Effective teaching methods

—Project-based learning in physics*

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Abstract: The paper presents results of the research of new effective teaching methods in physics and science. It is found out that it is necessary to educate pre-service teachers in approaches stressing the importance of the own activity of students, in competences how to create an interdisciplinary project. Project-based physics teaching and learning seems to be one of the most effective methods for teaching science for understanding. It is necessary to provide in-service teachers instruction (seminars) and prepare sample projects with proposals how to develop, run and evaluate interdisciplinary projects. Projects are important "real-world" physics modules, modern physics and everyday life problems can be integrated into the high school curriculum. Examples of projects that were worked out are presented.

Key words: physics; teaching method; project-based learning; renewable energy; water

1. Introduction

1.1 Aim of the research

The decline of the number of physics students can be seen at the universities in the Czech Republic. The level of knowledge is decreasing, physics is not very popular at secondary and high schools, physics is difficult (Research NPVII).

University teachers interested in didactics of physics started a lot of initiatives with the aim—"How to teach science for understandig". The goal is to find effective teaching methods and create a curriculum according to the requirements of the teaching and learning for the 21st century. Today's education system is characterized by a gap between how students live and what they learn and how they learn. To bridge this discrepance new legislative documents of the Ministry of Education are coming into life (*The White Book—The General Educational Programme*). The main tendency is to apply interdisciplinary relations. Science subjects are integrated in one field—"man and nature", where physics, chemistry, geography, geology and biology can be found. Teachers of these subjects (of one field or area) have to cooperate and use an interdisciplinary approach in teachnig and learning.

In-service teachers are not really prepared for the new way of teaching. This situation must be changed. We started our research from this point of view and the goals of the research were:

(1) To find appropriate teaching and learning methods;

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Renata Holubova, Ph.D., Faculty of Science, Palacky University Olomouc; research fields: problems of interdisciplinary education-preconcepts, new teaching and learning methods, motivation strategies in physics teaching and learning-simple (non traditional) experiments, science on stage, competitions.

(2) To discusse project-based learning;

(3) To find the best way how we can help our in-service teachers to improve the understanding in physics and motivate the learners.

1.2 Methods of our research

Methods of our research are: interview, discussion, visits at schools.

1.3 Observation findings

At secondary and high schools the chalk talk method is used most often. According to the curricula (*The White Book*), it is obligatory to organize “project days” at secondary and high schools. It is the only way to realize an interactive learning environment. The learners are devided into groups, the problem that each group has to solve is to do out-door experiments and elaborate work sheets or a poster. Projects at high schools represent mostly a background search of an interesting problem or a topic. This is not the project-based learning where projects are included in the curriculum.

2. Discussion

2.1 Question 1

Initial teacher training at our department started some initiatives to change this situation. In-service teachers complain of lacking time to prepare projects, they are not educated in the methodology of these methods. That is why we train our students in these new methods, they are taught how to use interdisciplinary relations. For the theoretical part interactive lectures and seminars are provided (subject about Physics-Technique-Nature). For the practical part, the following teaching methods are used:

(1) Seminars;

(2) Task-focused teaching methods;

(3) Observation in schools;

(4) Micro-teaching.

An expanded physical science curriculum for pre-service teachers is provided. We focus on motivating the learners in physics and science. For the motivation it is necessary:

(1) Good understanding of the problem;

(2) The school closer to the practical life;

(3) Computer based experiments;

(4) Simple low cost experiments;

(5) Research activities;

(6) Competitions.

Effective teaching methods are characterized by a shift from whole-class to small group instruction, by a shift from lecture and recitation to coaching, by a shift from competitive to a cooperative social structure, by a shift from all students learning the same thing to different students learning different things. We should analyze methods—problem-based learning, project-based learning, e-learning techniques, motivation by adventure in pedagogy, computer-based instruction and experiments.

2.2 Question 2

It was find out, that one of the best teaching and learning methods is project-based learning. Giving students freedom to generace artifacts is critical to their construction of knowledge. Project-based learning also places students in realistic, contextualized problem-solving environments. Projects can serve to build bridges between phenomena in the classroom and real-life experiences (Blumenfeld, 1991).

Project-based education requires active engagement of students' effort over an extended period of time. Projects are adaptable to different types of learners and learning situations.

Project-based learning (PBL) is an instructional methodology in which students learn important skills by doing actual projects. Students apply core academic skills and creativity to solve authentic problems in real world situations. Students use a wide range of tools and the culminating projects are tangible and observable artifacts that serve as evidence of what the students have learned. Student-produced videos, artwork, reports, photography, music, model construction, live performances, action plans, digital stories and websites are all examples of PBL artifacts. Project-based learning is based on the constructivist learning theory, which finds that learning is deeper and more meaningful when students are involved in constructing their own knowledge. Students are given the opportunity to select a topic that interests them within the required content framework and then they are responsible for creating their project plan. Rather than a lecturer, typically, the teacher's role is that of an academic advisor, mentor, facilitator, task master and evaluator (project-based learning handbook, 2007).

