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INTERACTIVE LECTURES AND ROLE PLAYING IN TEACHING PHYSICS AND ASTRONOMY

Teaching is the process of shaping and developing student's personality, knowledge, and business skills, in accordance with modern requirements. Therefore, also teachers should enrich their methods in accordance with these requirements. Game-like living situations, role playing, theatrical performances are possible tools in order to increase students' interest and allow them to acquire the knowledge and skills which could be applied in practice in the future. The main requirements for these games are an incorporation of learners into the image of professional-pedagogical thinking. Triggering an active participation of pupils and students is a part of constructivistic teaching strategies.

This article describes how to teach and explain physics and astronomy, using games, role-playing and theatric performances played by elementary school pupils. We report a long (15 years) experience developed in Poland at Nicolaus Copernicus University, and later applied in other places, including the National Science Center in Warsaw and also abroad.

Methods of increasing the effectiveness of teaching using role-playing games as an element of competition at school of Kazakhstan were considered. Both experiences revealed to be very successful.

Key words: teaching, game-based teaching, business games, role-playing games, constructivism.

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Физика мен астрономияны оқытудағы интерактивті дәрістер мен рөлдік ойындар

Оқыту – бұл білім алушының жеке тұлғасын, оның білімі мен құзыреттіліктерін және іскерлік дағдыларын заманауи талаптарға сәйкес қалыптастыру және дамыту үдерісі. Мұғалімдер 21 ғасырда педагогика ғылымдарының жаңа жетістіктеріне және қоғамның жаңа талаптарына сәйкес оқыту және тәрбиелеу әдістемесін белсенді түрде жаңартып отырады. Жаңа құралдарды, оқыту әдістерін қолдану – балалардың мотивациясын, білім алуға деген қызығушылықтарын, білім, білік, дағдыларын, құзыреттіліктерін арттыруға ықпал етеді. Педагогтер сол үшін бейнелі кәсіби-педагогикалық ойлауды жетілдіреді. Мұндай тұрғылар оқытудың конструктивті стратегияларымен байланысты болғандықтан педагог те, оқушылар да белсенділік танытады. Оқушылар мен студенттердің белсенді бастамашылық етуі конструктивті оқыту стратегияларының бір бөлшегі болып саналады. Мақалада ойын әрекеті, рөлдік ойындар және театр қойылымдарын пайдалану арқылы физика және астрономияны оқытудың тәжірибесі жинақталған. Бұған бастауыш сынып оқушылары қатысқан. Польшадағы Николай Коперник Университетінде қолданылған 15 жылдық оқыту тәжірибесі жүйеленіп, талданған. Бұл тәжірибе басқа да орындарда, атап айтқанда Варшавадағы Ұлттық Ғылыми орталықта және сол сияқты шет елдерде де таратылған. Қазақстан мектептерінде рөлдік ойындарды жарыс элементі ретінде қолдана отырып оқыту тиімділігін арттырудың әдістері қарастырылған. Польшада және Қазақстанда оқытудың мұндай тәжірибесін салыстыру екі елдің де табыстылығын көрсетті.

Түйін сөздер: оқыту, ойын арқылы оқыту, іскерлік ойындар, рөлдік ойындар, конструктивизм.

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Интерактивные лекции и ролевые игры в преподавании физики и астрономии

Преподавание – это процесс формирования и развития личности обучающегося, его знаний, компетенций и деловых навыков в соответствии с современными требованиями. В 21 веке учителя интенсивно обновляют методики обучения и воспитания в соответствии с новыми достижениями педагогической науки и новыми требованиями общества. Применение новых инструментов – методов обучения способствует повышению мотивации детей, интереса к приобретению знаний, умений, навыков, компетенций. Для этого педагоги совершенствуют образное профессионально-педагогическое мышление. Такой подход связан с конструктивистскими стратегиями обучения, когда активизирован и педагог, и учащиеся. Инициирование активного участия учащихся и студентов является частью конструктивистских стратегий обучения.

