Education and Culture

Socrates

Effective use of ICT in Science Education

EU-ISE: (226382 – CP – 1 – 2005 – SK – COMENIUS – C21)

Examples of good practice in ICT used in Science Education in Poland

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Abstract

In the year 1999 the Polish educational system was reformed and the use of ICT for science education was introduced into the core curriculum. As a result in the years 1999 – 2001 all lower secondary schools were equipped with computers, but unfortunately they are used mostly for learning only the basic ICT skills. The lack of good quality educational software and laboratory equipment, as well as the low level of teachers' competencies in the effective use of ICT, has resulted in no improvement in the quality of science education in Poland. Taking this into account and in an attempt to promote the efficient use of ICT for educational purposes, we created a network of three Universities (Poznan, Bialystok and Torun) and started a project using computer-aided science mini-laboratories. Each university collaborated with a network of 10 – 15 science teachers in developing the examples of MBL methods and tools as applied to science teaching. The results of the study were presented and discussed with teachers at consecutive meetings and evaluated by the Committee of the General Polish Competition for the "Computer Aided Experiments Applied at School Practice".

Since the year 2005 together with Partners from EU countries (Finland, Scotland, Slovakia and Spain) we collaborated within the EU SOCRATES COMENIUS 2.1 Project on: "Effective use of ICT in Science Education". First of all we elaborated and executed comprehensive questionnaire studies aimed at an investigation of the means in which ICT is actually used in science teaching. The Torun teacher-network continues its previous activities.

In this chapter the most interesting effects of the above-mentioned national and international projects are described, with examples of how good practice in use of ICT in science teaching in Poland are delivered. We try to answer the question: For what, when and how should ICT be used in science teaching?

1. Introduction

1.1. General role and functions of media

The role of media in our time is especially large. The second half of 20^{th} century is often called "media era". Multimedia (including some ICT methods and tools) assist people during their free time, are the main source of social information and communication, but also are a good tool of learning and intellectual work of mankind. Let's remember the saying: "Who has information, has an authority". (or 'Information is power'!) It means that media are 4^{th} kind of authority ('the fourth estate') besides legislative, executive and judicial authorities.

The first time visual media for teaching was introduced was by J.A. Komenski in the book "Orbis sensualium pictus" (1658). In the USA the guide for teachers: "How to use slides in school teaching" was edited in 1906. In the 1950s Skinner developed programming teaching, but in Poland only "technical teaching aids" were introduced. In Germany "media pedagogics" started to play an important role in home and school education. And now - we are living in the *Information Society,* where people use information tools mostly for communication and international integration. Thus, all societies have to have easy and fast access to the contemporary media (multimedia) to

receive and create information. In 1999 the international project *"e-Europe"* was founded aiming at:
♣ computer literacy,
♣ easy and cheap access to the Internet,
♣ on – line governments,
♣ the use of internet in the economy.

However, media can have positive, as well as negative functions. Let's mention some of them:

Functions of media:

positive	negative
Facilitate easy and fast communication of information	Manipulation of information (disinformation)
diagnosis and expert advice systems	diminish activity and creativeness (by lowering the knowledge)
stimulate people's development by the use of cognitive constructivism ideas	can illustrate criminal actions
promote positive system of values	create bad interpersonal relations and develop aggressiveness
develop appropriate beliefs and attitudes of people (especially children and youths)	can cause waste of time and health (computer spam, computer phobia, addiction to the Internet, etc.)

1.2. Incorporation of ICT into school education

It is widely acknowledged that there are now serious problems with school science in many countries all over the world. Such problems manifest themselves mainly in a progressive decline in pupil interest for school science across the secondary age range, and by the fact that only a few students are choosing to study physical sciences at higher levels and as careers [1,2]. As a remedy for this situation we can find in the literature some proposals mainly concerned with reform of the curriculum or schoolwork organisation. As we believe that the teacher is the real driving force of any educational change in schools and in society, we would like to put stress upon the programme of teachers' pre-service and in-service preparation, pedagogy and the methods of pupils' teaching and learning, including especially those based on the implementation of ICT methods and tools. In this paper we concentrate mainly on the last factor and try to provoke discussion on the questions: *"For what, when and how should ICT be used in science teaching?" and "What should we understand by the good practice of ICT use in science teaching?"*

Revolutionary educational system reform has been undergone in Poland recently (1999) and nowadays the Polish educational system consists of:
- primary school (6 grades, age 7 – 13),
- lower secondary school – gymnasium (3 years, age 13 – 16),
- upper secondary school - "lyceum" (3 years, 16 – 19),
- college and university.

During the first years of the primary school, one teacher is responsible for teaching everything within one subject (integrated teaching). There is "block teaching" in older grades (4 – 6), which means that nature subjects (including also geography) are grouped into one called "science" (3 hours per week per year). At this educational level ICT elements are poorly represented in the existing curricula. In the core subject curriculum we can find only some general remarks such as: *"pupils should be able to use ICT and find information in different sources, among others on the Internet".*

In gymnasia and in the upper secondary school (lyceum) students become acquainted with particular science disciplines separately, e.g. chemistry, physics and biology (3 hours per week per subject during three years) and they participate also in the so-called "interdisciplinary paths" – integrated activities (for example education for sustainable development, health, media and culture paths).

In addition since 2000 at the gymnasium level students are exposed to 2 hours a week of an obligatory subject "computer science", which in Poland is called "informatyka". The curricula of this subject include the following issues:

1. Computers in human life.
2. Work with the computer.
3. Utility software (text editors, graphics editors, spreadsheets, databases).
4. Multimedia sources of information.
5. Algorithms.
6. Simulation and modelling.

It is interesting to note, that this curriculum contains activities of students concerned with finding, exchanging and processing information, simulations and modelling, but does not include the activities aimed at the competencies of *measuring and controlling,* based on using sensors and special software for collection and evaluation of experimental data, which in our opinion is very important in science education!

