciplines up to 70-80%. The average performance of students in mathematics was 70%, which is 5% higher than before the introduction of this teaching strategy in the educational process.**

Keywords—business game, interactive learning, model.

I. INTRODUCTION

In today's highly competitive labour market, there is a greater need for highly qualified specialists with developed soft and profession-related skills. The employers would like to hire graduates fully prepared to perform well in the workplace. The employees should possess some practical skills as well such as the ability to learn new skills quickly, motivation for self-development, benchmarking skills. If graduates develop meta-competencies such as team working skills, decision making skills, thinking outside the box and logical thinking during their training at university, they will be competitive on the labor market. The important factors determining the competitiveness of national economies, as well as the effectiveness of their security strategies include the high rate of development of new knowledge and the creation of innovative products. According to the Decree of the President of the Russian Federation No. 642 dated December 1, 2016, science and technology play a special role in ensuring a sustainable development of Russia and determining its world position [1].

The country's competitiveness and independence are possible by means of making the effective system of development and maximum use of the intellectual potential of the nation. If the talented youth is provided with opportunities to build a successful career in science, technology and innovations, it will increase the potential for intellectual development of the country. To ensure the innovative nature of basic education, modern teachers require to implement a creative approach when preparing or reading lectures, conducting classes or seminars. One of the main tasks facing any higher educational institution is to prepare highly qualified and competent specialists. In addition, the university faces many other tasks, which include involvement of students in the development of cutting-edge technologies and their adaptation to the real conditions of the industry [2].

The creative activities of undergraduates at agricultural universities include experimental research, data collection, analysis and processing, and meaningful interpretation of the obtained results, for which mathematical and statistical methods are used. When conducting experiments at different levels: in research institutes, on farms, and in experimental stations, it becomes necessary to identify patterns hidden by the random form of their manifestation. For the reliability of diagnoses and forecasts, recommendations for the mass application of new methods of feeding, breeding, treatment and reproductive use of farm animals, it is necessary to establish the reliability of the results of those studies, on the basis of which relevant conclusions are drawn and the practical recommendations are made. Genetic analysis, like most theoretical and applied experimental research, involves the use of mathematical and statistical methods [3]. The probability theory and mathematical statistics deal with the study and construction of mathematical models, the identification of patterns of random events from the results of real experiments and observations. In order to understand the probabilistic-statistical approach to the phenomena under study, one needs to have an understanding of the concepts and methods of probability theory and mathematical statistics.

Now, the main focus is on active and interactive teaching methods and forms, which are in the basis of many educational innovations, including interactive lectures, group

projects, presentations, scientific seminars, case studies, modeling of production processes [4]. Interactive teaching methods allow training in a specific professional environment. One of the most effective interactive teaching methods is business games. As an instrument of socialization and development of meta-competencies, the business game "Logic. Model. Profession." Is held at the Omsk State Agrarian University named after P.A. Stolypin.

II. LITERATURE REVIEW

The method of training with the use of modeling of business processes, or a business game, was developed at the University of Chicago in 1963, and since then, it has been actively used in the educational process. The use of lectures, handouts, case studies, coaching and other methods are common for educational purposes. Each method has its own specific use and at the same time has its own characteristics. Business games are different from the traditional teaching methods and are valuable teaching technology. The scientific literature presents a wide choice of interpretations of the concept of the business game. The studies of A. A. Verbitsky indicate that the business game is a form of reconstruction of the subject content and social content of the future professional activity of a specialist, and modeling of those systems of relationships that are specific to a particular field of the activity. “A business game is a form of reconstruction of the subject and social content of the professional activity, and modeling of the systems of relationships that are specific to a particular field of the activity.” [5, p. 128]. Another interpretation of the concept of the business game is presented in the work of E.S. Polat and M.Yu. Bukharkina. The researchers emphasize the creative side of the business game, defining it as the imitation of activities aimed at knowing a particular role. “The business game is a means of developing creative thinking, including professional creative thinking; it is an imitation of the activities of managers and specialists, workers and consumers; it is an achievement of a certain cognitive goal; it is observation of the rules of interaction according to the assigned roles”[6, p. 172]. V.P. Galushko points out that the business game is a system for reproduction of certain processes, which makes it possible to establish the role of certain decision-making methods that can affect the results of an activity. “The business game is a kind of system for reproducing managerial processes that have taken place in the past or are possible in the future, as a result of which the relationship and patterns of the impact of existing decision-making methods on production results at present and in the future are established” [7, p. 8]. Based on the above studies, we can conclude that the business game is modeling various professional environments using the method of search for new ways to solve profession-related problems.