В статье обобщен опыт преподавания физики и астрономии через использование игровой деятельности, ролевых игр и театральных представлений. В них принимали участие ученики начальной школы. Систематизирован и проанализирован 15-летний опыт обучения, используемый в Польше в Университете Николая Коперника. Этот опыт распространялся в других местах, включая Национальный Научный центр в Варшаве, а также за рубежом. Рассмотрены методы повышения эффективности обучения с использованием ролевых игр как элементов соревнования в школе Казахстана. Сравнение такого опыта обучения Польши и Казахстана показал их успешность в обоих странах.

Ключевые слова: обучение, игровое обучение, деловые игры, ролевые игры, конструктивизм.

Introduction

Education is one of the key factors affecting the development of any country at any time. In a period of massive and fast spread of information, bringing some long-lived knowledge to the memory of the learner is not an easy task. The education system should prepare not only qualified teachers but also skilled and creative professionals, with high pedagogical capacities (Shulman, 1987) That is, the teacher of today should be able to choose the approach that corresponds to the topic and decide which method to use when planning lesson (Akimkhanova, 2020).

Already the founder of Western didactics, Jan Amos Comenius wrote in his *Didactica Magna* (1667) that teaching should be fast, pleasant and durable. It is number three in the list of famous saying by Confucius that learning through action is the most effective way of cognition: things created and experienced by person himself are more memorable (Kan, 2019). Therefore, it is extremely important to involve students and/or pupils into the process of learning, also emotionally. Today's teacher should use a variety of creative technology that is relevant to the topic, including role playing, interactive theatre (Rochowicz, 2011), and games.

Several authors find that game-based teaching/learning methods are the most effective and

promising way for professional development (Pivec, 2011; Awwal, 2016; Drachen, 2009). Role-playing and business games expect students to put themselves in the place of other people, look at the problem from other perspective and make the decision by themselves (Alimov, 2009). Role playing (and didactical theatre) is based on a pre-prepared dialog. Furthermore, participants do not have to read or memorize by heart their dialogs but natural role-playing is important (Karapetya, 2004). In role-playing and business games, students apply their theoretical knowledge in situations similar to life cases. They demonstrate the understanding the nature and content of problems in such games, and develop their creativity level by looking for solutions (Jackson, 2000).

Role-playing games are suitable for all population groups from children to the elderly, and to people with physical disabilities (Hawkes-Robinson, 2008). Especially, the role-playing games are useful for the maturation and development of the child (Mailybayeva, 2019; Usmanov, 2019; Kapenova, 2020).

In a role-playing game, a group of students is viewed as a reduced model of the whole society, or as a reflection of a social process, or a particular cognitive situation, where they are tasked to replicate, simulate, mimic, and “play out” public relations, problems, situations, imaginations etc.. That is why the main theme of role-playing games

is playing the “society”, considering and discussing the problems of society (Alimov, 2009). A scheme of goals in role-playing games and other educational theatric “events” is shown in fig. 1.

In this paper we describe three didactical tools to teach physics and astronomy developed at our schools in different countries:

- role-playing games as a competition at the Republican Physics and Mathematics School of Kazakhstan
- pupils’ theatre to play “Robot’s fairytales” by Polish SF writer Stanisław Lem
- interactive plays to explain the Solar system during lessons for children at Nicolaus Copernicus University.

Role-playing games as a competition in teaching physics and astronomy (Figure 2)

It is necessary not only to maintain the interest of young people in education, but also to motivate and increase their enthusiasm (Prosvirova, 2006). A student who studies gradually in one direction might feel that he or she had already achieved the necessary results, which will make him or her research less (Akhmedova, 2013). We, teachers, have to be able to properly organize the demonstration of knowledge and interest in science of talented students (Zvereva, 2015). Being able to show all fascinating and wonderful sides of science using games in education will pave the ground for their research and interests.