But, as far as the physics curricula (20 together in all) at the gymnasium level are concerned, we would like to stress, that only 10% among ten studied examples of curricula contain defined topics related to applications of ICT tools and methods in physics education. In 20% of curricula there are no links to ICT applications and in the remaining examples only some general remarks like *that ICT should be used in teaching physics* can be found. But, there is a national core curriculum introducing ICT in all subject matters, and teachers - providing that they are in agreement with the corresponding national core curriculum - can develop particular curricula individually.

In spite of the use of localised versions of international software such as Microsoft packages (MS Office, Word, Spreadsheet (MS Excel) and PowerPoint) the teachers can have access to Polish software like: Edu ROMs - science (physics, chemistry, biology) electronic textbooks for grades 5 and 6 of primary school and grades 1, 2 and 3 of lower secondary school (gymnasium), published by *the Young Digital Poland,* EcoLog - interface and software EcoLab for data collection and processing for environmental science experiments, distributed by Centre of Informatics Education and Application of Computers in Warsaw. For chemistry - with elements of ecology – a multimedia textbook for lower secondary school is available. For physics - multimedia software for grades 1, 2 and 3 of lower secondary school titled "Interesting Physics Experiments", published by *Wydawnictwa Szkolne i Pedagogiczne.* There is also a special software for learning physics on: "Physics, which you don't know", recommended by Polish Ministry of Education, and e-Physics (virtual Physics Laboratory), edited by the *NahlikSoft company.*

The first trial of the educational school system reform at the upper secondary schools in Poland has just finished this year. There is for example a lot of new curricula developed (up to now 20) - which has been accepted for the use in schools by the National Ministry of Education - for teaching physics at two levels: basic (13) and advanced (7). The common feature of these curricula is, in addition to the school tasks, an extra position: *The use of ICT methods for modelling and experimental results analysis*. This is inspiring and encouraging for authors of textbooks, editors and computer companies, who would like to create the specialised software devoted to ICT applications in science education. We already have observed the first effects of this process. There are two new CD-ROMs available on the educational market edited recently by the main Polish publishers: *Wydawnictwa Szkolne i Pedagogiczne* (Warsaw) and *Zamkor* (Krakow), but they contain mostly software for simulations and for processing the data introduced manually by the user. However, we would like to encourage our science teachers to use Microcomputer Based Laboratory tools and methods for performing real on-line experiments in their school practice. Fortunately, for example at the Centre of Informatics Education and Application of Computers in Warsaw, we can buy the hardware and Polish version of COACH 5 software (elaborated by CMA, Amsterdam) for data-acquisition, data-processing and for modelling.

Furthermore, thanks to the National Ministry of Education project, all secondary schools in Poland are actually equipped with at least 10 computers with indispensable peripherals - but unfortunately these are mostly used by the computer science teachers and only sometimes by science teachers.

It is also worth mentioning, that nowadays most of schools in our country are connected to the internet and students can use the educational resources of Polish educational web-sites as for example: www.eduseek.pl, scholaris.pl, www.wiw.pl, www.wspinet.pl/oswiata and draco.uni.opole.pl/moja_fizyka.
In the evenings or during the weekends students may have access to the Internet resources also in their homes or in internet-cafes.

As we can see from the above-mentioned activities concerned with *the use of ICT for science education* this method was introduced into the school core curricula after the educational system reform in 1999. Thus, teacher training on the use of ICT in science education began to be supported by the National Ministry of Education and also by some important local initiatives through the Regional Teacher Training Centres. Nevertheless, these courses were mostly devoted to learning only the basic ICT skills, not how ICT should be effectively implemented in school practice (to know, what we term, "*teachware*"). As a matter of fact there was only one interesting *Intel* initiative - *Teach to the Future* (for teachers of all subjects, including science).

Summarising, we would like to say that the lack of good-quality educational software and appropriate laboratory equipment as well as the low-level of teachers' competencies in the effective use of ICT has resulted in no improvement in the quality of science education in Poland in the last few years.

2. Computer Aided Science Mini-laboratory Project

Taking all of the above into account and, moreover, the official decision of EU Council dated 5th December 2003 promoting an efficient use of ICT for educational purposes, we created a network of three Universities (Poznan, Bialystok and Torun) to work on the improvement of science education by the use of ICT methods and tools. Each university collaborated with a group of 10 – 15 science (physics, chemistry and biology) teachers in elaborating examples of Microcomputer Based Laboratory (MBL) methods and tools applied to science teaching. The effectiveness of these methods and tools in the processes of science teaching and learning is very well documented in the literature [3-13].

Teachers planned their first topics of ICT-based activities based on classroom experience, which reflected students' difficulties with the understanding of particular physics concepts when presented in the traditional way. Thus, the most important of the selected topics were assumed educational objectives. Thanks to National Ministry of Education support, schools collaborating with us were provided with some necessary equipment (interfaces, sensors, video cameras, etc) and appropriate software. In this way school science mini - Microcomputer Based Laboratories were created (for the first time to such an extent in Poland). The training courses to furnish teachers with the abilities to use the MBL methods and tools (in our case based mostly on CMA, Amsterdam equipment [14]) were organised. The first course took place in Poznan and the next ones in Torun (see pictures below – Fig 1. and Fig.2) and in Bialystok.

Fig. 1. J. Turlo and A. Karbowski conducting the teachers' training course during the seminar in Poznan.

Fig. 2. The group of teachers collaborating with Education of Physics Laboratory members in Torun.

The first edition of this project finished in 2005. The results of the work (in the form of experiments and their theoretical descriptions) were presented and discussed at consecutive meetings with our network of teachers and then trialled at those teachers' schools. The best of them received awards from our competition-organising committee for the *practical application at school of computer-aided experiments)*. The Committee evaluated the following criteria for features of projects elaborated by teachers related to physics, chemistry and biology:

- ♣ novelty, originality of project's idea and realisation,
- ♣ importance of the project for the outcomes of education (e.g. global topics),
- ♣ usefulness within the science curriculum,
- ♣ educational value of applied ICT- aided method,
- ♣ feedback and possibility of working in teams,
- ♣ ease of use,
- ♣ high subject and didactical value of project's documentation.

