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Преподавание физики с использованием современных технологий: эксперименты с компьютерным управлением

Преподавание физики – интересная и сложная область, требующая постоянных исследований. Современные информационные технологии помогают в обучении и проведении исследований. С другой стороны, бывает сложно заинтересовать современных студентов. Более того, в век бурного развития информационных технологий избыток информации может привести к кратковременному хранению ресурсов в мозге. Поэтому одним из основных требований к преподавателям является умение эффективно использовать новые технологии на каждом занятии. Информационные технологии применяются в моделировании, создании и оценке предметных информационных сред, их сущностной и дидактической компоненты, которые развивают такие личностные качества, как рефлексивность, критичность к информации, ответственность, способность к принятию самостоятельных решений, наконец, толерантность и креативность, коммуникативные умения. В результате, использование на уроках физики современных технологий позволяет повысить интерес к изучению предмета, расширит возможности демонстрации опытов через использование виртуальных образов. Преподаватели имеют уникальную возможность сделать урок более интересным, наглядным и динамичным применяя ИКТ в учебно-воспитательном процессе.

В статье описываются совместные исследования, проведенные преподавателями из Университета Николая Коперника и Казахского национального университета имени аль-Фараби в начальной школе «Альберт Авраам Майкельсон» в Стшельно и в средней школе в Квидзыне, Польша.

Ключевые слова: обучение, практика, школьное обучение, PASCO, современные технологии обучения, система обучения в Польше.

Introduction

Teaching problems are always important issues in the society since teaching methods and technologies are developing day by day. According to the well-known Moores' law, the progress of informatics leads to doubling of the computational power every 18 months, or so. This does not translate immediately to new functionalities of the communication devices (computers, laptops, cell-phones), but the youth is first to adopt new technologies. That is why a modern teacher must always be attentive to the latest technology and methods to be effectively implemented in the lessons, and stay aware of what is currently happening in the world: these are not only the technologies, but also "likes" and "dislikes" on well-known internet portals.

In order to optimally solve complex tasks in teaching physics, the lecturer/ teacher should not only select the right method for the given subject, but also organize it properly, and, possibly, use the latest technology. Methods of teaching and forms of organization of the learning process are closely interconnected. University teaching offers a number of methods and forms (lectures, laboratory classes, seminars, conferences, etc.). Also in the secondary school the several forms of physics teaching are possible: traditional lessons, film lectures, training and industrial excursions, etc.

It is known that there are several types of teaching methods used in school life, and therefore the principles of their classification are different. The best of these is the classification based on the sources of students' learning and the joint activities of the teacher and the students. From this point of view, there are three types of teaching methods: 1) speech methods; 2) visual methods; 3) practical methods. *Speech methods* are provided by the teacher using a verbal explanation. The primary source of knowledge that is given to students is the teacher's words, and the teacher's actions are verbal explanations, students' activities, their responsibilities are listening, thinking and so on. The method of verbal presentation of the teacher's textbook is conducted through a talk, interview, explanation, and lecture. But new verbal methods also appear.

Nowadays, students acquire also a lot of information from internet and educational TV. Therefore, interactive methods, in particular discussing different issues with the class, to construct together the required knowledge becomes more and more important (Karwasz, Służewski, Kamińska, 2015). In the EU wording these methods are called "inquiry-based instruction" (Dostál, 2015) – the teachers just ask the questions, and students, together, construct correct answers.

When explaining a lesson using *visual methods,* the teacher demonstrates, illustrates, gives students to hold and sense physical phenomena, processes, bodies, and objects using visual and technical means. In this case, the word of the teacher plays an additional role, and the source of knowledge gained by the students is the visual aids. Here the teaching activity of the teacher is the demonstration, the learning activity of the students in the lesson is observation, reflection on the experimental facts, the conclusion, the enrichment of the knowledge base. Various visual methods include a demonstration experiment, schematic poster, drawing, movie, etc. The teacher and the founder of the didactics, Y.A. Komensky considered already in *Didaktika Magna* (1657) the visual method a "golden rule" for the teacher. Because it results in more effective learning for the students. For example, they see what they can see, etc.

