SIMPLE MULTIPLICATION AS A FORM OF PRESENTING EXPERIENCE WITH INTRODUCING DATA LOGGERS TO PHYSICS TEACHERS WHO DO NOT HAVE ANY EXPERIENCE WITH USAGE OF SUCH TOOLS IN EDUCATION

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Abstract
In this paper we present our experience with introducing CMA interfaces as CoachLabII+, EuroLab and MoLab to physics education in Slovakia. The situation in Slovakia is similar to other countries with less investment to education, where not all physics teachers and not all schools have any data logger. We are starting with definition of learning by W. Harlen “learning is making sense of new experience by a child in collaboration with others”. Then we discuss the aspects of experimental work in Diploma Programme of International Baccalaureate Organisation. Special attention we put on the development of selected concepts from secondary school's physics and development of pupil’s abilities in planning of physics experiments. On such roots we present outcomes of our work with in-service teachers in the form of simple multiplication: effect to learning = well designed equipment x well selected methods of education. As a base for methods used in physics education with data-loggers we take work of J.Hattie, R. Marzano and G.Petty.

Keywords: Data-logger, methods of education, planning experiment, concept development.

1 INTRODUCTION
It sounds optimistic that there is a pressure put on the physics teacher (and not only the physics) – let's teach with the use of ICT. But teaching with the support of digital technologies in many schools ends up in using the technology just for technology itself in the sense “because it is modern”. Quite frequently we also see that the creation of such “modern” tools is pedagogically unjustified. Yet in the community of physics teachers modern technologies are already put to use for a relatively long time – and in highly interactive and effective way. One can mention, for example, the computer based measurements and experiments that have relieved the students of boring data collection, in order to dedicate more of their time to understanding particular physical concepts. There is also a place for interactive animations and simulations. These are examples of the ways, how to increase the effectiveness of concept formation, interest in science and technology and the school subject physics also. The teacher has got a unique opportunity to make use of giant potential of modern hardware and software that serves for support of physics teaching and she can also benefit from the students’ attitude towards these technologies – she can combine business with pleasure. If based on serious methods of learning and methods of teaching, with well-developed goals, she acquires effective and powerful tool – it supports students’ learning and interactive involvement into events at physics lessons.

2 PHYSICS EDUCATION IN SLOVAKIA
Research as well as applied research in the field of formal physics education in Slovakia is in the last decades focused mainly to very specific tasks and the holistic approach is missing. Some teams have done research with the focus group - physics teacher or pupil/student in the last decade, but they were focused to popularization via interventions to education process, or by so called modernisation of physics education via adding some issues or tools. These suggestions have rarely been based on pedagogical research. Many of such projects and also outputs of many of such projects have marks of so called folk pedagogy, often are not based on the results of a serious research. In the more developed educational systems people actively go towards evidence based pedagogy, pedagogy
based on the results of research. In countries with well-developed educational system one prefers the “evidence based pedagogy”, what means education based on systematic research.

Quite often we in Slovakian physics education take and try to use some elements from abroad. Such elements are e.g. methods of education, software products, and way of assessment. Such choice is to high level random, do not make system, and do not contribute to improvement of the system of physics education. A teacher or a small group of teachers is in such endeavour often alone, without support. Of course, we are aware of some very well selected issues or systems, which have improved our system of physics education.

2.1 Data loggers in Slovakia – brief history

Schools in Slovakia have only very limited possibilities to acquire new tools and equipment. There is shortage of resources. This leads to two ways – some schools resign to work without real experiments, even without demonstrations. Some of such schools try to use applets and other interactive animations. Other schools/teachers go to much better way, they use simple experiments, experiments with simple equipment such as plastic bottles.

