# TECNOLOGIAS BASEADAS EM JOGOS PARA O ENSINO DE CIÊNCIAS NATURAIS PROFISSIONALMENTE ORIENTADAS PARA OS FUTUROS MÉDICOS

# TECNOLOGÍAS BASADAS EN JUEGOS EN LA ENSEÑANZA DE CIENCIAS NATURALES CON ORIENTACIÓN PROFESIONAL A LOS FUTUROS MÉDICOS

# GAME-BASED TECHNOLOGIES IN TEACHING PROFESSIONALLY ORIENTED NATURAL SCIENCES TO THE FUTURE DOCTORS

Nataliia V.STUCHYNSKA[1]
Nataliia V.OSTAPOVYCH[2]
Igor V. BELOUS[3]
Julia MAZURENKO[4]
Tetiana ZAKUSILOVA[5]

**RESUMO**: O objetivo do presente trabalho é analisar a aplicação prática de diferentes tipos de tecnologias de ensino baseadas em jogos em cursos de ciências naturais, especialmente física médica e biológica nas universidades. As vantagens e desvantagens do uso de jogos didáticos em sala de aula serão discutidos para oferecer uma classificação de seus diferentes tipos e limitações de uso durante os diferentes tipos de aulas. Estudo exploratório é fornecido para investigar a relação entre realizações de aprendizagem, motivação e engajamento dos alunos e treinamento baseado em jogos. Uma pesquisa foi realizada para avaliar como o sucesso de aprendizagem e a motivação dos alunos são afetados pela introdução dos jogos didáticos durante o processo de aprendizagem do semestre. Os resultados comprovam que esses resultados aumentam em relação aos semestres anteriores. Resultados estatisticamente significativos comprovaram a relevância das tecnologias baseadas em jogos para o aumento da motivação para aprender e várias restrições ao seu uso em termos de resultados de aprendizagem e aquisição de competências profissionais, que só podem ser concluídas com sucesso em adição aos métodos tradicionais de ensino.
**PALAVRAS-CHAVE**: Aprendizagem baseada em jogos; Física médica; competências; Ciências Naturais.

## Introduction

One of the main tasks of modern vocational education is the formation of the ability to professional adaptation in the face of rapid social, social, economic and technological

[1] Professor, Doctor of Pedagogical Sciences, Department of Medical and Biological Physics and Informatics, Bogomolets National Medical University, Kyiv, Ukraine. E-mail: nvstuchynska@gmail.com. ORCID: 0000-0002-5583-899X
[2] Head Teacher, Candidate of Pedagogical Sciences, Department of Medical Informatics, Medical and Biological Physics, Ivano-Frankivsk National Medical University, Ivano-Frankivsk, Ukraine. E-mail: natast@windowslive.com. ORCID: 0000-0002-0905-203X
[3] Teaching Assistant, Department of Radiology and Radiological Medicine. Bogomolets National Medical University, Kyiv, Ukraine. E-mail: drigor.belous@gmail.com ORCID: 0000-0002-9150-484X
[4] Teaching Assistant, Candidate of Physical and Mathematical Sciences, Department of Medical Informatics, Medical and Biological Physics. Ivano-Frankivsk National Medical University, Ivano-Frankivsk, Ukraine. E-mail: yumazurenko@ifnmu.edu.ua. ORCID: 0000-0002-8446-5280
[5] Ph.D.in Pedagogic Sciences, Senior lecturer, Department of the Social Medicine, Public Health, Medical and Pharmaceutical law Zaporozhye State Medical University Zaporizhzhia, Ukraine. E-mail: zakusilovatatyana@ukr.net, ORCID: 0000-0003-3741-8374

changes, ensuring professional mobility, which is based on the ability to quickly and thoroughly master new information. Changing the emphasis of professional training on the effectiveness of knowledge, the ability to use it in practice, the ability to self-study and self-development throughout life, the ability to adapt to social challenges is crucial in ensuring the competitiveness of the specialist in the today's world. In this context, there is a growing need to find appropriate learning technologies.