The business game is also called a business simulator, which can be used as a training tool for teaching business processes.

S.R. Gidrovich and I.M. Syroezhkin distinguish four main areas of use of business games. The game is used for organizing an educational process, as an assessment tool for certification of personnel and testing their competences. It can be used for research, or as a method of decision making and development of plans. [8, p. 5-6].

Being one of the interactive teaching methods, the business game is widely used in economics [9], [10], management [11], printing and publishing [12], land management [13], ecology [14].

The range of disciplines that address the business game is constantly expanding.

The business game is considered by many authors as an educational environment, but it has limitations in the educational effectiveness. Despite all the advantages of the business game, there is always a threat that it could be treated as entertainment, and not as a teaching strategy. This will not lead to any valuable results. Thus, to ensure success in the educational process, it is necessary to develop in detail all stages of the business game.

At the Omsk State Agrarian University, there is a tradition to hold business games annually at the Faculties of Economics and Land Management. The Faculty of Zootechnics, Commodity Science and Standardization organizes a business game in collaboration with the Department of Mathematics and Natural Sciences. Now, we will describe the procedure of the business game “Logic. Model. Profession".

III. RESEARCH METHODOLOGY

The business game “Logic. Model. Profession.” is held as part of the university’s activities, aimed to develop meta-competencies in students. The business game has been held regularly by the Department of Zootechnics and the Department of Mathematics and Natural Sciences since 2017. Participants in the business game are students of the Omsk State Agrarian University, who demonstrate creativity and high culture, proficiency in terminology, and the ability to apply modern technologies in practice.

The main goals of the business game are:

- to increase the prestige of highly skilled labor in the field of agriculture and the popularization of professions in the agricultural sector (Stages 1-3 of the business game);

- to form meta-competencies (soft skills) (Stages 2-3 of the business game);

- to identify the most gifted and talented students, to further improve their skills, develop creative abilities, interests in the profession, to foster proactive behaviour, stimulate growth of creativity (Stage 3 of the business game).

The main objectives of the business game are:

- to increase the interest of students in the profession and its social significance;

- to identify interdisciplinary links and interpret them in professional activities;

- to improve skills of independent work and develop creative thinking;

- to increase the responsibility of students for the work performance;

- to develop the ability to independently carry out creative projects;

- to form the qualities necessary for a creative person who is active and easily adaptable in the modern world.

The business game is held in one step. The results of the business game are summed up, and the winners are announced the same day the game is held. The organizers of

the business game are the Department of Zootechnics and the Department of Mathematics and Natural Sciences of the Omsk State Agrarian University. The organizing committee responsible for the whole realisation of the business game includes representatives of the both departments.

The functions of the organizing committee are the following:

- determination of the conditions for organizational and informational support of the business game;

- determination of the award procedure for the winners of the business game;

- preparation of an annual report on the results of the business game.

The participants of the business game form teams on their initiative, and give names to their teams.

The business game consists of the three stages: working with theoretical materials, answering the quiz questions, solving a practical problem, building a model and presenting the project.

The first stage is theoretical study. At this stage of the business game, the participants should study theoretical materials in mathematics, biology, genetics, and biometrics on their own. All materials were presented in the form of the diagram, which was made using the website www.pullenti.ru (Fig. 1), and on slides, some of which are presented in the figures (Fig. 2-10).