The teacher projects were divided into 5 groups:

1. The use of the interactive video method,
2. Computer-aided measurements with the use of sound cards,
3. MBL experiments with the use of Coach and other companies' software,
4. MBL experiments with the use of author interfaces and programmes,
5. The use only of software available at school.

As the result of this competition each year we got more than 50 papers with interesting propositions from the field of physics, biology, chemistry and environmental education. The best solutions were presented during the annual conferences of the Polish Association of Science Teachers - also organised by us - in different places in Poland.

Let's quote some examples of award-winning projects in the years 2004-2007, namely: computer-aided optical spectrometer; reflection of light as a function of roughness of metal surface; investigation of the physical quantities characteristic of a bulb with the use of Coach; investigation of the operating lives of different electrical batteries; electromagnetic oscillation in the RLC circuit; investigation of crystal growth; using Coach for measurement of the Doppler effect; the use of author's software for g-value evaluation and investigation of circular motion; studies of relative magnetic permeability of different substances; verification of gas laws; men's reaction time measurement; investigation of CO_2 concentration during the lesson time; bungee-jumping investigations; computer-controlled refrigeration based on the Peltier effect, and an active school model of a meteorological station. In addition, one of the most experienced teachers developed a guide with a comprehensive description of the computer-aided experiments, suitable for use during the lessons at the 1-3 grades of the gymnasium level.

3. European project EU ISE on Comenius 2.1. programme

3.1 Project's rationale

According to an OECD (2004) survey [15] the use of ICT in education in most countries concentrates on sporadic and mechanical information retrieval from the Internet. Thus, since 2005 together with our "network of teachers" we decided to collaborate with Partners from EU countries (Finland, Scotland, Slovakia and Spain) within the EU SOCRATES COMENIUS 2.1 Project on: *Effective use of ICT in Science Education (EU ISE)*. The pictures below (Fig. 3 and Fig. 4) are showing the Partners of this project at their contact meetings.

Fig. 3. The initiators of EU ISE Project at the Kopenhaga meeting, (from the left: Peter Demkanin, Jozefa Guitart, Bob Kibble, Jari Lavonen, Jozefina Turlo).

Fig. 4. The project partners at the EU ISE Seminar in Toruń (from the left: Jozefa Guitart, Julian Oro, Józefina Turlo, Peter Demkanin, Jari Lavonen, Bob Kibble).

The main objectives of this project are:

- ♣ to identify and collect the best practices of using different methods and tools of ICT in science education across Europe (based on the literature and the science teachers' school practice examples) and propose a system for benchmarking this area. These best practices can demonstrate how ICT-use can make science education more versatile and goal-oriented, inspire students to active and creative self-learning, promote co-operation and study in authentic contexts.

♣ design and test a model course for in-service and pre-service teacher training, and prepare model training materials.

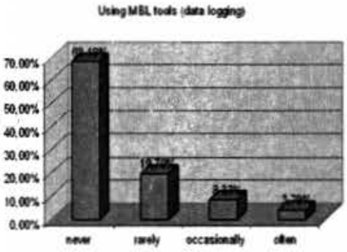
The outcomes of the project are intended to reach the following target groups: teachers of science in schools for ages 10-18 and trainee teachers of science as well as lecturers with responsibility for in-service and pre-service teacher training.

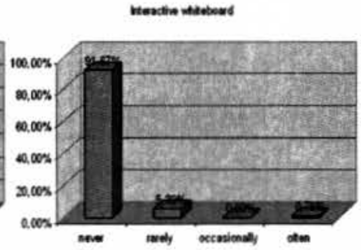
3.2. The project's first activity

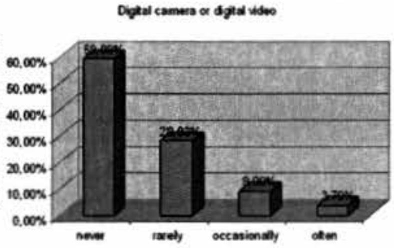
For the first activity we elaborated the international, comprehensive *Questionnaire* (http://www.fizyka.umk.pl/test/data.php) aimed at the investigation of the means in which ICT is actually used in science teaching on: *"Making use of ICT in science teaching"*. We collected 117 Polish answers (73% from women and 27% from men, among them more than 50% of secondary school physics teachers). The teachers investigated have a rather long school experience (80% of them 6-25 years, and are highly qualified (as nominated and certificated teachers).

We got some answers to the questions: *"When, for what, and in which way are you using ICT methods and tools in science education?"* They generally have good access to the computers and evaluate their ICT competence as good; more than 50% of their students are using computers at home. It is interesting that as many as 91 % of them believe in the positive effect of ICT on science education, and 85% that ICT is of particular benefit in making science learning more interesting. More than 70% believe that ICT makes learning creative, more active, more goal- and research- oriented, but only 24 % ascertain that "ICT has radically changed the way they teach science". One explanation of this situation might be, that school management still does not expect them to use ICT in their teaching enough, but rather science teachers "are persuading the school management to buy more ICT equipment for supporting teaching". This view can be confirmed by the fact, that even though school students have quite good access to the internet (at home or in the classroom), the amount of computers at schools is still not sufficient (only about 30% of schools are equipped with more than one computer per four students).

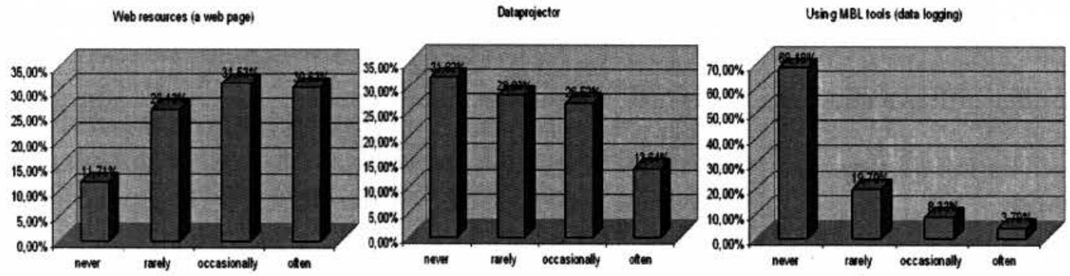
Furthermore, there are not enough digital cameras and MBL (data logging tools and sensors - only about 20% of schools possess these facilities) and especially digital microscopes and interactive whiteboards (they are in about 5% of investigated schools), which we can see in the figures below.