Among such technologies, especially gaming deserves a special attention. Currently, there is a clear trend of expanding the scope of didactic games in vocational education - in the training of teachers, economists, managers. Game technologies hide a strong enough didactic potential to intensify the acquisition of knowledge, skills and abilities, personal motivation, integration of fundamental and professional training.

Although the theoretical foundations of the use of game educational technologies in the system of higher professional education are not something fundamentally new in the pedagogical research, the problem of learning with the help of game technologies of professionally oriented natural sciences at the medical universities has remained mostly unnoticed by scientists.

The object of our research is the use of game technologies in the process of professional training of future doctors.

The purpose of the study is to theoretically substantiate the feasibility of using the developed methodology of game technologies in the teaching of natural professionally oriented disciplines at the medical universities.

**Métodos**

Bibliographically semantic, analytical, sociological, medically statistical and experimental methods were applied during the study. The sources of information were the results of a sociological survey on study the acquired competencies of students in the medical and biological physics, medical chemistry and radiology, as well as assessment of the knowledge level and skills of students.

The research was conducted among students of 1rd and 3th years of the Bogomolets National Medical University, where the game-based technologies were used. A pedagogical experiment was applied during the research and experimental work. The sample was made up of 304 students who entered the university in 2016/2017 and studied according to the typical

program of the disciplines «Medical and Biological Physics» and «Radiology» by training specialists of professional qualification «physician». Teachers and staff, a total of 37 people, also took part in the experiment.

The experimental group (EG) consisted of students from six academic groups, a total of 167 people; to the control group (CG) belonged five academic groups of the medical faculty, a total of 137 people. The calculation of the indicators and the evaluation of the results of the survey were carried out using statistical methods: for comparative analysis, calculations of derivatives, their errors and confidence intervals were performed, proving statistical significance – the Mann-Whitney criterion of probability, SWAT-analysis of methods of teaching using didactic games.

**Literature Review**

Game technologies form due to the integration of elements of different pedagogical methods and techniques an effective approach to the acquisition of new knowledge.

Based on a rich empirical and statistical material, the researchers from different countries analyzed the general theoretical issues of a «gamification» in the learning process, its advantages and disadvantages and didactic potential (*Furdu* et al., 2017; Pivec, 2007;), as well as its role in study of natural sciences (LIU; CHEN, 2013; CHEN; et al., 2018), math and system analysis (CHENG; SU, 2012; HUNG; et al., 2012), even of medical subjects (YIEN; et al., 2011). The special attention is payed to the increase of motivation by students by means of a digitalization in the teaching process (HUNG; et al., 2012; BODNAR; MIRKOVICH; KOVAL, 2019).

The experience of using game educational technologies in teaching medical students is rather interesting. An international consortium of researchers from 4 countries (Buffalo University, North Carolina, Rochester, USA, Coimbatore, India, Rome, Italy, Hamilton, Canadá) conducted a longitudinal experimental study involving 1,019 students during 5 years. The influence of didactic games on the level of knowledge of medical students in the main clinical disciplines, their satisfaction with the learning process, the development of practical skills, attitude to learning and medical behavior was studied. The study showed the exceptional effectiveness of didactic games in the motivational aspect and the rather relative feasibility of their use in educational activities as its auxiliary, additional component (AKL; et al., 2008, 2010; BHOOPATHI; SHEORAN, 2010; BOEKER; et al., 2009, 2013).

The leading Western expert Janet Voss wrote: "Whatever we call new techniques - suggestopedia, neurolinguistic programming, integrated accelerated learning - but it is optimal to combine three things: learning must be exciting, fast and full" (SADKINA, 2009). In Southeast Asia, beginners learn the basics of accounting in two days of accelerated learning by game methods. In small Liechtenstein, one instructor invented more than two hundred and forty games to teach almost all areas of knowledge - from patent law to geography, history, physics. The world's leading companies - Intel, Apple Computers, Bell Atlantic in the US, companies in the UK, New Zealand use similar technologies (games, music, relaxation) to train their staff in a short time. American educators Gene Marzollo and Janice Lloyd wrote: "The key to success is to turn the game into a learning experience and make sure that learning is mostly a pleasure" (ibidem).