Fig. 1. Scheme

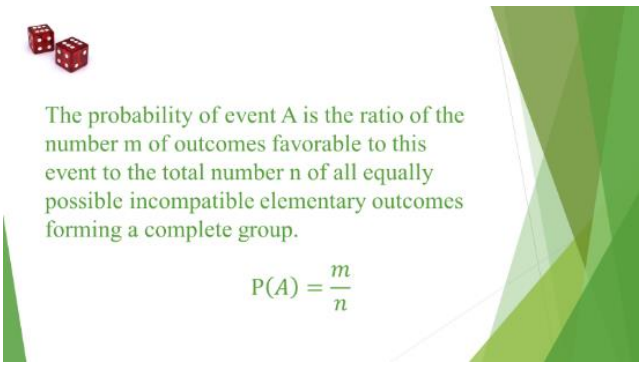

Fig. 2. The concept of probability of event

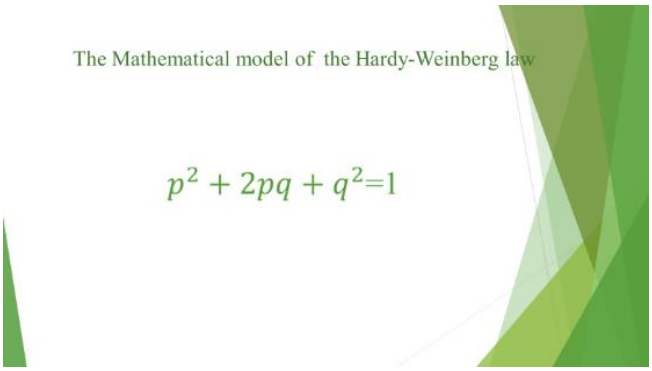

Fig. 3. The Hardy-Weinberg law

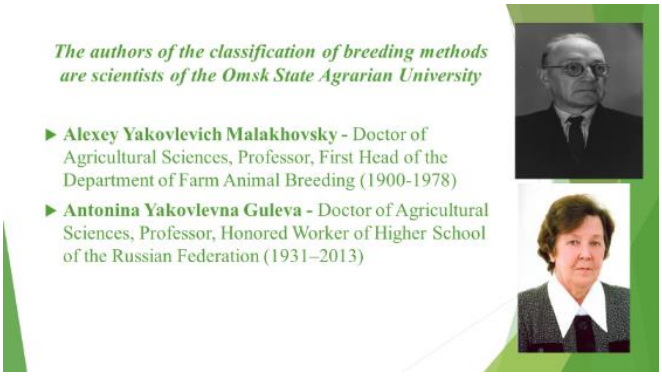

Fig. 4. Scientists of the Omsk State Agrarian University

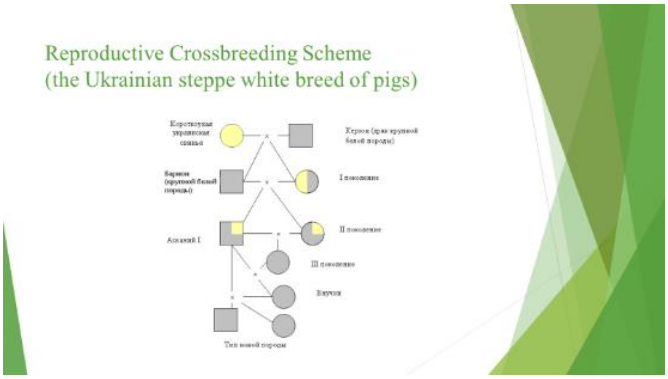

Fig. 5. Reproductive Crossbreeding Scheme

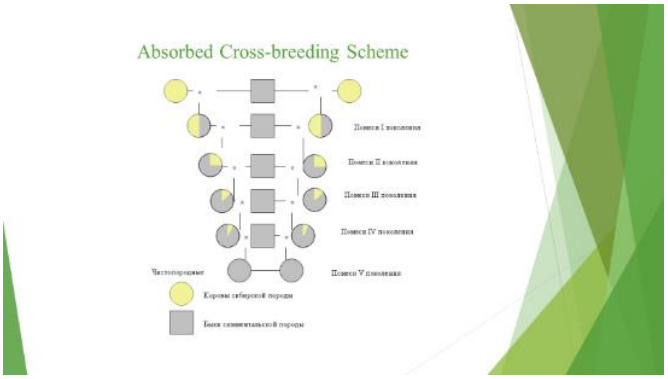

Fig. 6. Absorbed Cross-breeding Scheme

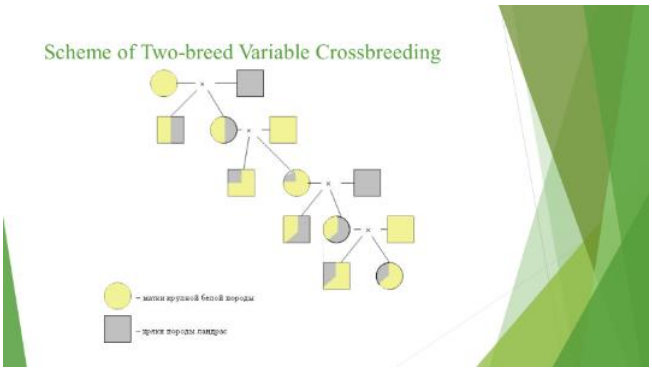

Fig. 7. Scheme of Two-breed Variable Crossbreeding

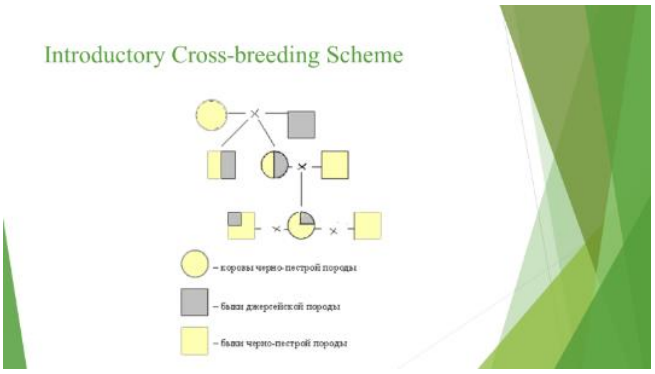

Fig. 8. Introductory Cross-breeding Scheme

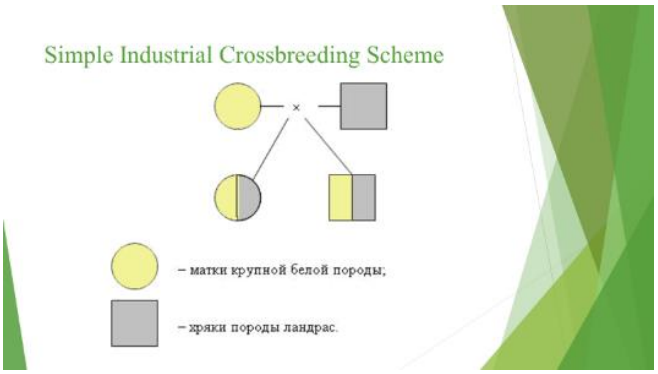

Fig. 9. Simple Industrial Crossbreeding Scheme

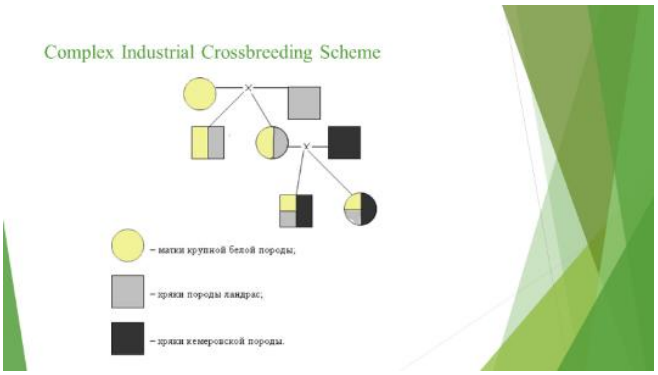

Fig. 10. Complex Industrial Crossbreeding Scheme