Learners activities are very different. Solving projects is the way how teachers focus students' learning on issues of problems and topics that are not included in textbooks (modern physics, environmental problems).

Project-based learning is included in the didactics of physics by other methods that approach stressing the importace of the own activity of pupils.

2.3 Question 3

The aim of the outcome of the research is to help in-service teachers. The best way to do it is to prepare projects that can be used at all school levels. These projects contain an instructional manual, the overview of the physical background of the problem, students activities, experiments, work sheets and evaluation. Examples are given to integrate the project into the educational program and an overview of the final competencies. We organize seminars for in-service teachers to strengthen collaboration. We have a continual feedback and assessment and professional development opportunities for teachers are created. We struggle to improve the quality of science instructional materials and create higher standards for science education.

3. Examples of the projects

Environmental problems are discussed all over the world and main environmental questions can be studied in physics. A great feedback has our project about reneveable energy resources, "Do you know the Sun". The aim of this "great" project is to study theoretical problems concerning the energy (solar energy, water-power, wind-power). Our most succesful project—the project water, and other projects (how to build a house, modern physics—nanotechnology, physics and medicine, world in motion, horror vacui) can be integrated in this main project. The final competences are included in the curricula—electricity, optics, transformation of energy, photovoltaic, semiconductors and energy flow.

3.1 The Sun—our nearest star

3.1.1 Topics

(1) All about the Sun—our star in the past and the future;

(2) Physics of the Sun (weight, radius, temperature);

(3) Thermonuclear reactions;

(4) Radiation;

(5) Motion of the Sun;

(6) What is photovoltaics?

(7) Some advantages and disadvantages of photovoltaics—discussion (Table 1).

Table 1 Photovoltaics—discussion

Advantages	Disadvantages
No emissions	Expensive production
No noise	Relatively low effectiveness (> requires large areas)
Long life	Depends on illuminance by the Sun (low effectiveness in winter, doesn't work during the night)
Can be manufactured out of common chemical elements	A small amount of toxic substances is used during production
Not use up any natural resources when in use	
Low costs for maintenance and use	

3.1.2 Experiments with solar cells

The aims of the experiments of electricity studies are:

(1) Understanding the way in which the plugging system works;

(2) Getting to know the solar cell as a power source;

(3) Comparing important effects of the circuit types series and parallel connection;

(4) Getting to know different electric users.

The aims of the experiments of optics are:

(1) Illustration of the solar cell's dependence on light;

(2) Getting to know the different types of radiation;

(3) Visual understanding of colour systems;

(4) Understanding of various optical delusions.

3.1.3 List of experiments

(1) Series and parallel connection of solar cells

Our technology allows only for the production of solar cells with a limited surface. In today's mass production crystalline silicon solar cells are manufactured with a surface of 12x12 cm^2. The voltage of such a cell is limited to 0.6V. These low voltages are hardly useful for technical applications. Therefore several solar cells are connected together to units. In most cases commercially available modules feature a 6V nominal voltage.

(2) Dependence of the power on the surface of the solar cell

(3) The dependence of the power on the angle of incidence of the light

This experiment can be used to determine the following physical values in dependence on the incidence of light α:

(a) Short-circuit amperage IK;

(b) Open-circuit voltage UL;

(c) Power at a fixed load.

3.1.4 Application: Tracking of solar cells

To achieve a high energy efficiency at the utilisation of solar cells, large solar plants track the sun, this mechanical system is always aligning the solar modules to the sun.

There are two basic tracking types: uniaxial tracking-the solar module is movable on one axle only. This type of tracking is performed in two versions: seasonable tracking and the daily tracking.

In case of the biaxial tracking the modules are pivoted horizontally and vertically. They track the sun with the help of a sophisticated mechanical system so that the solar module is always perpendicular to the incident light.

By the use of tracking the energy balance of a solar module is significantly enhanced, for example, daily uniaxial tracking can generate approximately 20% more energy. In contrast, the energy expenditure for the tracking motors is just about 0.2% of the total generated energy of the system.

(1) Dependence of the solar cell power on the illuminance.

(2) Dependence of the short-circuit current and the open-circuit voltage on the illuminance.

(3) Dependence of the power on the illuminance with a given load.

(4) Determination of the efficiency of a energy conversion (This experiment uses the solar motor to convert electrical energy into mechanical energy. This is carried out by rolling up a weight on the drive shaft and therefore performing lifting work).

(5) Internal resistance of the solar cell.

(6) Diode nature of the solar cell.

(7) Shading characteristic.

(8) Dependence of the voltage-current characteristic on the illuminance.

