APPLICATIONS IN THE FOCUS: PHYSICS TEACHING FROM A NOVEL TEXTBOOK

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ABSTRACT

The National Curriculum of Hungary and the curriculum frameworks for all subjects were renewed in 2012. The curriculum framework "A" for physics corresponds to the Science Education Standards applied all over the world. Novel textbooks have been developed by the authors for teaching physics in secondary schools according to this curriculum framework. These textbooks were published by the Hungarian Institute of Educational Research and Development in 2015. They contain up to 30% of significantly new material, very close to everyday life, and the newly developed application-led classes. This paper presents the new textbook and some examples of the application-based classes.

INTRODUCTION

According to national surveys, we can say that physics education is in crisis in Hungary. Poor results of the PISA surveys and our teaching experiences made it clear to us that the majority of the students have serious problems in learning physics. We emphasize this fact not as a theoretical statement but rather as a practical consequence of the changes in physics teaching that have been made in the last decades. Another measureable fact is that students dislike physics and, as a consequence, there is a growing shortage of physics teachers in the secondary schools. One of the possible causes of this may lie within the inherent nature of the subject. Physics is a difficult subject to learn, requiring maximum effort, and the achieved grades may not always reflect the effort that students have paid [1]. For example, understanding modern physics needs strong abstraction far beyond everyday sensing. Further causes may arise from external circumstances. The time devoted to teaching physics in Hungarian schools has been reduced by approximately 50% during the last 25 years. In contrast to that, the content of the physics classes remained the same, or even increased. As a consequence, an average physics class today contains 40% of theory (definitions, laws, formulae), 40% of computational exercise and, only additionally, some practical knowledge about the applications and performing experiments. Young physics teachers often follow the way they where taught: standing in front of the board with a piece of chalk and explaining. This is the easiest way for the teacher, but not the best for the students.

PARADIGM SHIFT IN EDUCATION

The National Curriculum of Hungary and the curriculum frameworks for all subjects were renewed in 2012. Concerning physics, about 30% of new content appeared, in order to turn the subject into a more practical and useful one. Some examples from the new topics are: working principles of the radar and GPS, the way our cars get the energy to move (fuels), physical background of human live-functions and sensing, energy of the nutrition, physics of the weather and climate, global climate change, working principle of CCDs, and 3D displays, physical background of some medical therapies, etc.. These new topics give the teachers possibility and freedom to turn the traditional subject of physics into a more practical one.

The earlier paradigm for physics teaching was developed during the 1950s. According to this paradigm, the definitions of the physical quantities and the laws should be taught first, in their mathematical form. Every student should learn this scientific background and should be able to solve a set of basic computational exercises. The arrangement of the material, even the titles of the chapters, follow the order of the books used in universities. Applications are not in the focus of the teaching, or they have only supplementary role in the books and during assessment. From this point of view, following the logic of science, the material can be arranged only in a few ways: general mechanics is taught first, then the theory of heat, static electricity, electric current, electromagnetism, physical optics, atomic physics, nuclear physics, astrophysics.

At present there are two curriculum frameworks in Hungary. One of them, which denoted by the letter “B” follows this earlier paradigm of physics teaching. In curriculum framework “A” topics are not strictly arranged according to the logic of the science, but they try to follow the logic of everyday life instead.

Novel textbooks have been developed by our group and have been produced and published by the Hungarian Institute of Educational Research and Development (Fig.1.). At present at least fifty teachers have started to teach according to our textbook which follows more the logic of the appearance of the physical knowledge in everyday life than the logic of university books.

Fig.1. Cover of the new textbook for class 11 and an inner page, about the ways of transmitting television broadcast signals.

TOPICS OF THE TEXTBOOK

Let us provide a short list about the main topics of the textbook, following the order of their appearance:

class 9

Time scales and distances in the Universe, from the tiny up to the huge.

Physical background of transportation by vehicle. How are cars moving, how fast are they?

How to turn a car safely, what happens when we try to stop a car? How rockets work.