The theoretical materials included the definitions of the concepts “probability”, “gene”, “variability”, “heredity”, “population”, and “consanguity”. The Hardy-Weinberg law was formulated, the mathematical model of this law was built. The main breeding methods were indicated. The contribution of the scientists, who were the members of the department, Prof. A.Ya. Guleva, who was the initiator of the use of interbreeding in the Omsk region, and Prof. A.Ya. Malakhovsky, who was the author of one of the classifications of breeding methods, was described:

At the first stage, the participants had to analyze the information presented on the diagram and on the slides in order to use it in the future, at Stages 2 and 3. The teams could make short notes on the flipchart; each team had its own one.

The second stage consisted of two parts. The first part was a quiz. The quiz questions were made by the organizers on the basis of the materials presented at the theoretical stage. The example quiz questions are shown in Figures 11-14.

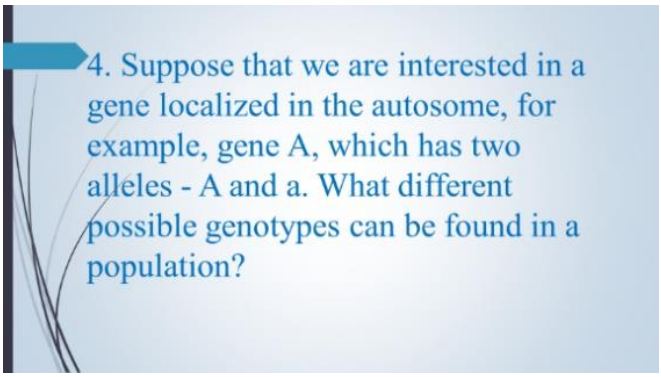

Fig. 11. The quiz question in genetics

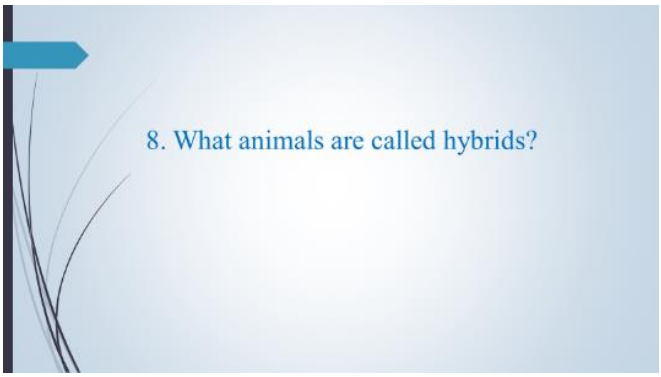

Fig. 12. The quiz question about crossbreeding

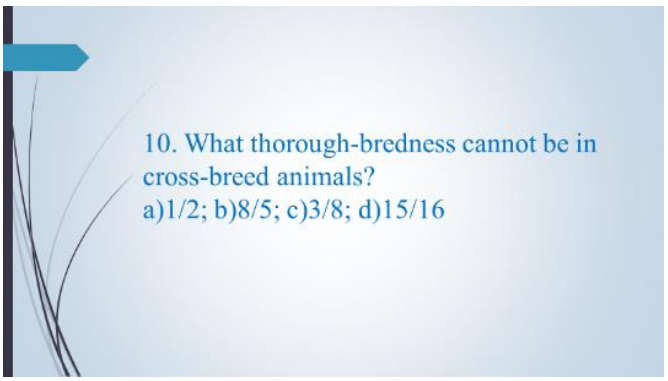

Fig. 13. The quiz question revealing meta-discipline links between genetics and mathematics

One score was given for each correct answer. The similar questions for the teams were presented on the slides. The maximum number of scores that could be gained at this stage was 10. The teams wrote down their responses on a flipchart. One part of the quiz questions was presented in the form of a test with only one correct answer, which had to be indicated. The answers to others questions had to be given in a more

detailed form. The correctness of the answers to the quiz questions was evaluated by the jury of the game.