(9) Dependence of the voltage-current characteristic on the temperature.

(10) Dependence of the solar cell power on the temperature.

(11) The solar cell as a transmittance measuring device (This experiment simulates the use of solar cells in optical measuring devices. The cell acts as measuring device for the transmittance of foil).

(12) Dependence of the solar cell power on the frequency of the incident light. (Figure 1 & Figure 2)

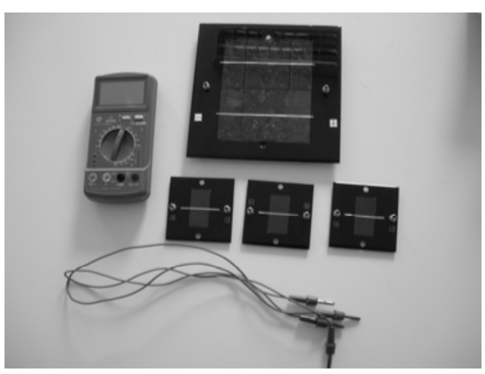

Figure 1 Solar cells

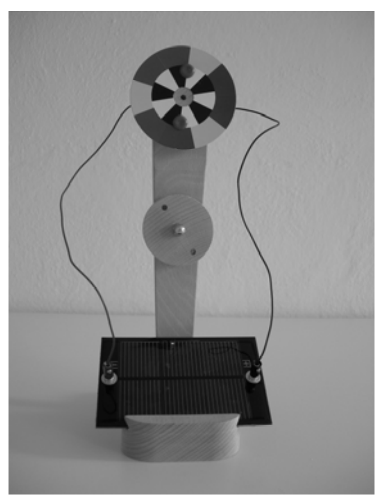

Figure 2 Sunstick

3.2 Photoelectric effect

Interdisciplinary relations: physics (qauntum character of the light, semiconductors); art (shapes, scene); literature (stage play).

Students have to prepare a stage play—they perform the conception of the photoeffect (electrons, holes, photons, energy=snack).

3.3 Energy of the Sun—where we can find it?

Interdisciplinary relations–physics (energy, energy transport, electromagnetic radiation), Geography (environment, hydrological cycle), chemistry (photosynthesis), biology (plants and biomass), geology (water), ICT-power point presentation.

3.3.1 Topics

(1) Radiation from the Sun—how can we use the energy.

(2) Wind—one of the transformation of the energy from the Sun.

(3) Water—energy from the Sun and water—subproject water can be included.

(4) Biomass—explanation, how can we use it.

(5) Analysis of the environment around the school, how effective is to build there a wind or solar power station.

3.3.2 Water

The basic aims of the project Water—interdisciplinary relations (Figure 3): physics (density, state), chemistry (chemical properties, solvent, sewage works), biology (life), geography (rivers, sea, ocean, map), mathematics (statistics, calculations), language (fairy tails), arts (water in work of art), music (B. Smetana—The Vltava river from the symphonic poem *My country*).

Figure 3 Water for life

3.3.2.1 Water as a concept

(1) Basic part of the environment;

(2) Chemical matter;

(3) Necessary for life;

(4) Part of the society;

(5) World's Day of Water (22nd of March);

(6) The year 2003—the Year of Water.

Basic concepts—hydrosphere, hydrology, areas with a lot of water and deserts.

3.3.2.2 Water resources all over the world

(1) Sea and ocean 70.7% of the Earth's surface (361 mil.km^2), but only 0.1 % and 0.24 % of the mass of the Earth;

(2) The world's ocean represents 97% of the Earth's hydrosphere;

(3) The average water depth of the ocean is about 3790m. If the water of the ocean burgeon out the whole Earth, the water will have a tickness of 2440m;

(4) Water cycle (small, great, the hight of the atmosphere of 7km contains about 12400km^3, flowrate and its

measurement);

(5) Biologocial function of water (basis of life, the content of water is greater in youth and at lower level of the Darwin's range, photosynthesis, transpiration, evaporation);

(6) Chemistry of water (Lavoisier, Cavendish, Gay-Lussac, Humboldt);

(7) Water in physics (clear colourless liquid, without taste and smell, freezing point 0ºC, bowling point 100ºC, anomality of water-increasing of the volume by freezing of 1/11, salinity).

3.3.2.3 Ecology

1/5 of people has not an accession to unexceptionable water, 2.6 mld of people has not a basic hygienic background (http://www.un.org/events/water/factsheet.pdf).

3.3.2.4 The price of water

(1) Effects of global warming-water pollution, environmental degradation and unsustainability;

(2) Consumption and need of water;

(3) Bottled water—in the 18th century bottled mineral water, 20th century—polymers;

(4) Water in the history—towns and settlements near the rivers, survive with fishing, transfer Water as an element;

(5) Flood x dryness (in Africa 1991-1992—area of 6.7mil.km^2, 24 mil. people suffer from shortage of water)

(6) Water industry-ponds (8th century), dams (since 1903) (Table 2 & Table 3).