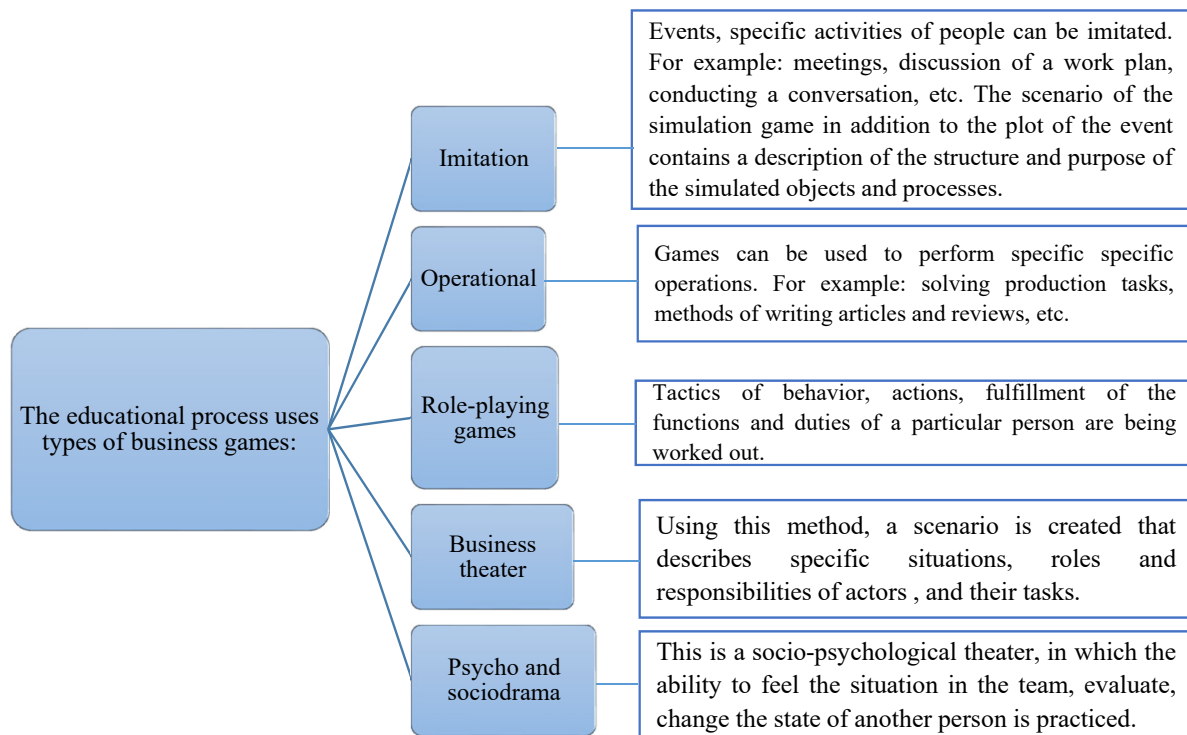


Figure 1 – Types of business games in educational process (Kungurova, 2013)

As mentioned above, role-playing in training helps the participant to raise their interest in physics and behave freely. We have practiced the role and business game with students of the Physics and Mathematics State School outside of classes several years. The results show that this game is very interesting, positive and scientific, and students are glad to participate in the tournament and show their interests in doing science works. The pupils are looking forward to and preparing for this “competition”. The format of this game likes to the “International Tour-

nament of Physicists” (from the IPT official website, 2020). The site archive contains unusual problems and study progress of research that are very interesting in physics also you will be able to see detailed results and individual performances (IPT problems).

Unlike typical physics exam, the problems must not only be presented, but also challenged and reviewed by the other participants (Concept of the IPT: the Physics Fights, 2020).

In the figure 2 shown some fragment from the game.

Each team prepares to 12 practical activities in advance (presentations, photos and videos), while the parts are divided among each member of the team (reporter, opponent, and reviewer). This means each team has a speaker, an opponent, and a reviewer. Now, let us discuss the parts in brief (orderly):

Reporter makes the team's solution to the problem orally. The report should contain a statement of the problem, a review of the available data on the nature of the problem, the main ideas and methods for solving the problem, including a description of observations and experiments, as well as clearly formulated conclusions. The report is accompanied by presentations.

Opponent makes a speech by giving constructive feedback to the solution, made by the speaker, as well as content and the form of the report. The opponent should highlight the positive points in the speaker's speech. Possible inaccuracies and mistakes in the opponent's understanding the problem's nature and in the solution proposed by him should be noted in his speech. The opponent must agree or disagree with the report's conclusions and may offer his own conclusions.