The second part involved creating a crossword puzzle. Using the website http://cross.highcat.org/ru_RU/#, each team created a crossword puzzle with the terms, the other team had to make up questions about the terms in the crossword puzzle. The crossword puzzle had to cover minimum 25 cells and contain minimum 15 words. Then, the jury compared the crossword questions of the participating teams. The scores ranged from 5 to 10. You can see an example of the crossword puzzle in Figure 14.

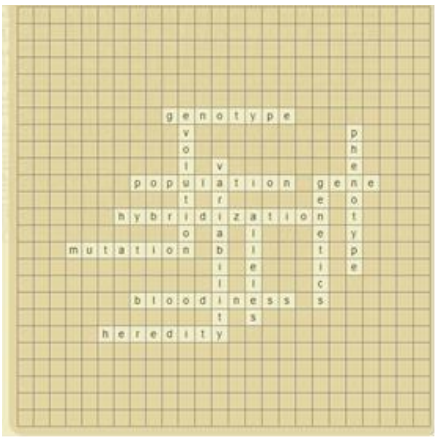

Fig. 14. An example of the crossword puzzle

The third stage involved solving a practical problem, building a model and presenting the project. The teams prepared and presented a model for solving case-study profession-related tasks. The maximum score for this task was 10 (the content, information content, compliance with the case-study assignment, technical quality and artistic merit were the assessment criteria). In different years, the tasks at this stage were offered to teams in different ways. The teams were offered to choose from two options of case-study tasks. In the game of the first year, the teams were offered to solve profession-related tasks. In order to solve the task, the participants needed to apply the Hardy-Weinberg law and analyze the answers received. However, this year one team got a case-study task, where it was necessary to apply the Hardy-Weinberg law and analyze the results, the other team had to build a cross-breeding plan and analyze it, in order to solve the problem of the case-study task.

Now, we are going to describe the conditions and the detailed solution procedure.

Task 1. Make up a model of the frequency of gene occurrence. The farm has 200 heads of cattle, including 192 hornless animals and 8 horned animals. Determine the number of animals of each genotype.

Decision. Since hornlessness is a dominant trait, 192 hornless animals have the AA and Aa genotypes, and 8 horned animals have the aa genotype. Let's suppose that this population is in equilibrium, then using the Hardy-Weinberg formula, we find the frequency of the recessive gene q. q^2=8:200=0,04.

In order to find the frequency of the gene, we extract the root from 0,04, then q=0,2.

We find the frequency of gene A by the formula p+q=1, thus p=1-0,2=0,8. The frequency of heterozygotes can be found by the Hardy-Weinberg formula. 2p·q=2·0,8·0,2=0,32, and the frequency of homozygotes equals p^2=0,8·0,8=0,64. According to the task, we have 200 animals in total, so multiplying the frequency number by 20, we can calculate how many animals of each genotype will be in this population:

- horned animals with aa genotype: 0.04-200 = 8,

- hornless animals with genotype Aa: 0.32-200 = 64,

- hornless animals with genotype AA: 0.64-200 = 128

This task was performed by the "Indigo" team. The results of the task were presented by the team (Fig. 15).

Fig. 15. Presentation of the solution model

Task 2. Create a model of cross-breeding, which is used to obtain the Oryol trotter Lyubesny, if it has consanguinity with the Arabian breed. Take into consideration the following:

1) Lyubesny's father is Bars who was the son of Polkan and the Dutch mare Seraya. Polkan is the son of an Arabian stallion Smetanka and Danish mare Bulanaya;

2) Lyubesny's mother is a mare Gnedaya who was the daughter of Arab and a mare of the Mecklenburg breed.