The next question was: *How often and what kind of tools do you use as a part of your science teaching?* As we expected (see figures below) it appeared that the teachers mostly like to use Word processing, PowerPoint, Internet and web resources, and CD-ROMs; occasionally they use Excel, applets, other simulations and data projectors, but rarely use e-mail for discussion with students, for publication of educational materials or for performing experiments with the use of MBL tools, and almost never use a digital camera, interactive whiteboard or videoconference method.



The answers to the next question on *training and development needs of teachers* were related to the situation in the classroom as described above. The teachers generally do not need training on using the internet, PowerPoint or on the use of ICT software packages (CD ROMs) etc., but they would appreciate courses on the use of an interactive whiteboard and data logging, as it is shown by the data below.

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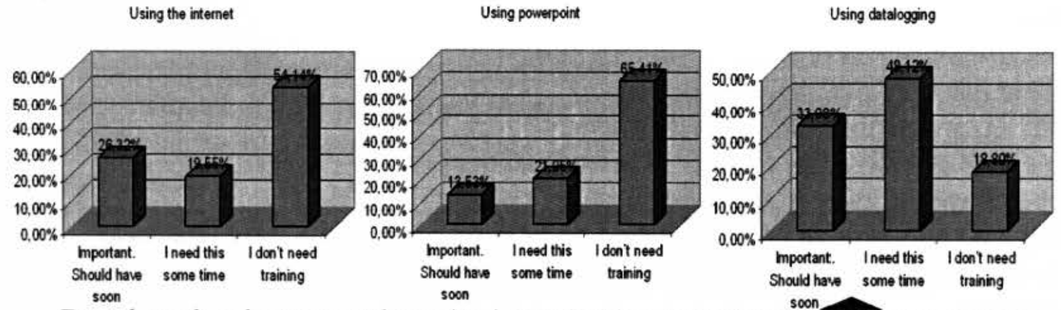

Based on the above questionnaire investigation and discussion with teachers, and if the methods and tools of ICT are of a good quality from a technical point of view, we can try to find some general and pedagogical features, which allow us to answer the question: *When, for what and how ICT should be used in science (physics) education?* (see Table 1.a and 1.b below).

Table 1.a. General and subject aspects of ICT use in science education [16-19]

When?	For what?	How?
If the school curriculum is old-fashioned or school laboratory is not sufficiently equipped	To modernise, update and extend knowledge and skills of students by the use of modern ICT technology	By the use of different ICT resources, including virtual and distance learning
If there is necessity to exchange the ideas by students from all over the world on issues concerned with common topics	To stress some essential goals of school education, including education on the important global problems	Discussion forum with the use of Internet and students' discussion e.g. within SAW or other science projects
If the students have a variety of pre-conceptions and misconceptions	For better (deeper) under-standing of difficult physics concepts by the constructive learning approach	The use of simulations, modelling, databases, interactive video, MBL experiments, data logging
When there is little time (hours in the curriculum) devoted to physics teaching	To use learning time in a much more effective way	Software designed in order to save learning time

If students don't manifest the ways of scientific thinking	For developing skills needed for scientific work	By providing access to the resources used by scientists

Table 1.b. Pedagogical aspects of ICT use in science education [20-22]

When?	For what?	How?
When traditional methods don't offer differentiation of teaching	To adjust teaching to the individual knowledge and abilities of students	To elaborate different options of work (menu options) with software
If teaching-learning process is passive	To make learning much more active and motivated	To provide interactive learning by feedback of students with software
When traditional methods don't allow the achievement of subject learning objectives	To gain the main subject learning objectives successfully	To execute appropriate ICT supported lesson plans
When students don't have ability to work in groups	To promote active collabo-ration of students in teams	To promote active collabo-ration of students in teams
If traditional teaching is not effective enough	To increase the effectiveness of teaching by the use of the contextual method	To create multimedia and MBL methods using the pedagogical rules

Summarising, let's try to list some of the most evident positive answers to the question:

For what use is ICT in science education?

- attract, arouse interest, motivate students,
- increase effectiveness of work in science laboratory,
- encourage the answering of the question: "what will be, if…
- increase memorising and understanding of knowledge by assuring feedback,
- facilitate realisation of the school curricula due to integration of ICT with the contents,
- to provide application of multimedia methods,
- to assure the use of simulations, modelling and investigations in real-time,
- to construct the knowledge of students by their creative individual work,
- cause association of computer-aided work with simplifying of science understanding, as computer helps to solve ordinary as well as complicated problems,
- also allow students to extend their knowledge beyond the computer resources.

3.3 The exemplary MBL exercises for science education

Taking into account the results of the questionnaire studies, we decided to work with teachers on their most desired (but mostly unfamiliar to them) MBL method. We first presented them with some exemplary MBL experiments elaborated by us, and then with our help they accomplished their own ideas. In two years of collaborative work we have organised 11 meetings (for 15-20 persons of our network) and 2 intensive courses for the participants at the Polish Association of Science Teachers Annual Meetings (about 200 teachers took a part). In that time we have also designed and published a textbook for science teachers entitled: *"Examples of the use of ICT in Science Teaching"* (in Polish [23]), which has and is intended to be used as the educational material during pre-service and in-service courses for teachers.

All science teachers who collaborated with us received this textbook. Let's list some selected experiments, which we recommend for the use in school science education.