In this situation some groups decided to try to introduce data loggers, first swallows we have introduced more than 20 years ago. We have summarised this brief history in [1]. The history of the usage of such tools in schools in Slovakia goes to years around 1986, when computers "Didaktik" has been produced and supplied to schools. Even if these computers have been produced by Slovak company producing also other equipment for science education, and the fact that about 100 000 such computers have been produced (many of them for export) it has not been broadly enough accepted by teachers and has been used only by some enthusiastic teachers. After 1992 the production has been stopped and these computers in schools have not been used any more. During years 1988-1992 some enthusiastic teachers inspired by some projects (e.g. Phare) or by the research of universities tried to use other computers (e.g. Sinclair and later computers of types 386, 486) and some applications for science education from abroad. The estimation is that the number of such enthusiastic teachers was less than 1 out of 50 teachers.

Around 1992 two streams of progress in utilization of ICT tools in science education have been tried. One group equipped 15 secondary schools, each by 10 IBM compatible computers with some modelling software (e.g. for geometrical optics) and also with one set of MBL tools of German producer Leybold Didactic. The delivery has been supplemented also by in-service teacher training, but this stream diminished soon and now we are not aware of any schools using these tools. Other stream grouped around V. Koubek together with groups from Belgium, Czech Republic, Finland, Poland, Sweden and Netherlands, as a part of international project MAPETT. The system IP-Coach has been developed and still is developing and produced by CMA in Amsterdam.

The basic idea of the use of the system Coach from the beginning is “open learning” featured in CMA Catalogue 1994: “For a long time it has been clear, that Microcomputers and New-Media provide effective means to support the activities of measurement and data capture, and processing and interpretation of data. Integration into the learning process is optimal, when the software and hardware also integrate, to provide all the desired facilities.”

The concept even in the year 1994 has been based on the vision of pupils learning by investigating like scientists, utilization of the system for a wide age range and in a broad variety of scientific and technological work with pupils and students, open software and hardware environment and offering application in varied educational situations.

Fig. 1 – 4 illustrates the innovation of the MBL hardware. Even if the innovation of the interfaces is still going on, the sensors can be still used and the hardware is still supported by new software. So the innovation is not so radical as in a case of computers itself – the computers produced some years ago are quite quickly replaced by new, what is somehow costly.
Even if the system CMA Coach is incorporated in curriculums of pre-service teacher training at Slovak universities, the broader utilization of the ICT tools at secondary schools in Slovakia still has not been noticed. We can say that education and especially science education has never been a real social priority in the years after 1989. The national plan for informatics in schools had been realized by the project Infovek (after 1999), sometimes tried to focus utilization of computers delivered to schools to as much as possible school subjects, but the numbers of classrooms equipped by computers allowed almost only the use of them in the special subject called Informatics (Computer Science).

Systematic course to use MBL tools in physics education in Slovakia we established in 2004 by the project Infovek within which small subproject was devoted to introducing MBL tools in science education at secondary schools. From each of the participated school 2 teachers were invited to 5-day training. One of 2 teachers was physics teacher, second was teacher of other science discipline (usually chemistry, in some schools biology). The participating schools were equipped by one set containing 1 data logger (CoachLabII), software Coach 5 and sensors (pressure, temperature, pH, sound). We have prepared one year course - distant learning (combination of synchronous and asynchronous) with distant support of the teachers. After the year we have organised present 5-day training. At the end of the project the schools reported utilization of the equipment in their classes.

Followed by this project a series of other national projects have been accepted and now the universities preparing future physics teachers are quite well equipped, almost all MBL tools used in Slovak universities preparing future physics teachers now are produced by CMA Amsterdam.

2.2 Methods used in physics education

As we mentioned already, physics education in Slovakia is changing very slowly. We do not have serious research into methods used in physics education in Slovakia, but it seems that the result of such research would clearly show that great majority of physics teachers use transmissive, content based teaching. The transmissive teaching is often supplemented with project work, but project based only on internet search and presentation of information gathered from internet.

2.3 Assessment in physics

Assessment and marking of students in physics is fully a competence of the school, often the teacher. External written evaluation is missing even on the level of final exams. Official documents presents
wide range of aspects if the assessment, however majority of schools/teachers take into consideration only knowledge presented in written and oral assessment prepared by the teacher [2]. Many teachers consider also interest into physics education presented by the student [3].