The stallion Arab is the son of an Arabian stallion Pers and a Persian mare Belaya.

Decision is in table 1.

TABLE I. EXAMPLE OF TASK SOLUTION

Lyubesny $\left(\frac{1}{4}\right)$ Arabian							
O Bars $\left(\frac{1}{4}\right)$				M Gnedaya $\left(\frac{1}{4}\right)$ (Dutch)			
OO Polkan $\left(\frac{1}{2}\right)$		MO Seraya (Dutch)		OM Arab $\left(\frac{1}{2}\right)$		MM Mecklenburg breed	
OOO Smetanka (Arab)	MOO Bulanaya (Danish)			OOM Pers (Arabian)	MOM Belaya (Persian)		

This task was carried out by the team "Old Grapes". The results of solving this task were presented by the team (Fig. 16).

Fig. 16. Presentation of a solution model

The final stage in holding the business game is the assessment, which is important, as it evaluates the achievement of the goal. The student training is assessed by the effectiveness of the business game [15].

IV. Results

The business game “Logic. Model. Profession.” joins together several disciplines and it is aimed at identifying meta-discipline links. Table 2 presents modules of disciplines that are integrated into the business game model.

TABLE II. DISCIPLINES AND THEIR MODULES IN THE BUSINESS GAME MODEL

Name of discipline	Name of Module	Structure of tasks, %
Mathematics	Probability theory and mathematical statistics	25
Biology	Biological features of livestock	25
Genetics	Inheritance of various traits	25
Biometrics	Selection and genetic parameters of the population	25

Table 2 shows that the tasks in disciplines are evenly distributed. However, the application of various approaches to solving case-study problems implies the demonstration of mathematical competencies. Practical work shows that the lack of such competencies will not lead to a successful result in the business game.

In addition, the learning process in the business game involves the development of meta-competencies, such as communication and teamwork skills. Being engaged in the game, all participants learn 1) to develop joint decision-making skills, 2) to present their point of view, 3) to find the best solution, 4) to listen to the opponents’ opinions. Working in the team is especially important when completing the tasks of Stage 3. High performance in completing the task at this stage is achieved due to the team's ability to correctly distribute roles among team members.

The data for filling out Table 3 and Table 4 were taken from the examination records.

TABLE III. QUALITY OF KNOWLEDGE IN DISCIPLINES

Name of discipline	Quality of knowledge, %
Mathematics	70
Biology	80
Genetics and Biometrics	78

The data in Table 3 show the quality of knowledge in students assessed at the examinations in these disciplines. The quality of knowledge in mathematics was 70%, which indicates the effectiveness of the learning process. In order to make a full analysis of the results of educational activities, it is important to take into account the average student performance in the academic group (Table 4).

TABLE IV. AVERAGE STUDENT PERFORMANCE

Name of discipline	Average performance, %	
	Before the business game	After the business game
Mathematics	65	70
Biology	74	80
Genetics and Biometrics	72	78

The average student performance characterizes the effectiveness of learning the materials by the whole group of students. The data in Table 3 indicate the effectiveness of interactive learning of mathematics at the agricultural university. So the average student performance in mathematics increased by 5% after participation in the business game and the average student performance in biology, genetics and biometrics increased by 6%.

V. Conclusion

The use of business games in the classroom provides an opportunity for students to understand, consolidate, systematize previously studied materials from various perspectives.

Modern society poses new challenges for universities. There is a need for implementing innovative forms and methods of teaching professional knowledge in the educational process, with the help of which students will increase their interest in disciplines, and develop such important qualities as sociability, adaptability, tolerance, and stress resistance. From the first days of training, university teachers should support students’ steady interest in the discipline under study, focus them on self-education, and stimulate their interest in scientific research. It will allow the future specialists to see the application of the acquired social and professional skills in the professional practice.

Active implementation of business games in the educational process will allow teachers to meet new challenges and solve the tasks set by the society.

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