List of the exemplary MBL exercises [23]:

1. **Mechanics experiments**
- Laws of dynamics - experiments with using the air track
- Free fall investigation – checking the Galileo law
- Motion parameter investigations for harmonic oscillations and any other motions in gravitational field using ultrasound, based on Doppler effect motion detector
- Investigation of circular motion
- Acknowledgement of the rules of operation and ways of application of satellite system GPS

2. **Acoustic experiments**
- Acoustic oscillations and waves, computer analysis of sound
- Verification of the acoustic Doppler effect
- Noise and infrasound investigations in the environment. Hearing of human exploration

3. **Thermal and thermoelectric experiments**
- Measurement of air humidity and thermal phenomena with the use of data logger
- Computer investigations of Brownian motion with the use of interactive video method
- Computer studies of reversible phenomena using Peltier effect device

4. **Electric, electromagnetic, optics and nuclear physics experiments**
- The use of data loggers in UV and IR investigations
- Investigation of condenser discharging and electrophysiological processes (ECG)
- Investigation of copper electro-sedimentation process - fractals
- Computer aided investigation of ionising radiation

5. **Chemical and biological experiments**
- Monitoring of respiration and photosynthesis processes of plants
- Monitoring of germination and fermentation processes
- Effect of different factors on the rate of chemical reactions

Furthermore, we are advising: teachers to use also simulation and modelling software developed by us; for introduction and presentation of phenomena which are too difficult to teach in another way, as for example:

1. Brownian motion simulations, evaluation of Avogadro constant
2. Thermodynamics phenomena: ideal gas – phase transformations, internal energy, I principle of thermodynamics
3. Introduction of statistical physics elements – Ehrenfest's model
4. "Imagined experiments" of Einstein – special theory of relativity
5. Optical phenomena – in nature and in the laboratory
6. Radioactive decay of nucleus
7. Action of nuclear power station

Some of the most interesting experiments (in the opinion of our teacher network) were presented to 1200 secondary school students at the Institute of Physics on the occasion of Nicolaus Copernicus' birthday anniversary on 19 February 2007.

MBL science experiments developed by teachers

To organise the activities of the teachers we divided them into 3 subject "working groups": physics, biology and chemistry. The first ideas of the MBL experiments were planned, and accepted - in consultation with us - by the members of these groups, and then presented and discussed by whole network of teachers. Furthermore, the most active teachers had prepared video film presentations showing their school lessons with the use of MBL. At the resource material section of our project web page we placed the following lessons: 1. Mass and weight (by physics teacher Stanislaw Niedbalski), 2. Respiration and photosynthesis (by biology teacher Piotr Felski) – see http://www.fizyka.umk.pl~pdf/EU_ISE/output.html

We think that it is worth mentioning in brief descriptions of some other selected results of teachers' work, as for example experiments on:

- ♣ Effectiveness of cooling with the use of refrigerator, based on Peltier's effect
- ♣ Studies of a magnet falling down in tubes made from different materials
- ♣ Studies of the relative magnetic permeability of different materials
- ♣ Checking the dependence of electromagnetic induction on current flowing in a coil
- ♣ Effect of different factors on chemical reaction rates
- ♣ Studies of milk fermentation
- ♣ Effect of some medicines on the pH of gastric fluid
- ♣ Respiration of a cricket (grasshopper)
- ♣ Measurements of water acidity

In addition Mr S.Niedbalski wrote the guide: *Physics and astronomy curriculum at the lower secondary school aided by experiments driven by Coachlab II and Coach 5.*

3.4 Detailed description of the selected good practice MBL cases

♣ ***Experiments with the use of the ultrasound motion detector***

We designed and constructed an inexpensive motion detector working with continuous, coherent wave of 40 kHz frequency, working with microcontroller PIC 16C84 and memory EEPROM aimed at investigation of position, velocity and acceleration of moving bodies, measuring the distance with the resolution below 0.2 mm, time with the resolution of 300 μs [24].

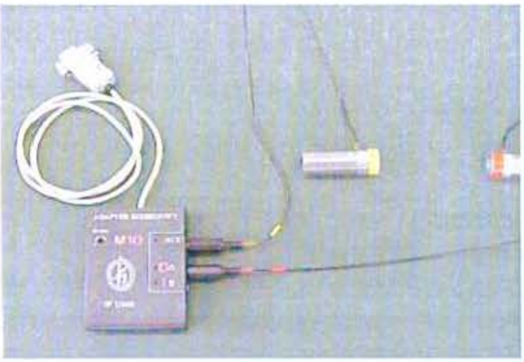

Fig 5. The ultrasound 40 kHz motion detector with transmitter and receiver.

Fig. 6. Mr Andrzej Karbowski is studying the pendulum motion in the real time.

Some interesting results obtained by the use of the above motion detector

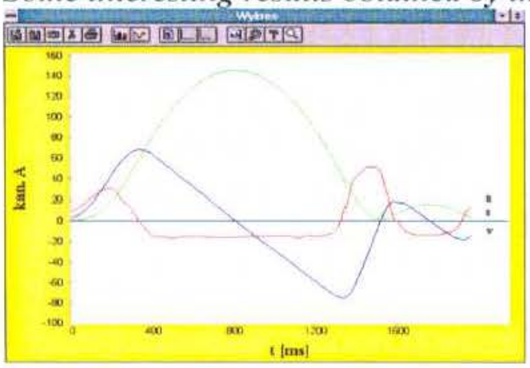

Fig. 7. The graphs of position, velocity and acceleration of school version of Galileo experiment (car moving on the inclined plane)

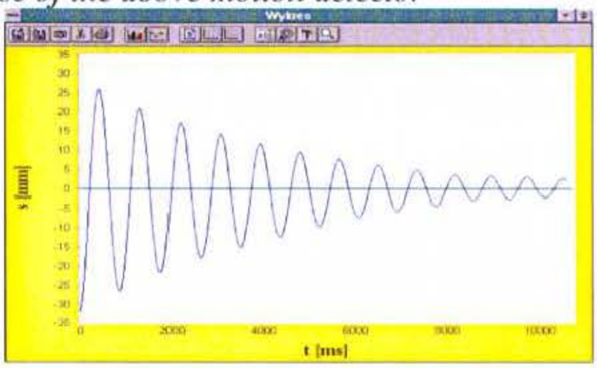

Fig. 8. The graph of position of damped harmonic motion (mass attached to the spring, placed inside the water).