The leading American scientist Prensky (2007) advocates in a number of his works the widespread use of didactic games not only in corporate training of adult professionals (from large companies to the armed forces), but also in the education of junior students. He invented the terms "digital natives" – the modern generation that grew up with information technologies, and "digital immigrants" - middle-aged people who, as teachers of "digital natives", are forced to learn these technologies "by the way". In order to effectively teach the current generation, they need to reconstruct the course of their thoughts and way of thinking in general to correct didactic strategies. This is most effectively achieved by gaming tools. On the other hand, a significant disadvantage of the generation of "digital natives" is the less developed ability to reflect than by the older generation. This opportunity for the development of such qualities should be provided, including problematic, design and research didactic games. According to the scientist, training should be exciting. However, there is a certain European educational tradition (in our opinion, not only Western), which associates learning with suffering.

One of the tasks of pedagogical theory and practice in modern conditions is to optimally combine educational and entertaining components of the didactic game, turning learning largely into what in the West is denoted by the latest term "educainment" (from the English words "education" and "entertainment"). The author rightly warns against excessive fascination with computer simulator games (popular in the West, including in the teaching of medical students). In his opinion, the systems of tasks, ways to check them, the results "at the exit" in them are generally unrealistic and too simplistic. Therefore, teachers should use them

carefully, checking on real professional situations, in order to reduce the number of errors and establish limits of application (PRENSKY, 2002).

**Results**

If we consider the game as an activity, then its structure will organically include goal-setting, planning, goal achievement, as well as analysis of the results in which the individual activates himself fully as a subject. Analyzing from a didactic standpoint the phenomenon of the game in the scientific literature on psychology, philosophy in the historical and cultural context, we believe that the didactic game is an educational technology based on basic psychological and pedagogical invariants of game activity, has a clear didactic strategy in order to achieve the projected result.

If we explain the essence of the definition formulated by us, which is based on the understanding of the basic psychological and pedagogical invariant of game activity, it includes as mentioned above the concept of didactic purpose, procedural strategy to achieve the predicted result.

It is obvious that the didactic game should be based on the main invariant attributive characteristics of the game activity adapted to the psychological and pedagogical conditions of the educational process. Various philosophical concepts of the game conditionally determine such invariant components of the concept of "Game": cognition, aesthetics, competitiveness, seriousness, ethic (KOVAL; POLYEZHAYEV; BEZKHLIBNA; 2018). Analysis of the works of leading researchers of the made it possible to distinguish such its main characteristic as dichotomy or ambivalence, i.e. the game involves the implementation of both real and conditional behavior, but in this case, only the conditions in which the "playing person" mentally puts himself are imaginary, the feelings that he experiences in these imaginary conditions are real ones. The conventionality of game relations mobilizes and activates the capabilities of the individual, promotes the realization of human creativity, encourages him to seek new, unexplored ways to solve the game (life) problems, adhering to the rules and norms of behavior and relations (BANTASH; KOVAL; BASHYNSKA; KOZLOVTSEVA, 2020). From the psychological and pedagogical point of view, most researchers noted that didactic play as a special type of such activity has a special value for its participants (as a way of self-affirmation), involuntary and ease of its procedural course, almost complete lack of practical orientation (this last characteristic causes our serious

warning) or vice versa – focus on non-internal, non-game, practical result (HORDIYENKO-MYTROFANOVA, 2006, p. 58-59; EL'KONIN, 1978).

Thus, the basic invariant characteristics of the game educational activity should also include: - subject-subjectivity of the relations of the participants of the game educational process; - activity, agonality, procedurality and efficiency; consensus collectivity; personal individualization; - problem-orientation and polymotivation; conscious development of learning; favorable affective background; - activation of reserve capabilities; conventional organization of the game space, a kind of "gentlemen" social agreement; removal of the obvious didactic orientation, which is the key to effectiveness in achieving non-immanent, non-game, didactic goals.