Practical methods include laboratory work in the process of teaching physics, physical exercises, extra-curricular observations, and writing assignments. They form the students' experimental, measurement, research, and general work skills and abilities. The ability of students to independently perform various types of practical work, think and solve tasks is the source of their knowledge and skills. Here the teacher's job is to help them to conduct, check and summarize the work. When it comes to visual methods, complementary accessories at the school can be attributed to the demonstration experiment. And the methodological value of the physical demonstration experiment is that it requires a teacher to consider the following:

1) the practice should be directly linked to the curriculum being taught;

2) the demonstration experiment should have a specific purpose;

3) the physical experiments to be shown in the lesson should not take much time;

4) the experiment must be successful;

5) the experiment should be clear;

6) physical experiments should be used mainly to prove the quantitative meaning of physical laws;

7) the demonstration experiment should be "Eurecal", in which case the students themselves will discover the novelty or come to an appropriate conclusion.;

8) when demonstrating the experiment, only the necessary tools should be placed on the demonstration table;

9) drawings and diagrams related to the experiment should be drawn on the board in a timely manner;

10) the methodological skills of a physics teacher are extremely important for a successful physical experiment (Semey State University named after Shakarim, 2013).

Computer-guided experiments help much in complex fulfillment of the requirements as given above. In particular, in contemporary both measurements (point 3 and 4) and the visualization (points 8 and 9) can be done. Obviously, running both the physical experiment and the computer programme brings new challenges to the teacher (Ellermeijer, Tran, 2019) and requires the integration of these new methodologies into traditional school curricula (Ghavifekr, Wan Athirah Wan Rosdy, 2015).

A successful use of new technologies requires, at the same time, also the change of the pedagogical approach. Differently from traditional laboratories, where students find all instructions ready and tables to fill down, in computer-guided experiments both the virtual and real worlds appear. Therefore, much more group collaboration is needed, in which every member of the group can bring different cognitive competences (Karwasz, 2019).

And finally, as we also show in this paper, this common constructing of the knowledge, with the use of new technology but also of new pedagogy, must be pleasant and joyful (Karwasz, 2016), as it was already stated by Komensky.

In our (Zh.Akimkhanova, K.Turekhanova) previous communication (Turekhanova, Akimkhanova, Gani, 2019) we described a successful implementation at Al-Farabi Kazakh National University of the internet-based educational material from Nicolaus Copernicus University. In this paper we describe the development (and difficulties in implementations) of another new teaching technology – computer guided laboratories and interactive lessons with the use of real-time experiments. We again compare two realities, both in the avant-garde of own national university systems: al-Farabi Kazakh National University and Nicolaus Copernicus University.

PASCO computer-guided experiments in physics

Physics is one of the most popular subjects in school in Kazakhstan: in 2016 more than 30% students graduating from schools choose physics as the main discipline for the Unified Final Test. In the Strategy "Kazakhstan-2050" (2012) of the first President of the Republic of Kazakhstan, Nursultan Nazarbayev, a special attention is paid to the educational system and to science in particular. The President of the Republic of Kazakhstan, Kassym-Jomart Tokayev also noted that improving the quality of education is an urgent problem (2019) (Beysenbayev, 2018). In addition to the regular state educational system, so-called Intellectual Schools (Official website of NIS) had been launched in 2008 on the initiative of the First President of the Republic of Kazakhstan, Leader of the Nation Nursultan Nazarbayev.

The requirements for students entering Intellectual Schools are very high, however, those who finish schools have many opportunities to study abroad at prestigious universities (Kazinform 2017, 2019). To enter such a school one must pass a very serious competition. For example, before the 2018/19 school year at least 14,795 children applied for 2066 grants, giving in average of 7.2 candidates for one place (Bekenov, 2019).

PASCO is a world-class company producing modern equipment (lab equipment) in the fields of physics, biology and chemistry. In our case, in the Physics field, it contains Mechanics, Fluids & Density, Rotation, Thermodynamics, Electromagnetism, Waves & Optics, Quantum areas (Official website of PASCO). In Kazakhstan, equipment of PASCO is used in almost all Nazarbayev Intellectual Schools (Brett Sackett, 2009). Nowadays, there are 21 schools with physics, mathematics, chemistry and biological profiles in all cities of the Republic.