♣ *Verification of the acoustic Doppler effect*

Taking into account the important and interdisciplinary role of the Doppler effect in physics and in physics education we propose the use of the MBL tool and specially written software to perform simple experiments enabling to make the qualitative verification of Doppler's law for acoustic waves in real time [25]. To analyse this effect we demonstrate a relation between the frequency shift and the velocity of moving bodies (source or observer) relative to the medium (air) in which the sound waves propagate. To simplify the situation, we consider only the case where the velocities of both source and observer lie along the line joining them.

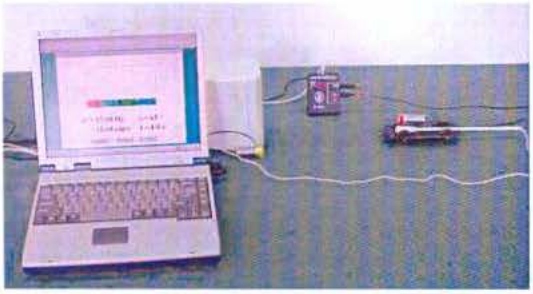

Fig. 9. A car with microphone and ultrasound receiver is moving with a speed v_0 towards the loudspeaker and ultrasound transmitter, which are at rest on the table.

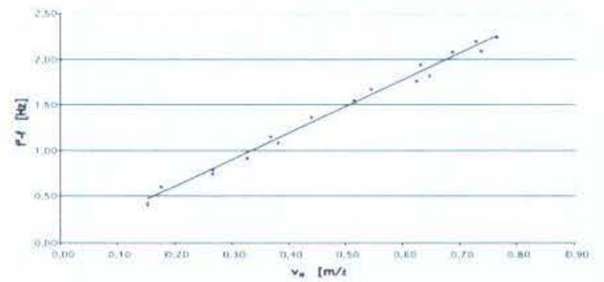

Fig. 10. The plot of relation between the frequency shift and the velocities of moving observer towards the stationary source.

Mr Karbowski designed also a special 20-questions test, aimed at comparison of knowledge, understanding and application in practice of the idea of the Doppler effect by two group of students - one learning this issue with support of MBL and the second taught traditionally. It is good to note, that the first group demonstrated much better results (in some cases the mean classroom result was as much as 50% better!)

♣ *Infra logger – infrasound detector*

At the Institute of Physics we also have constructed a special computer - aided device for investigation of infrasound (in the range 20Hz-0.01Hz), and wrote software for registration of sound signals, which can be analysed with programmes such as Cool Edit, Goldwave and Origin. Having such a device at our disposal we are able to detect and register sounds, which we don't hear, but they are a danger. We would like to add, that the ordinary microphone couldn't detect infrasound.

Fig. 11. A general view of our Infra logger.

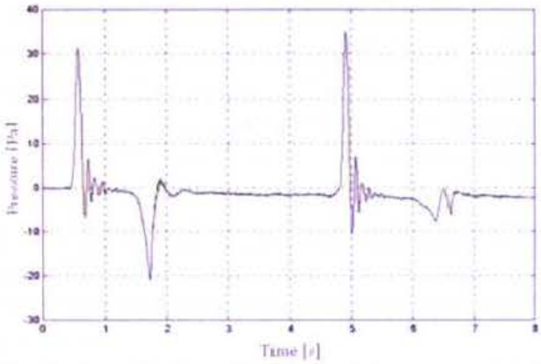

Fig. 12. Perturbation of pressure in the room caused by opening the window (two times).

♣ *Ecological refrigerator - model of a smart refrigerator for environmental education*

In this experiment we would like to emphasise the educational value of experiments using the Seebeck-Peltier's semiconductor junctions. For this purpose we constructed a working model of a heat pump consisting of two commercially available Peltier's batteries connected in a cascade.

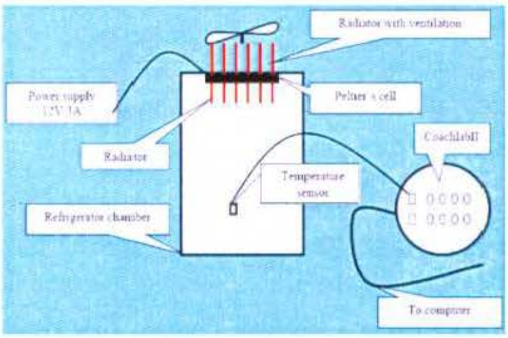

Fig. 13. The scheme of the Peltier's device.

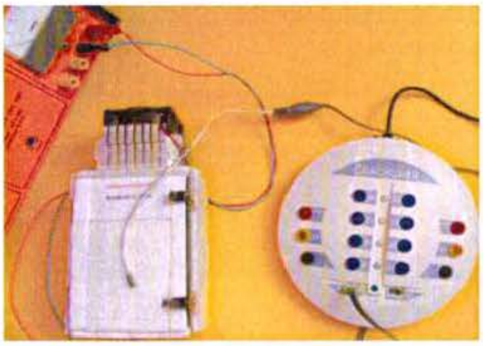

Fig. 14. The use of Peltier's cell for cooling.

With this device one can demonstrate heating with an efficiency greater than 100%, cooling without ecologically undesirable noise and freons, as well as the reversibility of the observed phenomena. It can be used as a refrigerator or heater by simply changing the direction of electric current, but at the same time it can also generate an electric current if we keep the junctions at different temperatures.

♣ *Studies of a magnet falling down in tubes made from different materials*

Let's describe in short the experiment devoted to the MBL investigation of a strong magnet falling down inside plastic, copper and aluminium tubes. The motion of strong magnets inside a metal tube induces an electromagnetic force, which has an influence on falling-down motion parameters - velocity and acceleration. We can measure the values of downfall time and induced potentials using CoachLab II interface with Coach 5 software and evaluate the g-value. Furthermore, we can compare the motion parameters for the magnet falling down only in the gravitational field (inside a plastic tube) with a motion inside diamagnetic (copper) and paramagnetic (aluminium) metal tubes. Calculation of the induced potential in copper and aluminium tubes give us a chance for verification of induction phenomena and Lenz' principle. On-line data and graphs illustrate the change of induced potential in different tubes.