Of course, the games can be classified as didactic games only if there is a clear educational goal, often not obvious, in the form of a game learning situation (the principle of "hidden didacticism", the removal of the obvious didactic orientation). Otherwise, it risks becoming a pure game without a pedagogical effect, with vague goals and the dominance of a purely competitive, entertaining component, as described in the work of Raf Koster: "We often discuss the purpose of games to be "art for art's sake "a kind of a puzzle, that allow more than one correct answer, leaving space for interpretation. But both art and game always rise complex scientific questions, including ethical ones. Games will never become adult and educational if their authors do not find out the answers to these basic questions and put these puzzles in order in their brains". (PRENSKY, 2002, p.20)

Considering the poly-targetiveness of the game activity (at least for the simultaneous achievement of inherent game and non-game didactic goals), in our opinion, it is worth talking about the dominant didactic goal: formation of subject knowledge, formation of motivational and moral values, integration of knowledge.

The analysis of the positive domestic and foreign experience of using game technologies in the educational process testifies to the need for careful preliminary elaboration of the procedural strategy by the teacher and the content of the didactic game as a pedagogical technology. According to the right remark of the leading domestic psychologist D.B Elkonin, in didactic games there are always not only rules, but also a plot ("collapsed game situation") (ELKONIN, 1978, p. 265). That is why didactic games are ethical, implemented in the principle of collectivity.

When developing a procedural strategy of a didactic game, it is important to take into account the age, intellectual, motivational and other personal characteristics of the target audience, if necessary, "fall" to its level so as not to be in the situation described in Erasmus of Rotterdam's "Praise of Stupidity": they use their erudition to write for an educated minority, they do not seem to me to be very lucky, but rather suffer from their constant “self-torture” (PRENSKY, 2002).

The formulated definition of the game as an educational technology makes it possible to implement the classification of game initial technologies. We have reason to base the classification on the criteria that reveal the essence of the didactic game and form the basis of this definition: - the presence of a clearly set didactic goal; - use of procedural strategy to achieve the projected result.

Thus, one of the classification criteria may be a didactic goal. We use the term dominant didactic goal due to the poly-targetiveness of game technologies. According to the dominant didactic purpose, the games are divided into those aimed at forming: - subject knowledge systems; - motivation and moral values; - practical skills; - team-work skills, etc.

The procedural strategy for achieving the predicted result provides grounds for classifying games into: quest games, role-playing games, battle games, brainstorming games, etc. In addition, for the classification of didactic games, we used such a criterion as the nature of the pedagogical process, which allowed to distinguish between educational games, monitoring games, integrating, educational, professionally oriented games.

In addition, didactic game technologies can be classified according to the level and nature of their use (KOSTETSKA; KHUMAROVA; UMANSKA; SHMYGOL; KOVAL, 2020). The subject of our study were games used in the educational process of medical and biological physics, medical chemistry, radiology and are of practical interest in teaching other natural sciences to future physicians. Here they form a hierarchy: macro-technologies (can be used at the general or interdisciplinary level), meso-technologies (thematic, modular), micro-technologies (personality-oriented, local). We have developed a set of different levels of didactic games of various kinds.

The first category includes well-known television games adapted to the needs of the discipline "What? Where? When?" and "Brain Ring", which are a kind of "time-lapse brainstorming". We have developed a system of professionally oriented tasks, which allows us to use them in almost all topics of the discipline. However, it should be noted that such

intellectual games require a lot of time to prepare and conduct, which significantly limits their scope. In our methodological system - it is mostly educational activities, independent work of students, and in the educational process - only practical classes, where games are a means of developing skills of team problem solving and even a simplified model of the medical council.