Reviewer summarizes and analyses the discussion between the speaker and the opponent, gives concise feedback to the speaker and the opponent's speech, highlighting positive points and possible flaws. He also makes his own conclusions regarding the discussed issue.

The jury assesses them for their preparation for the game and their role-play. Time should be followed strictly according to the regulations.

Figure 2 – Game process



Figure 3 – Schoolchildren of Physics-Mathematics State School are playing role games:

a) A student in the role of «the opponent» is asking the reporter of the opposite group questions

b) A student in the role of «the reviewer» is making his own conclusions regarding the discussed issue

This is a role playing game according to the pupils:

- improves business relationships;
- helps spend free time very usefully;
- creates and motivates interest in science;
- searching for solutions to practical problems improves worldview.

According to teachers, conducting role-playing games as a competition makes it possible to see and evaluate the different sides of each student; and schoolchildrens are very interested in acting the parts of “the reporter”, “the opponent”, “the reviewer”, also, role-playing games as a competition helps the structure of “research” competencies.

In generally, situation based role-play games are the space for intensive communications that provide

opportunities to gain experience in interpersonal interaction, as well as experience of controlling own expectations.

Playing live physics

Physics, even in the form of lectures with shows, is usually presented *ex-cathedra*. The lecturer and the viewer are separated by a long table and an impassable barrier: “I teach, you learn.” This barrier should be abolished by all possible means, if we want to form really independently thinking “work-force” (Awwal, 2016).

Historically, in the USA, already on 60-ties, the first opening of physics towards broad public were interactive exhibitions and science-centres, see for

ex. (Karwasz, 2012). The free interplay of the visitor with the physical objects changes roles: everybody is induced to a free research. As one of us (GK) wrote in 1997 in the introduction to “Toys and Physics” (Karwasz, 2005): – *Can I play? – Definitely, you’ll discover something!*

“Physics and Toys” exhibitions were invented by prof. Vittorio Zanetti from University of Trento and then brought to Pedagogical Academy in Słupsk, where we (GK) moved in 1996. From 2006 “Physics and Toys” spread further, also to NCU Toruń. NCU had, in turn, experience in lessons, with showing many experiments, open to schools. Still, admission to the cathedral of the main lecture hall at the Institute of Physics was forbidden for children and adolescents.

This changed in 2007 when the competition of the Department of Physics of the Nicolaus Copernicus University for primary schools was announced for the first time. The theme was competition in making fly self-made hot air balloons. The pedagogical point was not on the very construction but on the involvement of the whole class, supporting

the school team. The competition consisted in three categories:

1. prepare a poster on the *mongolfiera* balloon or the history of flights (here, unfortunately, parents did majority of the work)
2. construct a balloon that will fly up to the ceiling of the lecture hall for the longest time, see fig. 4a
3. make the most noisy support: here the whole class was involved and we measured the applause by the acoustic noise meter, see fig. 4b

The competition released unexpected resources of fantasy, technical passion and the will to compete, see the faces of pupils in fig. 4. The old hall of Nicolaus Copernicus never heard such an enthusiasm of children!

The next year, the theme was music and sounds. The competition consisted of bands of several pupils who were allowed to play on any object, but only one could be a real musical instrument. This time cooperation required help from music teachers. Some teams played kitchen pots, and the winners – the zips from own coats.



Figure 4 – Pedagogical interactions in didactics – inducing the emotive involvement and group collaboration via teaching physics: competitions “Pumping a balloon” for primary schools at NCU in 2007. Idea G. Karwasz, implementation with K. Rochowicz, K. Przeglęta, A. Karbowski and K. Służewski (on left photo). Photo A. Karbowski, from (Karwasz, 2012) reproduced with permission

Our next competition associated, as every year with Science Festival in Toruń, introduced theater as a didactical tool. The competition was associated with the International Year of Astronomy (2009). We proposed reading (and performing) a masterpiece of Polish literature of the 20th century, which are “Robot Fairytales” by Stanisław Lem. The goal was another attempt to stimulate the cooperation of teachers, this time of physics, Polish language, music, art and, as the main aim – a creative activation

of children. The competition consisted in the preparation and presentation by a group of students of a short theatrical performance, being an illustration or inspired by one of the “Robot Fairytales” (Lem, 1964) by Stanisław Lem. We wanted pupils to be as creative as possible and to stimulate their imagination. The results really exceeded expectations.