Movement of the objects of the Solar System: satellites, planets.

Energy, work and power: the main concepts.

Simple machines: torque and balance.

Waves and oscillations: La Ola wave, earthquake, resonance catastrophe.

Energy: The ways we consume energy, power stations, and many actual topics: calories, fuels, the Sun, passive houses, atomic energy, global challenges for mankind, energy crisis.

class 10

The water around us.

Motion of the air and water: winds, storms, oceanic streams, physics of flying and swimming.

Global environmental problems: ecological footstep and climate change.

How musical instruments work.

Sparkles and thunders.

Electric current: use of batteries

Safe usage of electric machines, domestic electric networks.

Creation and transportation of electric energy. Electric generators.

class 11

How do our eyes work? About eyeglasses, colours, the working principle of movies, imaging techniques in medical diagnosis (CT, MR, X-ray) and safety (X-ray at the airport).

Global communication: communicating via electromagnetic signals (television, mobile phone, digital coding of information).

What are things made of? Light sources, cameras, electrovoltaic cells, colours of different materials.

Radioactive radiation: medical applications, safety issues, nuclear power plants.

World of the stars: what does the star light tell us?

Universal questions: extraterrestrial life, “At the beginning…”, is it really written in the stars?

Physics of the Solar System.

Space exploration.

The topics mainly were selected because of their importance and strong presence in everyday life. We tried to cover almost each phenomenon which could be important for a kid to now. Despite of the fact that applications are in the focus, arrangement of the topics sometimes follows the traditional order of physics teaching. For example knowledge about mechanics can be found mainly in class 9 in the topic of the transportation, but the inner coherence of the topics are not as strong as usually, it is easier to change them or to omit some of them.

To summarize: according to this approach we should teach physics as it appears in our everyday life, in the streets, in the kitchen, in the household, during transportation, while using our mobile communication devices, when going to the cinema, etc.

Let's have an example about the waves. When we are teaching this topic according to the new book, the starting point of the teaching is not to give definitions of some quantities or draw up the definition of mechanical wave, transversal and longitudinal waves but to observe and examine the waves that are present around us. La Ola is similar to the shock wave, and a good example that a wave can transfer the energy in a certain direction without observable particle transfer. Students are interested in earthquakes, so it's a good chance to give them simple explanations of the surface and bulk waves produced by the earthquake (Fig.2.). At this point it's possible to speak about longitudinal and transversal waves as well, but the main aim is still not to define them very strictly, but to explain how the energy of the earthquake is dissipated and to expand the horizon of the students' mind.

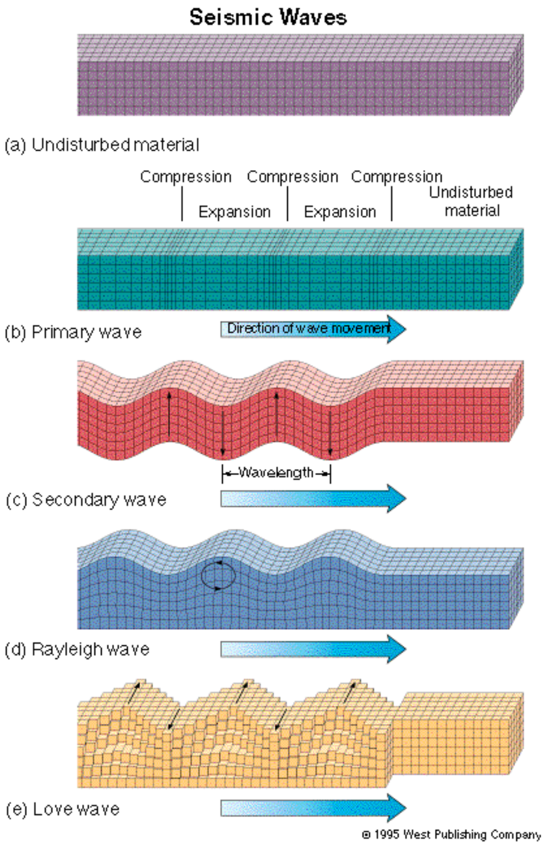

Fig.2. Different types of waves produced by an earthquake [2]

Standing wave and its frequency are coming into the picture when we are explaining how the guitar is able to produce a sound. The main aim in a normal group (having 2 hours of physics per week or less) is not to teach the formula of the frequency of a standing wave on a string with fixed ends, but to develop the qualitative understanding about the working principle of the guitar – up to a certain extent.