2.4 Time allocation for physics

In the last few years radical changes were done in physics education in Slovakia. The basic document ruling the content and goals of physics education has been developed and authorised in the parliament as a part of The National Curriculum (ŠVP) [4], the implementation of the external final exams in physics has been stopped, and work on a new series of textbooks has been initiated. All these changes are done very quickly in time pressure, without broad enough discussion and without allocation of necessary resources. The most radical was the change in the time allocated for physics and whole science education.

Physics as compulsory subject in Slovak curriculum has allocated 10 week hours (45 min) as in tab. 1.

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Tab. 1 includes also allocation for optional subjects. Some of these week-hours can be allocated to physics, by the management of the school, or in some bigger schools by pupils. Even if schools allocate some of the optional week-hours to physics, there still can be seen radical reducing of this subject. Such radical changes and also quite obsolete curriculum issued in necessity to prepare the physics curriculum in new format. Firstly, we saw the high pressure to physics content. Teachers used to teach content based curriculum could not easily adapt to teaching less content in less time.

3 RESEARCH INTO POSSIBLE CHANGES

Our group started research, and now in such situation we would start probably in the same way, in presenting great possibilities, which are linked to data loggers in physics education. It was year 2003 and we had well developed links to teachers and perfect environment for e-course design (Moodle). Now we see, that this was quite naive approach – even if at first sight it does work well, some time ago we had seen that at some schools it does not work at all. In the next lines we bring some ideas of our previous research.

3.1 Teacher training for raising ability to use data-loggers

In discrepancy with situation from 20 years ago we do not see any necessity to teach students to use the software. The research done with more than 400 students (age 15-18) on software Coach 5 and later Coach 6 on the level of measurement, data processing and presentation proved that the students only need to be informed about parameters of the system. Software is so user friendly that we can start to use it on intuitive level. This finding does not apply for software for modelling and videomeasurement, some instructions are necessary here if we want the students to use them independently and effectively. From this point of view it is good, if these parts of software are joined in one software environment, such as Coach 6. This finding does not apply for teachers; teachers need some instructions and training.

The supply of equipment (interface and sensors) is necessary to complement also by teacher training. We found as effective 3-4 days face to face training and at least 1 year distant learning with final report demanded from each participating school. The supply without face to face teacher training and also teacher training some months before supply we found as not effective. Short teacher training (1-2 hours) done without instant delivery of equipment to school can be considered just as an information for the teacher about possibilities and inspiration for teachers to activate them in effort to gain the equipment. Incorporation of ICT tools (data loggers) offers much more activity oriented education and this shift can be strengthened by curriculum and textbooks design. The potential of data loggers is not self-exploiting. To take advantage of ICT tools, these should be not taken as something odd, or special, but should be incorporated into the whole process of physics education.
Some students and also some teachers are quite exam centred, they try to prepare themselves for exams and quite often do not follow all goals of physics education. We have tried (and not only we) to incorporate some aspects related to MBL tools also to written exams questions. On our pre-search we see, that such questions in written exams motivate teachers to include MBL experiments in their teaching plans and also bring them ideas for new attitudes and new experiment designs [1].

3.2 Planning experiments in physics education

Focusing students’ laboratory work to planning, data collecting, data processing, evaluation, manipulative skills and personal skills has been proved as effective way in keeping the students active. The combination of this new (new in Slovakia) strategy together with new equipment made the laboratory work much more effective in relation to time and also in relation to the goals of physics education. The design of experiments by students takes some time and we should allocate this time [5]. Quite reasonable number of teachers considered this time as not effectively spent. With such teachers we should patiently discuss the goals of physics (science) education.