During their laboratory works, students use a variety of methods, such as recording and storing data on the screen using various sensors, finding maximum and minimum points, plotting mathematical patterns, and constructing tables. In this way, students can visualize the order of natural phenomena and draw concrete conclusions. In order to integrate modern equipment into the learning process and efficiently use it in the classroom, Nazarbayev Intellectual Schools teachers were first trained in PASCO Scientific at Rosewill in California, USA, and at different types of schools in Roseville.

Currently, similar courses are being delivered by company representatives to Kazakhstan and are regularly organized on the basis of local Intellectual Schools laboratories. In these courses, the organizers not only teach them how to work with new equipment, but also provide the Intellectual Schools teachers with comprehensive information on the subject's science background, and the latest news in teaching technology. According to Mark Kotlyar, representative of "PASCO Scientific": "The teacher should give the child knowledge that will not be forgotten after the exams but will be nourished and sustained throughout his life. In order to be well-educated, a child needs to do some major and minor research in every classroom. During laboratory classes, the student is offered a scientific quest without any step-by-step guidance, as usual. Students begin to think, ask questions, make hypotheses, and collect data, which is further analyzed and discussed. The teacher, on the other hand, guides the child to the right solution. Of course, this method can take a lot of time, but it is the most effective way to teach thinking" (Bilim ainasy, 2017).

Figure 1a shows schoolchildren (age 12-13) demonstrating an experiment with Pasco during a seminar at 58 school (in city Astana). It is a common practice in Kazakhstan that seminars for teachers are often organized regularly at different schools in the country to exchange experiences and methods.

b) c)

Figure 1 – Computers and robotics in school laboratories in Kazakhstan.

Primary school children, studying at 58th school in city Astana use Pasco system to study the kinematics. Photo by Nurgul Yeshimova (2017).

(b, c) Snapshots from robotics lessons in Kazakhstan. Photos by Gaziz Diusembayev

PASCO is the most powerful computer-based experimental system for schools, but not unique. Arduino is a relatively new (born in Italy in 2005) microprocessor system with open-source instructions and software. (The name comes from the first king of Italy, who reigned from 1002 to 1014). It's a cheap and versatile system and gains the all-over world market.

Recently, additional classes in robotics were introduced in Kazakh schools (Dosanova, 2019). In 2019 the Kazakhstan robotics team took an honorable third place at the First Global Challenge in Dubai in which 191 countries participated (Official website of NIS). Almost every year, starting from 2014, Kazakhstan's robotic teams receive prizes (Zagipova, 2019).

In the figure 1b,c we show snapshots from the Robotics course at specialized Lyceum (No. 165 in Almaty) aimed for children gifted at the physics and mathematics. Pupils (10-11 years old) learn how to assemble a "start" button with an ultrasonic rangefinder, luminescent diodes and other sensors.

Summary of the resources framework

As a pilot testing of the educational efficiency we chose lessons on acoustics at the level of upper classes of the primary school. Here we present results from "A.A. Michelson[1]" school in Strzelno, small town 50 km from Toruń. Nicolaus Copernicus University collaborates with this school from several years, but mainly at the level of lower-level education (interactive lessons for 9-10 yrs old pupils). Now we extended the collaboration also to higher grades of that school. A wireless equipment of the most recent (2019) PASCO system (Official website of PASCO), see fig. 2, was used in Strzelno.

Wireless motion sensor PS-3219. The Wireless Motion Sensor uses echolocation, similar to a dolphin or bat. In order to determine the distance to an object, an ultrasonic pulse is emitted from the sensor. The sensor listens for a signature 'echo' which reflects off the object's surface. The object's distance is calculated by determining the elapsed time between the ultrasonic pulse and detected echo, then, this value is used with the speed of sound to calculate the object's distance. Measurements of velocity and acceleration are derived algorithmically using numerical methods. This provides a balanced approach to calculating numerical derivatives, which reduces noise and minimizes smoothing effects on high-frequency peaks. This device is used to show harmonic oscillations (Figure 3a).