Table 2 Water in industry (need of water by production of these products)

Product	Need of water (liter)	Product	Need of water(liter)
Beer 1*l*	25	milk 1*l*	865
Corn 1kg	1 000	rice 1kg	1400
Meat 1kg	13 000	cheese 1kg	5500
Paper 1kg	300	wool 1kg	150
Steel 1kg	200		

Table 3 Water at home

Activity	Water (liter)	Activity	Water (liter)
Lavoratory	10-12	washing machine	40-80
Bath	100-150	washing hands	3
Shower	60-80	washing a car	200
Washer	15-30	drinking (per day)	1.5
Dripping spigot	4 *l* /h	unsealing toilet	80*l*/h

Interesting facts—dessication of the Aral lake, glacier discharge (glaciers in Alps hidden by a sheet), superionized water (inside of Neptun), water in the Universe (Mars).

The functions of water in living matter—solvent, chemical activator, thermal regulator, pressure and shape regulator, transport medium, economy (conservation) agent for aquatic organism.

3.4 Wind around us

(1) Interdisciplinary relations: physics (energy, wind power stations); geography (environment, atmosphere); art (maps, paper windturbines); ICT-power point presentation (Figure 4).

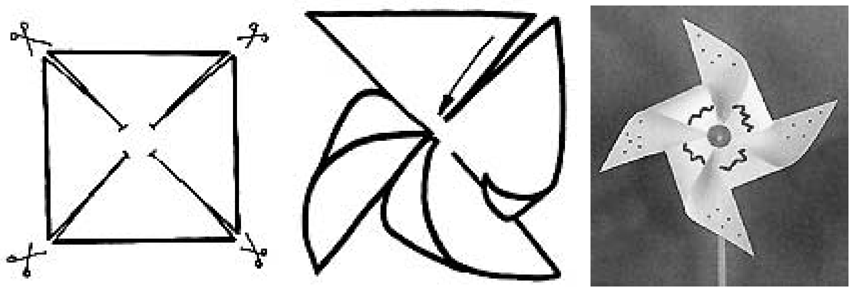

Figure 4 Paper vessel

(2) Theoretical part: informations about the wind, wind power stations in the region.

(3) Experiments: students prepare paper vessels. They can measure air vessel propertires (frequency and diameter of the vessel, frequency and direction of the wind, frequency and wind force, see Table 4 & Figure 5).

Table 4 Wind power station capacity in European Union countries in 2007

Country	Power in MW
Czech Republic	116
Belgium	287
Bulgaria	70
Denmark	3,125
Estonia	58
Finland	100
France	2,454
Ireland	805
Italy	2,726
Cyprus	0
Lithuania	50
Latvia	27
Luxemburg	35
Hungary	65
Malta	0
Germany	22,247
Netherlands	1,746
Poland	276
Portugal	2,150
Austria	981.5
Rumania	7
Greece	871
Slovakia	5
Slovenia	0
Spain	15,145
Sweden	788
United Kingdom	2,389

Figure 5 Wind power station in Nova Ves

4. Conclusion

There are a lot of advantages and disatvantages of project-based teaching. Our finding is that the advantages of this type of instruction are the activity of students and a chance to solve interdisciplinary problems. The activities can be done outside the school environment. Projects lead to teamwork, students learn to work as researchers, with various tools, technologies and materials. New teams can be created not only from students in one classroom but all over the school. Students have a chance to present their work. We found some disadvantages too—teachers are not able and willing to prepare interdisciplinary projects and collaborate. On the other hand, a lot of project days are organised at schools according to the new educational program (it is one of the compulsory outcomes). It is more difficult to evaluate the work of the individual member of the team. More time is necessary to study a problem by project based teaching. A presentation of the project is necessary. Nowadays the greatest advantage of projects is the ability to study problems that are not included in school textbooks, problems of modern science, presentations of recent research discoveries in science can be done. At our department we struggle to prepare various types of projects that will be included in modules. Undergraduate students take part in these activities—their diploma thesis are often completed by examples of projects.

Project—the basic steps to prepare and realize project work can be pointed out:

(1) Preparatory work;

(2) Background reading;

(3) Literatury search;

(4) Realisation;

(5) Report;

(6) Presentation;

(7) Discussions;

(8) Conclusions.

Project-based teaching and learning can be a part of our motivation activities. It can be shown that Physics is irreplaceable for the progress of our society, because modern technology involves physics, learning physics leeds to the development of thinking skills and understanding the other science. The future employment market will request people with skills that can be developed only in natural science. Physics is the basis for all types of analytical and measuring systems. In the next year an entire instructional material about project-based teaching and learning in physics with projects' manuals will be prepared.

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