A group of students from the middle school (13 yrs old) in Toruń presented an almost professional performance in which a whole range of stage mea-

tures (including walking on stilts, see photo 5 on the left) was used. Another group (14 yrs old) answered the question, how from quark-gluon *melassa* the universe appeared in Big Bang. Girls in three fundamental “colours” of quantum chromo-dynamics danced.

A great surprise for all viewers was a carefully thought-out and prepared presentation of the Primary School students in Zieleń, the small village not far from Toruń. The subject was about a electro-dragon which started to eat the Moon (in fact, it resembled a French *croissant*). The dragon resisted any attempt to destroy it, until a mathematician

send him three instructions. The last one was to make operation “Moon” minus “Moon” = ? See the result on the photo below (fig.6a). Students (and teachers) have shown extraordinary creativity. We brought the team to Warsaw, to the national science festival: Robot’s theatre became a part of the permanent show. Zieleń is a small village, so prize (a working robot) brought them an immense happiness. Didactics is not only the contents on physics, but also opening all possible capacities of the pupil: communication, self-presentation, proud of the place of origin, collaboration in the group, emotions to win (and loose).



Figure 5 – Fun, didactics and learning in one staging:

a) “How has the world survived?” by S. Lem in the implementation of the gymnasium from Toruń, in the background a lecture on the transit method of planet discovery;

b) “How did the universe arise form the quark-lepton soup?” – question asked and answered by young people from Bydgoszcz middle school

(photo: K. Służewski).

Interactive physics and astronomy

The main conceptual change in teaching physics for schools that brought to NCU in 2007 is the full (i.e. possibly full) involvement of the audience in any lecture that we do for schools, open public, university students. Coming again to Confucius, we can read the formula of Galileo’s transformations for a constant-velocity motion, we can try to understand why Newton’s first law does not distinguish the rest from a uniform velocity, we can speak about Einstein’s equiva-

lency, or, simply we can fly with closed eyes on a hovercraft, convinced that staying at rest (and the whole audience is laughing). Nobody will forget this experience.

The experiment with hovercraft was not invented by us. We introduced two elements: the first one is the didactics of the constant-velocity motion. Without an external system of reference (i.e. in silence and with eyes closed) there is no way to distinguish the motion from staying at rest. The second element is pedagogical: we divide the roles – a bald space traveler (he or she must weight possibly un-

der 35 kg mass, for technical reasons) risks his/ her life to report us the space flight experience and the whole audience, who follows the “flight” not knowing the didactical scope.

The initial point of our interactive/ role playing didactics is always the same: please, identify the difficulty in the process of understanding and use the

whole your imagination to explain it with physical objects. In astronomy we have a kind of dualism: Copernicus said the Earth rotates around Sun, so we keep this picture in our mind, but in reality we see something different – the Sun rises and falls. Should we believe Copernicus (and school teachers) or our eyes?



Figure 6a – „Electro-dragon which started to eat the Moon” by primary school students from Zieleń.



Figure 6b – Proud creators with the prize in their home village



Figure 7a – The lecture „Copernicus in a short trousers”: the experiment with hovercraft used in the didactics of the constant-velocity motion



Figure 7b – The student pointing at the Earth (pin head size) in the proposed Solar System model

If we enter into details, a number of questions rises, for “common” people, i.e. those, to whom science divulgation is addressed: why the clock arrows go “clock-wise”? Where should we search planets? How far is the Moon? 11 hours by a rocket, if going on a straight line. How big is Jupiter?