Intensity sensor PS-2109 - The sound level sensor makes accurate sound measurements on the dBA scale (matched to the sensitivity of the ear) and dBC (equal for all frequencies). This device can be used both in the classroom and in the field (street, airport, train station). Three measuring ranges allow you to work in different conditions, depending on the sound level . It was used to determine the acoustic level of the voice (Figures 3b, c).

figure 2a – Wireless motion sensor PS-3219. It is small (8x8 cm) light, and easy to mount

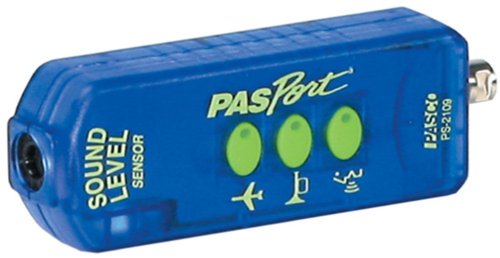

figure 2b – Intensity sensor PS-2109.
Source: www.pasco.com

PASCO system that entered recently into didactical laboratories at Didactics of Physics Division at NCU (Toruń, Poland) are used also in interactive school didactics. Here we present the pedagogical outcome of an interactive lesson on waves and oscillations performed by us (Zh.Akimkhanova and K.Fedus) in the primary school in Strzelno. 50 km from Toruń (the school bears the name of Abraham Michelson, the first American Nobel prize winner, born in Strzelno and emigrated to the USA in the age of 3 years).

Using the wireless motion sensor, harmonic oscillations can be easily explained by plotting (in

[1] The school bears the name of Abraham Michelson, the first American Nobel prize winner, born in Strzelno and emigrated to the USA in the age of 3 years.

real time) the position of a vibrating spring over time. For this aim we chose a soft but long spring with a mass of 100 g attached at its end and a flat surface glued (an old CD). PASCO motion sensor was mounted below, see fig. 3a. The experiment is run by one student, while all other, in real time, observe a sine graph on the screen (fig.3b).

In another example, the teacher turned on the sound level sensor and spoke softly in order to determine the intensity of his voice, the device showed 71.9 dB. When the students were asked if they would like to know the highest intensity of their voice, a student came out voluntarily, his screaming produced an intensity of 110.0 dB, see fig. 3c.

Such an interactive approach releases students' positive emotions which play an important role in the learning process. The entire lesson lasted 2x45 minutes and it was full of other similar activities with PASCO equipment. We had no problems in keeping attention of children. This confirms our dedication to all interactive forms of teaching (Karwasz, Kruk, 2012): computer-aided experiments allow to enlarge the contents to be transmitted (e.g. children formally do not know the sine function), accelerate the lesson and make it more "funny".

According to students from Strzelno (and the present, doctoral students from Kazakhstan) this lesson was very different from typical lessons, offering new didactic features. Didactical and pedagogical goals are coupled, thank to the immediate response of the computer-based measurements and full involvement of the whole class.

a) b) c)

figure 3 – PASCO implementation in primary school (aged 13) in A. Michelson school in Strzelno (30/01/2020)
figure 3a – Wireless motion sensor PS-3219 in use: the search for a harmonic motion.
figure 3b – A real-time read-out and graphical presentation on the screen of the harmonic motion.
figure 3c – Level of the sound (student's screaming) as an interactive involving students' emotions into teaching.
Lesson teacher is K. Fedus, photo by Zh.Akimkhanova

The second pedagogical case study was run in Kwidzyn, 50,000 inhabitants town 50 km north from Toruń. Kwidzyn, thanks to foreign investments develops quickly, and the small, emerging industry requires a qualified work-power. This was the background of the school competition in informatics, robotics, and also environment questions that was organized there on 29/01/2020. Two present authors (G.Karwasz, K.Fedus) participated there with an interactive lecture. Here we present two, best examples of the pedagogical outcome from this competition.

In fig. 4a we present the photo of two winners, girl from 1st Lyceum in Kwidzyn, both aged 15. They have constructed a meter for the level of sounds, and applied it to measure the noisiness in different environments in their school. From the technical point of view the achievement was not very complex. What is important is the whole pedagogical *entourage* of the event.