The latest author's intellectual games-quests "Error - Millenium" and "Pentagon" have revealed a high enough didactic potential for use in seminars, practical and laboratory classes. These games are to some extend more technologically complex, but productive for generalizing and deepening knowledge of educational material. Didactic game " Error - Millenium " is aimed at finding and eliminating physical errors. Students are provided with a small text or video with encrypted physical errors that need to be corrected over time. In the "Pentagon", students can receive a maximum of five sentences about a particular physical quantity, phenomenon, law, or pattern, which are gradually provided by the teacher. Students who give the correct answer with fewer tips win. These games are components of the author's technology, developed and tested by us in the dissertation research and can also be attributed to macro-technology. Almost universal is the express game "Erudite-lotto" (several questions with 4 possible answers, one of which is correct) due to technological simplicity, short time and proximity to traditional tests, it can be used as an educational work (in pauses between full-fledged intellectual games), and as a means of current express control of knowledge in seminars, practical classes, laboratories and even lectures.

The favorite students' “quiz-shows” in radiology classes are arranged in approximately the same way. The screen shows a certain pathology and different answer options, the first team who raised their hands is supposed to answer and wins or loses a point (in case of an incorrect answer). The voting takes place via mobile phones with the "real-time" display of pseudo-voting results on the main screen. Analysis of the image and explanation of the teacher make it possible to understand why this answer is correct, and the emotional background contributes to the better acquirement of the material.

There are inexpensive ways to use virtual reality for today, such as a phone adapter, and very expensive ones, such as virtual reality rooms with omnidirectional navigation tape and partial tactile feedback. For use in the process of teaching radiology, we consider it quite sufficient to use a conventional virtual reality helmet with a high-resolution matrix, since image detail is important.

We include role-playing games in meso-technologies. The paper considers the scenario of using a role-playing game in the study of one of the most difficult topics of the course - "The effect of the electromagnetic field on biological tissues". In the classroom, students are asked to act out the situation that occurs in the physiotherapy room: to play the role of a doctor, a physics engineer, a nurse - on the one hand, a patient and his concerned relatives - on the other. According to the role, the student must deeply study one of the aspects of the topic, and then, during the game, which takes place in a dialogical competitive form, a holistic framework of knowledge about the influence of the electromagnetic field on biological objects is formed. Role-playing games require a lot of time to prepare and quite painstaking preliminary work of students.

According to the results of our research, associative didactic games and “productive failure” are highly specialized (those related to micro-technologies), which are effective at the stage of presenting new material during lectures and practical classes. For example, at the beginning of the lecture "Electrography and electrical conductivity of tissues and organs" students are asked to form associative chains to the words "dipole", "vector", "golden section" and supplement them with visual images, which helps students with better understanding of the Einthoven's theory (OSTAPOVYCH, 2014; STUCHYNS′KA, 2012). Using "productive failure", students are asked to solve a problem that requires the use of an unknown physical or mathematical apparatus, and only then explain, based on what laws, it was or can be done. The experiment showed that the knowledge obtained in this way is characterized by significant temporal stability. This method has proven itself well in the study of "Thermodynamics of biological processes". Mathematical battles are also used locally, which in the form of the game "Sea Battle" have shown their effectiveness in practical classes on differential calculus. The author's development of the game "Sea Battle" is a successful tool in teaching differential calculus, because the complexity of the tasks here largely depends on the number of internal functions in the compound or the number of steps to bring the formula to the standard form. This allows in accordance with the complexity of the task to set the quantitative characteristics of ships: one-, two-, three-deck.

In addition to the use of didactic games in the classroom, an important aspect of the study was educational gaming activities in extracurricular educational and entertainment activities. The focus here is not so much on the formation of subject knowledge, but on the formation of personal qualities of the future doctor - communicative competence, ability to

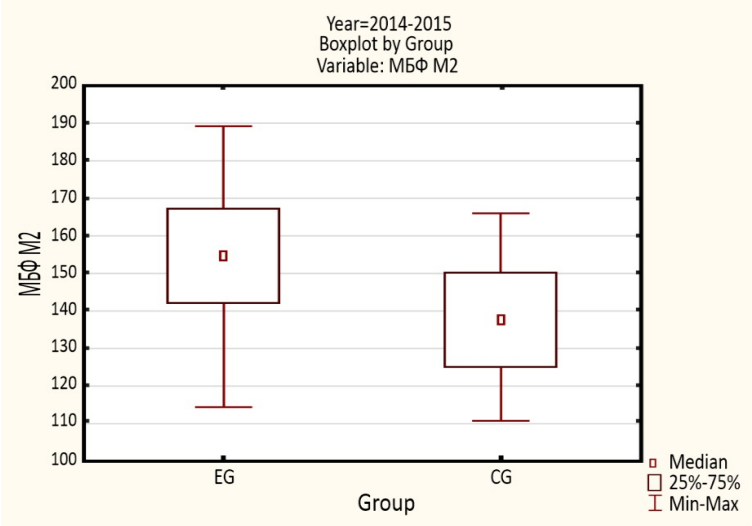
work in a team, emotional and volitional resilience in stressful, timeless situations, psychological ability to make responsible decisions (CHALYI; et al, 2014; STUCHYNS′KA; et al, 2011).