There are many advantages and disadvantages of teaching in this way to consider thoroughly, but what is more, there is a possibility to observe the behaviour of the teachers and the progress of the students working with the new textbooks.

INNOVATIVE TEACHING METHODS

In order to understand the approach, it is important to keep in mind that the main aim is not to teach and make the kids memorize each and every useful fact found in the books. There are plenty of them and they can be found either in the book, or on the World Wide Web later. We neither aim at teaching more and more definitions and formulae, nor try to teach how to solve different types of computational problems. The aim is rather to give scientifically correct explanation of everyday issues up to a certain level of abstraction that is affordable for the pupils. This level depends on many factors and can be changed according to the prior/background knowledge of the children, and according to the aims of the school. It is good to use innovative methods that develop creativity, communication, cooperation and critical thinking of the students. These are accepted as the key competences for building a successful career in our quickly changing world.

Gamification is one of the promising innovative methods [3]. Look at the board (Table 1.) of the game with atomic energy levels. To start the game, our electron should stand in the ground state.

Table 1. Board of the physics game.

electron energy	-12 eV	-7eV	-4eV	-2eV	-1eV	0eV	1eV	2eV	3eV
electron state	ground	excited	excited	excited	excited	excited	free	free	free

After throwing the dice the electron can move from one energy state to another one. The rule is the same as in photon excitation: the electron can accept the energy (the number) only if it is equal to the energy difference between the present state and a possible excited state. A controlled trial experiment was performed at the University of Debrecen in 2014 to find out whether playing this game helps the students. There were two groups selected from first-year students with about 15 pupils in each. Both groups got the same lecture about photons, photoelectric effect, and energy levels of atomic electrons. Group B played the game as the application of the theory, while group A solved some computational exercises. After 3 weeks both groups wrote a test without previous announcement. Overall performance of the gamified group was slightly better than that of the other group.

Mobile phones are getting used widely in active learning because they can be used as measuring instruments [4]. Camera (CCD detector), microphone (sound detector for examining waves), three-axes accelerometer sensor can be found in every phone, ambient light sensor, magnetic field sensor are usually available. Popular applications (like compass, spectrum analyzer, metal detector) and applications for physical measurements (like Physics Toolbox) are quickly downloadable.

Using a frequency meter application, it is easy to tune empty bottles to create a musical sound with the desired tone [5] (Fig.3.).

Fig.3. Making music with bottles from [5]

In our experiment six groups were formed from the secondary school pupils, there were about three members in each groups. The task of each group was to tune their bottle into the desired note of the tonal scale (do, re, mi, fa, sol, la, ti, do). Members of one group calculated the frequency for each sound using the formula in the book; while others found a musical sheet for a simple song (see Fig.4.).

Formula for the simple major scale.

$$do\cdot\frac{9}{8}=re\,,\;\; re\cdot\frac{10}{9}=mi\,,\;\; mi\cdot\frac{16}{15}=fa\,,\;\; fa\cdot\frac{9}{8}=sol\,,\;\; sol\cdot\frac{10}{9}=la\,,\;\; la\cdot\frac{9}{8}=ti\,,\;\; ti\cdot\frac{16}{15}=do \quad (1)$$

Fig.4. Sheet for a simple winter song starts with: do-do sol-sol la-la so, fa-fa mi-mi re-re do

At the end of the class it was possible to play a simple melody and that was a really good result of the cooperative effort.

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