It is difficult to underestimate the didactical importance of girls' Arduino construction. They had to learn independently notions on the levels of sound (distinction between wave-amplitude and power, decibel), frequency characteristics and environmental questions needed in projects of urban viability (Garzon, Schepis, Karwasz, 2006), architecture, and even in monitoring the home environment). And what is the most important – the creativity, technical competences and enthusiasms of young girls, in times of the virtual "reality" have been triggered. Equally, social competences – the ability of self-presentation, the requirement of clear public explaining, and the sympathy – are also crucial. All this emerged from several pieces that summed up to a long interview which authors (K.Fedus, G.Karwasz) did with the two winners. In its totality, it is a new, emerging form of constructivistic didactics.

Figure 4a – Noise indicator - a simple construction with LED indicators, based on Arduino standards. The two girls (Zuzanna Seklecka i Maja Ostrowska) from the 1st Lyceum in Kwidzyn won the prize at the local competition. Supervisor: Joanna Poźniak.

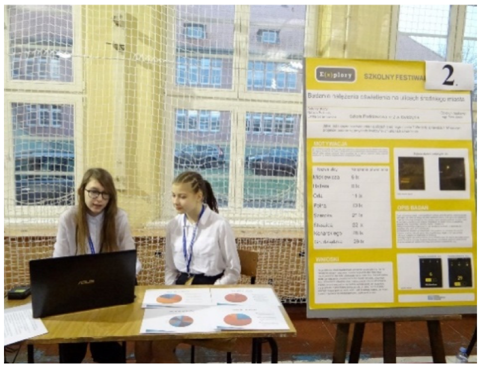

Figure 4b – A similarly simple idea – measuring the level of luminosity in different environments using a photo-camera from a cell phone. Idea and implementation Emilia Szramowska and Natalia Poźniak (Elemantery school No. 2 in Kwidzyn). Supervisor: Ewa Jurek.

Finally, in fig. 4b we present two girls from the last form of the primary school in Kwidzyn, participating to the same competition. They even did not construct anything, but used "a program found in internet" to make measurement of light intensity with their cell-phones. For girls it was just "fun" to show how many *lumen* are under different lamps in the gym hall, but physics behind (and human eye's physiology) is quite complex. Even if they were younger (13 yrs) old than the rest of the pupils in the competition, they proved to be quite able in convincing the visitors to stand by their poster and listen to their explanations.

None of girls were not assisted by teachers in their presentations, and some lacunas and omissions in their knowledge show that they even were not *trained* before the competition. The success of the school competition proves that a properly chosen research goal (monitoring the environment), with sufficient sensibility (all participants to the competition were well informed on the atmospheric pollution) and some hints for the choice of technical solution can trigger the whole range of positive attitudes, required in the modern, so-called "knowledge-based society" (Rocard, 2007).

Conclusions

All cases presented here show that introducing microcomputer and computer-guided experiments allows to obtain important didactical goal:

– integration between the experiment and the presentation of its results

– new notions in informatics, applied to real-time digital/ analog proceeding

– better understanding of notions in physics (velocity, acceleration, sound level, luminosity etc.)

– inter-connecting to mathematics and graphical presentation of data

– "come-back" to the real, physical world, from cell-phone and internet "clouds",

The main pedagogical outcome of students' activity is that spontaneous activity of pupils, at all levels (and in different cultures) is triggered. The use of modern technologies in teaching physics becomes, both in Poland and Kazakhstan, and indicator of the innovation in didactics in general: schools that use these technologies are more competitive on the local (and global) level. In turn, also teachers improve their competences.

In conclusion, the use of complementary technology in school will always lead to successful teaching, especially in the area where physics teaching is a pursuit and always strives for innovation. However, the use of innovations in teaching must be supported by the systematic state policy in education. In Kazakhstan some systematic nationwide actions were undertaken to keep the student's interest in physics at relatively high level. On the other hand in Poland innovations in teaching physics are introduced usually only at local levels. Further collaboration between al-Farabi Kazakh

National University and Nicolaus Copernicus University should contribute to development of innovative forms and methods of both didactics and pedagogy.

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