Fig. 15. Tadeusz Kubiak presents checking the dependence of magnetic induction on intensity of current flowing in the coil.

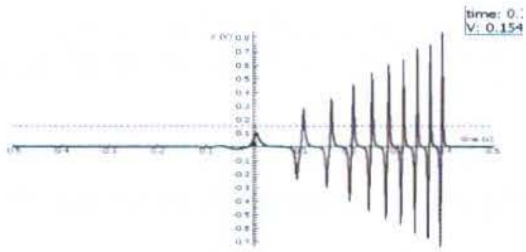

Fig. 16. On-line data and graphs illustrate change of induced potential in the plastic tube.

♣ ***Studies of relative magnetic permeability of different substances***

In this experiment students can measure the magnetic induction (B) of different metals and from the value of μ (factor of magnetic permeability) to recognise the kind of material (diamagnetic, ferromagnetic or paramagnetic).

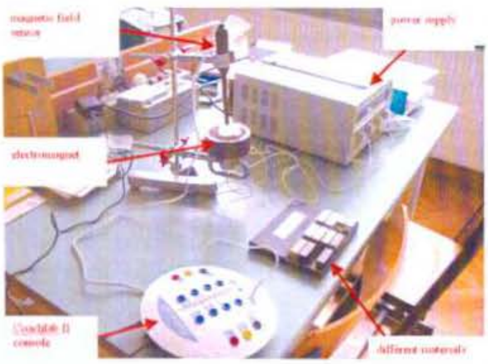

Fig. 17. The experimental set (designed by M. Kamiński) for measurement the permeability of different materials.

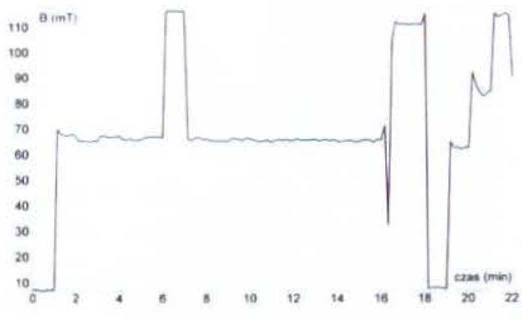

Fig. 18. The experimental results related to measurement of μ for diamagnetic and ferromagnetic – cast iron and steel (7 and 18 min).

♣ ***Monitoring of respiration and photosynthesis processes of plants***

The other MBL experiments were proposed by the biology and chemistry teachers in collaboration with us. The first experiment is concerned with the investigation of photosynthesis and respiration of plants. This experiment allows investigating of the changes of oxygen and carbon dioxide concentrations as a function of absorbed light energy for corn growing in a plastic bottle. In this activity we also used the Coach Lab II interface, the oxygen and CO_2 sensors. In the picture below the plots of oxygen and CO_2 concentrations for corn growing in darkness are presented.

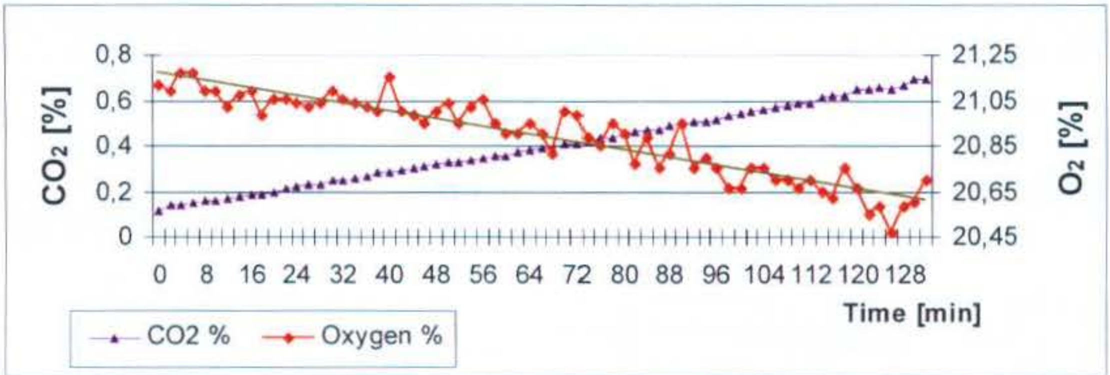

Fig.19. Concentration of oxygen and CO_2 for corn growing ca. 2h in dark.

The obtained results allow students to draw the conclusion that plants also have to respire at night (in darkness).
Furthermore, precise analysis of the achieved data also permits the uncovering of the relation between O_2 and CO_2 concentrations. The plants respire using the oxygen and expire CO_2 in the proportion 1:1.

The other biological experiments are related to oxygenation process of plants germination and non-oxygen alcoholic fermentation of *Saccharomyces*.

♣ ***Monitoring of germination and fermentation processes***

Fig.20. Mr Piotr Felski is presenting his achievements during meeting of teachers.

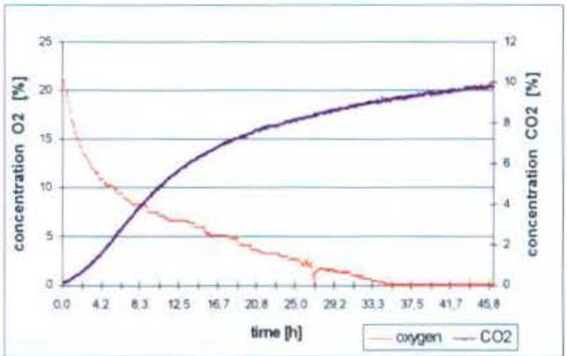

Fig. 21. Changes of oxygen and CO2 concentration during pea germination in darkness.

♣ ***Effect of some medicines on pH of gastric fluid***

In this experiment students can verify what are the effects of different medications on different diseases, such as excess - acidity or stomach pain.