We use two “master” didactical concepts: first, we construct the knowledge in interactive manner, using the notions brought by the audience. We call

this concept hyper-constructivism (Karwasz, 2019), as we go beyond the social constructivism of Berger and Luckmann (Berger, 1966). The second basis of our didactics we call neo-realism: one should show everything with physical (i.e. tangible) objects.

In the question of planet sizes we use an orange, a pin, and a bigger (5 mm head diameter) pin. We place the pin (Earth) at ten meters from the orange (Sun): “no! further, further! go outside the class”.

Again it is not saying “The distance Earth-Sun is 150 mln kilometers” or even “The distance Earth-Sun is approximately one hundred times bigger than Sun’s diameter”, but an interactive playing with students carrying the orange and the pin – a heuristic surprise to everybody. To show dimensions of Earth and Moon we have two rubber balls with different diameters, see fig. 6a. For the mechanics we need three pupils: the Earth revolves fast, rotates around slow, and Moon? Does it revolve? See figure 8 for two scenes from this lesson.

Elements of the theater are present in all routine shows performed by the Division of Didactics of Physics at the Nicolaus Copernicus University. This is not only because we operate in the hometown of Nicolaus Copernicus. Our sad consternation is that even in Copernicus’ town nobody knows (nobody reads) what is written on his monument. In Latin it says: “*Terrae motor solis caelique stator*”. And using this Latin sentence, we close the “duality” gap in teaching astronomy to the man-in-the-street.

Here, the first impression after participating as a spectator to such interactive lessons (Zh.Akimkhanova):

The organizers of the lecture proved that even the “complex (i.e. difficult) physics” can be understood and remembered by young pupils and they show a vivid interest in physics. Presented in simple, interactive way physics is not difficult if you under-

stand. Physics starts from grade 7 schools in Kazakhstan, but to my knowledge, experiments in such a big lecture hall are never shown. In Toruń, some children were from 4th form of elementary school. As a future scientist and university teacher, it was a unique experience for me.

I would recommend to provide such interesting lectures in Kazakhstan, including the interactive “theatre”. This lecture presented experiments and games, together with examples which interested each participant, including me. It seems difficult, if not impossible, to attract children from different schools and regions for more than 1 hour. What was the most surprising that they didn’t want to go home. Moreover, after the lecture, some pupils came to the professor to find out answers to their questions which were arisen after they had listened to the lectures and some schoolchildren asked for an autograph. This is shown by the experience of the organizers and their successful examples. They proved the effectiveness of teaching using game elements in physics lessons.

The common goal of these activities is to release creative activity among children through surprising, interdisciplinary activities, by stimulating the unity of action within various arts and sciences. Didactic theater seems to be a great way to stimulate interdisciplinary cooperation of teachers, group cooperation between students and to awaken their fantasies and creativity.



a) Explaining relative sizes of Earth and Moon.



b) Simulating the mechanics of Solar system: Earth rotates in 23h56', Moon revolves in one month, Sun rotates in 24,5 days

Photos by Zhuldyzay Akimkhanova

Obviously, as we wrote in the introduction, the role to be played by the public must be very well planned before the lecture and all technical aspects checked before. The hovercraft is hidden during the whole lectures, and only when all aspects of traveling to Moon are explained (it is cold, it is dark, it is silent), we take-out the “space craft”. Then we need a rocket. “No! this is not an old vacuum cleaner! This is a rocket”. Like in a good drama, the surprise is absolutely needed.

Also the requirement to the lecturer are high. He/ she must keep the narration fast (when children are emotionally involved it is difficult to control the attention of the whole, 200 pupils, audience). He/ she must be able to answer quickly all possible questions. Finally, she/he must know both physics and pedagogy. But the constant, lasting interest in interactive lectures in Toruń is a sign that we could apply them also in Kazakhstan.

Conclusions

In this article, we summarize the achievements in learning through the rational use of role-playing games. This is due to the fact that games in people’s memory remain long and interesting.

Activating participants’ learning materials through role-playing – allowed participants to think critically, to discuss and to study, to look at the task from an alternative points of view. Role-playing games also allowed participants to gain experience outside the classroom, prepare for specific learning scenarios and feel more responsible. The role playing as a competition gives students the opportunity and motivation for further learning.

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