3.3 Interactive animations and videomeasurement used in physics education in Slovakia

As we have noticed some schools/teachers try to replace real experiments by virtual - by interactive animations (simulations, applets). This tool is still not well spread in Slovakia, but reasonable number of teachers quite randomly look for applets on the web. In 2002 a group of teachers with their secondary school students translated applets by Walter Frendt [6]. Quite popular are also simulations of physical phenomena from the PhET™ project at the University of Colorado [7]. Till now we have mentioned interactive animations prepared by somebody. Some teachers were trained also for preparation of their own simulations in Modellus [8].

Our research from last few years is focused to interactive animations in Coach 6 – both prepared by somebody else and also prepared/adjusted by the teacher. Now let's try to summarize some few fundamental attributes of interactive physics animations that are their advantage when comparing with real-life experiment or observation – and that lead to improvement of process of cognition. Subsequently, we will touch on the risks, which are associated with the inappropriate use of interactive animations in the physics teaching.

We're going to start with free definition of the concept of learning according to W. Harlen [9]. Learning is giving meaning to experiences in collaboration with others by the child itself. Acquisition of experiences through the work with mathematical relations, reading the verbal formulation or using the still images, is not sufficiently attractive for the students [10] and for the student it's often unsurpassable abstract. Yet the most fundamental form of human cognition is acquisition of experiences so, that the several senses are involved. Well prepared and well applied activity or animation can lead to students’ experience and it is acting on students’ senses by the several information channels, than the common forms of presentation of physical phenomena. Needless to say, it can only complement experiences acquired in everyday life and in the process of teaching by real-life experiments (or observations and measurements). In the ideal case, in addition to the experience of the discovery process, students should also get a longer lasting knowledge or information. But this effect is often thwarted either by the difficulty of the experiment, or its (not) understanding – course and/or the interpretation of the results may not be obvious to each of the participating students. As an example we can point to well-known demonstration of real and functional model of the electric motor (in the demonstration experiment).

Interactive animations can be applied when there isn't any instrument or tool available or available only in limited quantities - so for all the students it is relatively easy to participate in experimentation. The teacher will demonstrate a real-life experiment, which the students then carry out or influence through animation.

More complex calculations and mathematical procedures that we encounter quite often in physics, may not be the easiest to solve, either manually or with use of a spreadsheet. In such cases, it is advisable to use a specialized mathematical (simulation) computer program. For the school physics purposes we consider as the most suitable the complex solution - the software CMA Coach 6, or more precisely the features "Modeling" and "Animation".

The fact, that the presentation of the experiment or physical phenomena is done on a PC, can distract some students from the original objective, for example, they may focus on aspects of the software or...
animation that are not directly related to the phenomena that we want to observe, or to the experiment, which we want to execute in this form. There is also a threat that they will just aimlessly and passively “work” with the animation. In the case that the animation is operated by one student of the group, it may happen that the others will switch themselves from the “activity” mode to the “cinema” mode. It is positive if students have the joy of experimentation and learning, when they take that all as a game. However, if they limit themselves only to this aspect, the resulting effect will be rather counterproductive. The fact, that the animation is a transfer of the real phenomena to some software environment may be its disadvantage from the ground up - in the real world, everything happens in accordance with the laws of nature, in the virtual world we replace them with some model. Model is some kind of a mathematical representation, idealization or approximation - this means that we commit a greater or lesser inaccuracy. In addition to our deliberate idealization of the phenomena, it also sometimes happens that we will bring the misconception into our model (or some error, mistake) that may lead to such behaviour of the model, which is not consistent with reality. So the animation that was previously helpful can become our burden.

We can say OK that all is really nice, but methods of using animation in physics teaching has been tested and verified so many times. And on the web there are loads of freely available and fully functional physics themed simulations and animations.” That's right; activities with use of animation aren’t anything revolutionary new. Nevertheless, we think that it is important that the teacher would not only be the user but also the creator of some interactive activities - at least in the form that he would modify the activities on the level of the common PC user and editing the instructional texts – very important parts of the interactive animations.

To illustrate our previous considerations, and to show that it is really possible to create interactive physics applet without any knowledge of programming, we have prepared the activity named “Ball” (Fig. 5).