For this purpose, the intellectual games "Brain Ring", "What? Where? When? ", were used, an interdisciplinary (based on the integration of knowledge in medical physics, chemistry, food hygiene) game" Weighed and happy ", as well as socially oriented role-playing game" Hospital for bear cubs ".

To test the effectiveness of the use of didactic games as an educational technology, an experimental study was conducted. The control (CG) and experimental (EG) groups were selected for this purpose. The experimental group consisted of students from six academic groups, a total of 167 people; to the control - five academic groups of the medical faculty, a total of 137 people. Samples of students of CG and EG were formed on the basis of the results of educational achievements at the previous stages on the only measuring materials, which did not differ significantly (were statistically insignificant at p = 0.05). Teachers and staff, a total of 37 people, also took part in the experiment.

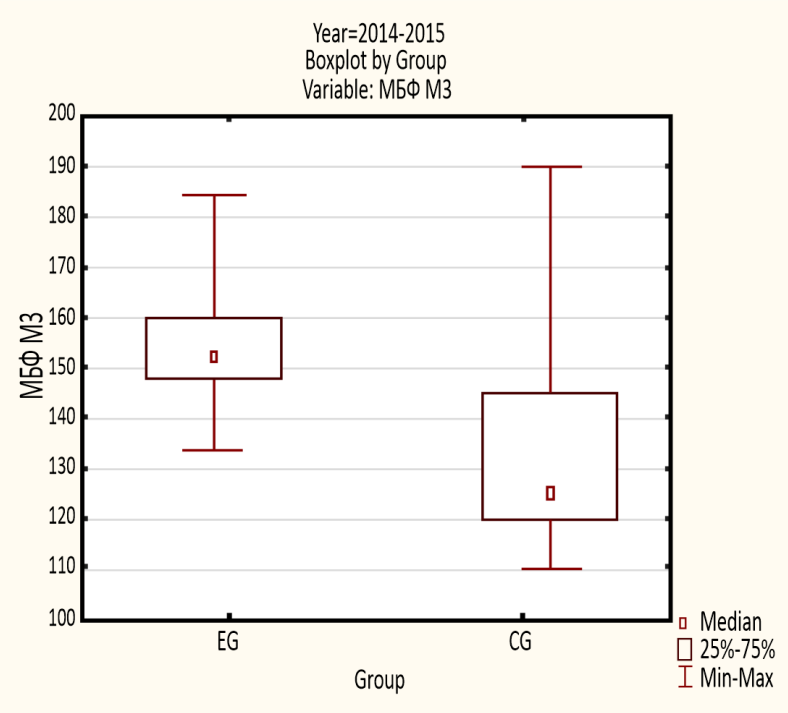
Box-whisker diagrams show the differences between the medians and scatter values in the experimental and control groups at different stages of training during one year (Fig.1).