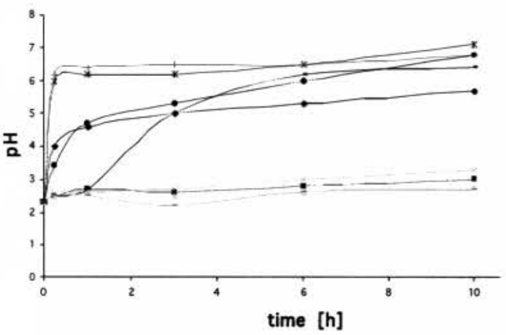

Fig. 22. Changes of pH of cola simulating stomach acid as a function of time after adding of different medicaments

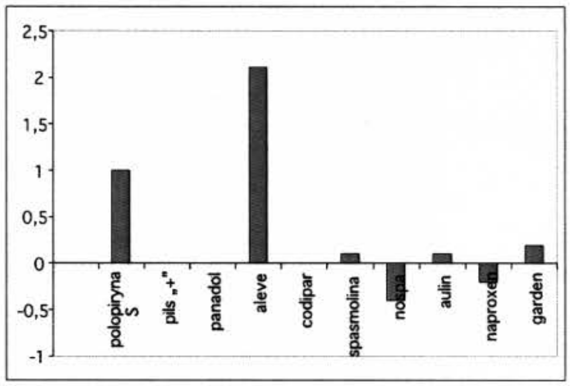

Fig. 23. Changes of pH of cola simulating stomach acid as a function of time after adding of different pills reducing pain.

♣ *Studies of milk fermentation process*

Chemistry teacher- Ms A. Dyszczynska, proposed to use a pH computerised sensor for investigation the process of milk (or vine) fermentation.

Chemical equation describing milk fermentation:

C6H12O6 + milk bacteria   2 CH3CHOHCOOH + 22,5 kcal
sugar   milk acid   energy

The changes of pH of different types of milk (country milk, Torun –TSM milk, Danone, Zott, Bacoma and KSM milk) during 10 hours of fermentation have been investigated. It was discovered, that the pH value of different types of milk and the concentration of oxygen as a function of time are decreasing for country and Torunian (TSM) milk much faster then for the other probes. It can indicate that the other samples contain pseudo-milk microbes instead of the real ones and the students can detect this themselves during their chemistry or science lessons!

♣ **Investigations of water acidity**

Could we know what kind of drinking water is healthy for us? To get an answer for this question we need information on the quality of this water, indicated mostly by the pollution agents which change its acidity. We can use a pH sensor connected to a computer and investigate the acidity of different samples of water (e.g. natural spring water, underground and country, sea and river, dub, plash and rain as well as different mineral waters). The results of measurements are shown in Fig. 25. It is interesting that we have still acid rain in the vicinity of Torun (pH = 5.9), mineral water with CO_2 has a pH of about 6.0, but boiled water has a pH = 7.9.

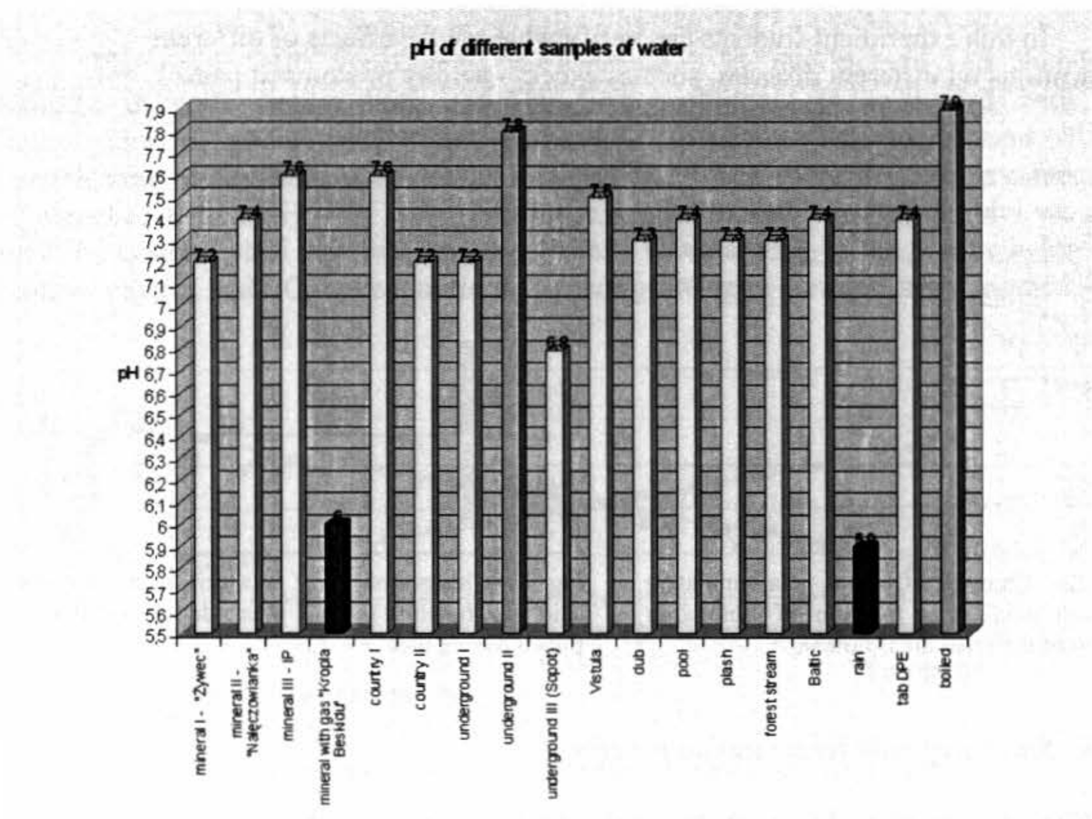

Fig.25. Diagram of data obtained from the measurement of pH of different samples of water.

Acknowledgements

We would like to express our sincere thanks to the Directorate-General for Education and Centre of Culture for the financial support of the SOCRATES-Comenius Project EU-ISE No.226382-CP-1SK, which allowed us to present the activities of this project at the GIREP'2007 Conference in Opatija and at the MPTL12 Conference in Wroclaw, 2007.

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