It would be hard to find a student who had never thrown a stone before - we can throw a stone just for fun, perhaps in an effort to throw at some particular spot, or as far away as possible, maybe as high as possible. Most students are impressed when they see a friend who has got a really good throwing technique. Also competitiveness during PE classes plays its role. Maybe you’re asking yourself - why we resort to the experiment in a virtual environment, when we should try to do just the opposite - the real experiments with real devices and tools, embedded in real-life situations! Students have a wealth of experience and we are developing also their abstract thinking and imagination.

Output of the model is interactive animation and set of graphs, as we see in Fig. 5. Graphs are in the same environment as we use in the measurement activities. An important part of our creation is also an accompanying text that will introduce a student to the topic and it will illustrate some important concepts and correlations. The text does not attempt to “offer the facts that lay on the golden tray”, but asks many questions that, if we come to think of them, may lead us to the knowledge without the use of textbook or some other reading material.
In the activity there are also found some interesting task situations, as well as assignments (computational exercises) in “classic” style. However, with an original approach to solving them - students can come up to the result through animation.

In this article we have described and brought complete interactive animation ready for use by teachers at elementary and grammar school. A specific feature of interactive animations in the CMA Coach 6 environment is a very simple way to create such animations, to edit them or to modify them for our own needs. We investigated capabilities of elementary and secondary school teachers during the training of physics teachers. Teachers carried out, under the guidance of lector, instructional activity with duration of approximately 120 minutes and then were asked to create an animation of an apple falling from a tree, or eventually horizontal throw of the ball from the windows of the building. After approximately 30-40 minutes the teachers prepared such animation (based on previously prepared model). Some even managed to prepare an animation of package fall from a flying aircraft (on a desert island in the sea).

3.4 Scaffolding Guided Inquiry through Lesson Design

Very important part of the usage of modern technologies in the education is well developed lesson. We have mentioned it in some parts in this article, but this part focuses to our experience in the lesson planning. Some our previous activities we can see e.g. in [11] and [12]. The new activity we designed is inspired by the work of M. Klentschy [13]. He organized lesson planning to three crucial phases – intended, implemented and achieved curriculum.

In the first phase, intended curriculum, the teacher should, for himself, define content goals of the teaching sequence. There are some binding documents in every education system. For the teacher in Slovakia the most important is The National Curriculum (ŠVP), ISCED 3 [4]. In the part Electromagnetic radiation and the elementary particles it is stated that student should know about refraction of light and index of refraction. Next, in the Guided Inquiry, it is important to formulate a Big Idea of science which identifies what and why it is taught and also it is recommended to display it in the class during the lesson. In our case, we used the idea of Richard Feynman: “The eye is a piece of brain that is touching light.”

Before student inquiry starts, the teacher must prepare suitable working conditions, he should be aware of the language, words, vocabulary, previous knowledge and the tools which will be used. It’s important that students will be conscious of meaning of the activity; it must make a sense for them. We were sure, that the student had mastered the concept of ray of light, real image and virtual image.

At the beginning of implemented curriculum there is something what attracts students – engaging scenario - article, picture or teacher’s demonstration. Implemented curriculum in our activity takes place in two cycles. Each of them begins with short story. The first is about fisherman - amateur. He wants to catch fish which is immersed in a lake as in Fig. 5. In which direction he should aim his spear to hit the fish?

![Fig. 5 Engaging scenario](image)

Inexperienced students’ answer is that the best strategy is to aim the spear directly at the fish. Teacher should ask if it is really true and raise doubts by students, compel questioning. We want to raise thoughts if something can change a way of light. To answer these questions require a model of this situation. The phase of plan and conduct the investigation follows. Students get some tools – opaque bowl, coin, water, which lead up to experiment.

Students work in small teams; slowly pour water into the bowl with the coin glued on the bottom. They observe position of the coin; adapt conditions that the coin is not visible at the beginning, but after they poured water in, the coin can be seen. Students shall interpret the results of this experiment. They must change their first attitude – it is not optimal when fisherman would aim the spear at the fish.
They find that apparent position of the fish is not real. Fisherman must aim his spear in front of the image of the fish. They mean the cause is water. Light doesn’t travel in straight line, it curves, diffracts.