**Figure 1 – The results of the first stages of training**




**Source**: Prepared by the authors, 2020

**Figure 2 – Results of the final stage of training in experimental and control groups**

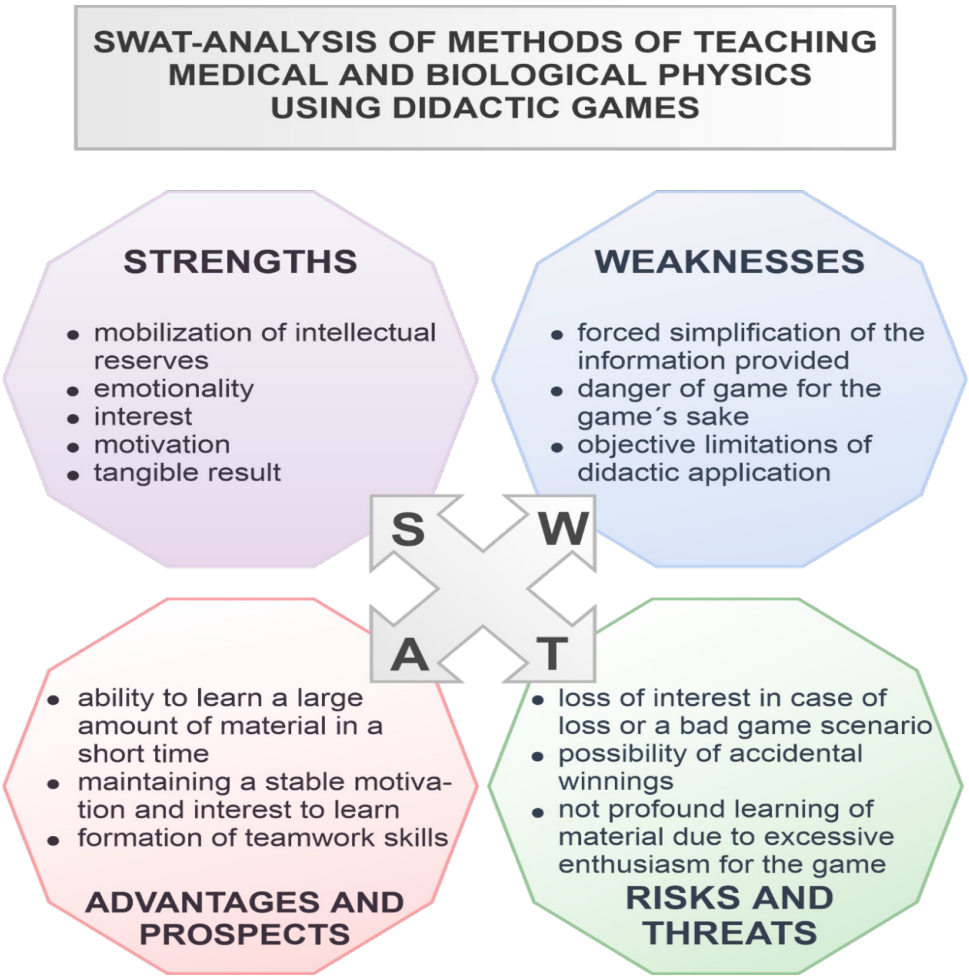



**Source**: Prepared by the authors, 2020.

According to the Mann-Whitney test, the total points scored by students at each stage of study were analyzed for the presence of statistically significant differences for EG and CG in the dynamics at three different stages. In particular, at the first stage in the experimental group the results are lower than in the control, and at the second and third in the experimental group higher than the corresponding results of students of the control group, and the difference increases in the transition from the second to third stage (Fig. 2).

To determine the strengths and weaknesses of our proposed method, we conducted a SWAT-analysis of the method of using the didactic game (Fig. 3).

**Figure 3 – SWAT-analysis of methods of teaching medical and biological physics using didactic games**




**Source**: Prepared by the authors, 2020.

As our SWAT-analysis shows, the strengths of the methodology (S) include the mobilization of intellectual reserves of students, emotionality, interest, motivation to learn, a tangible result.

Weaknesses (W) include the forced simplification of the information provided by the teacher, the danger of the game for the game´ sake, the objective limitations of the didactic application.

The advantages and prospects of the method (A) include the ability of students to learn a large amount of material in a short time, maintaining a stable motivation and interest in students to learn, the formation of teamwork skills.

Risks and threats of the method (T) are: loss of interest in students in case of loss or a bad game scenario, the possibility of accidental winnings without learning anything, not profound learning of material due to excessive enthusiasm for the game.

## Conclusions

Summarizing the above, we can say that the use of game technologies complements the traditional methodological system of interactive learning methods (role play, project method, small group method, competitive group method, heuristic, problem, research, discussion method, associative method); with the special additional game tools (game tables, game scripts, multimedia tools, computer equipment); forms of learning (group, individual forms of learning, research work) and gives the opportunity to achieve broader goals (formation of scientific, critical and reflective thinking, stimulation of activity and initiative, development of teamwork skills and culture of discussion, empathy).

Learning with the help of game learning technologies is effectively provided when there is: a clear didactic goal; procedural strategy with a detailed description of the script, timing, distribution of roles; protection to neutralize the hidden threats of certain aspects of gaming learning activities: exclusively "procedural pleasure" (playing for the game´s); emotional tension and nervousness due to hypertrophied competition; conditionality and ambivalence of the game as such.

## TECNOLOGÍAS BASADAS EN JUEGOS EN LA ENSEÑANZA DE CIENCIAS NATURALES CON ORIENTACIÓN PROFESIONAL A LOS FUTUROS MÉDICOS

***ABSTRACT*:** The aim of the current work is to analyze the practical application of different types of the game-based teaching technologies in course of study natural sciences, especially, medical and biological physics at the universities. Advantages and disadvantages of using didactic games in classroom are discussed to offer a classification of their different types and use limitations during different kinds of classes. Exploratory study is provided to investigate the relation between learning achievements, motivation and engagement of the students and game-based training. A survey was conducted to assess how students' learning success and motivation is affected by introducing the didactic games during a semester learning process. The results prove that these results increase by comparison to the previous semesters. Statistically significant results proved the relevance of game-based technologies for the increase of motivation to learn and several restrictions of their use in terms of learning outcomes and gaining of professional competencies, which can be successfully completed only in addition with the traditional methods of teaching.
**KEYWORDS:** Game-based learning; medical physics; competencies; natural sciences.

**GAME-BASED TECHNOLOGIES IN TEACHING PROFESSIONALLY ORIENTED NATURAL SCIENCES TO THE FUTURE DOCTORS**

**RESUMEN**: El presente trabajo tiene como objetivo analizar la aplicación práctica de diferentes tipos de tecnologías de enseñanza basadas en juegos en la carrera de ciencias naturales, especialmente, física médica y biológica en las universidades. Se discuten las ventajas y desventajas del uso de juegos didácticos en el aula para ofrecer una clasificación de sus diferentes tipos y limitaciones de uso durante los diferentes tipos de clases. Se proporciona un estudio exploratorio para investigar la relación entre los logros de aprendizaje, la motivación y el compromiso de los estudiantes y la formación basada en juegos. Se realizó una encuesta para evaluar cómo el éxito en el aprendizaje y la motivación de los estudiantes se ven afectados al introducir los juegos didácticos durante un proceso de aprendizaje semestral. Los resultados demuestran que estos resultados aumentan en comparación con los semestres anteriores. Los resultados estadisticamentes significativos demostraron la relevancia de las tecnologías basadas en juegos para el aumento de la motivación para aprender y varias restricciones de su uso en términos de resultados de aprendizaje y adquisición de competencias profesionales, que solo pueden completarse con éxito como complemento de los métodos tradicionales de enseñanza.
**PALABRAS CLAVE**: Aprendizaje basado en juegos; física Médica; competencias; Ciencias Naturales.

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**Submetido** em: Julho/2020.
**Aprovado** em: Outubro/2020.
**Publicado em**: Novembro/2020.

**Como referenciar o artigo:**
V.STUCHYNSKA, N.; V.OSTAPOVYCH, N.; V.BELOUS, I.; MAZURENKO, J.; ZAKUSILOVA, T. Tecnologias baseadas em jogos para o ensino de ciências naturais profissionalmente orientadas para os futuros médicos. ***N*uances**: estudos sobre Educação, Presidente Prudente-SP, v. 31, pc012020, p.160-175, jan./dez. 2020. ISSN: 2236-0441. DOI: 10.32930/nuances.v31i0.8215.