Now we pretend leaving topic, and start the second cycle of implemented curriculum. Again we use a story. Lifeguard is on the beach and sees the man who drowns. He must rescue him in the shortest time possible. In which direction he should start running? In the first short discussion teacher should clarify that lifeguard runs faster than swims and simplify the situation – ignore water flow in the sea. We expect two hypotheses about ideal trajectory: “Lifeguard should run in the shortest path, in straight line between his position and the position of the drowning man” and “We know that lifeguard runs faster than swims. So he should swim the shortest possible distance. Therefore he should enter to water vertically to the position of drowned man.”

Students can verify their hypotheses using interactive animation created in Coach 6 as in Fig. 6. They can change position of entry to the sea and measure time of rescue. After the series of tests they rebut their hypotheses and find ideal trajectory. It is apparent that it’s not a straight line. Trajectory is refracted by crossing between beach and water. This discovery is really surprising for them.

![Fig. 6 Lifeguard in Coach 6](image)

We created graph (time of rescue depending on position of entry to the sea) to complete the situation. Student can make themselves certain that is only one specific trajectory.

Now follows the last phase of teaching sequence – achieved curriculum. The major task is raised by the teacher – provide the feedback. It doesn’t mean only grading students. In fact, many research studies show that grades have any influence to results achieved by students. Teachers must provide comment directly associated with content and process of inquiry. It’s important to identify possible improvement. Also they should introduce right terms, raise significant discoveries.

In our case, teacher connects both discussed problems. Statement “Light is a lifeguard!” helps students to connect two phenomena, make an analogy. It means, in each medium light travels with different speed. Between two points it “chooses” path which is passed in the shortest possible time. It’s needed to name this phenomenon like refraction of light. Light doesn’t curve or diffract. Also teachers should warn that this phenomenon is consistent with a straight-line propagation of light. But the straight-line propagation of light is limited to one material. In this phase, we come back to first problem – hitting the fish by spear. Teachers should call upon students to drawn approximate run of rays of light and find virtual image of the fish.

### 4 RESULTS OF OUR RESEARCH – WHAT WE HAVE LEARNT

The main result of our research seems to be quite silly, very simple. We would say, that we were probably not enough educated in theory of physics education, cognitive psychology, management of education and in many other subjects when we say such well known truth. Aware of such possible criticism we present the result, which was quite long time not known by our team. And we know many other teams, which are doing the same mistake as we did. The main result is that the effect to science
education does not bring the use of data-loggers itself. Even if very well developed and up to date
designed, the data loggers must be supplemented by methods of education, well selected, or
developed together with the activities designed for usage of such tools. The most complete lists of
methods we consider are in the work of R. Marzano [14], J. Hattie [15] and G. Petty [16]. And we can
say that there is a multiplication, as in Fig. 7. If one of the factors is zero, the effect to the education is
zero, even if the second is very high.

![Fig 7 Simple multiplication as a form of presenting experience with introducing data loggers to physics
teachers who do not have any experience with such tools](image)

There it is clear, that at schools one teacher should use limited, well selected methods what is well
formulated in the pedagogical principle of sameness. The same stays also for the usage of the
technologies. We see that even if we know many mutually similar environments for
videomeasurement, or we know some tools for modelling, it is much better for the pupils to have order
in such tools. We must keep in mind, that the pupil has another subject every hour, every physics
lesson is a new lesson for her (not as for teacher, who might have the same lesson in more classes
and also could have similar lesson last year). So too much disorder or too much divergence could take
more attention, that is optimum and the attention could be focused to technology, not the subject
studied and problems which should be solved (as planned by the teacher). This is one of the reasons,
why we have decided to use one complex system Coach not only for measurement and data
processing, but also for interactive animations, modelling and videomeasurement, as we illustrate on
the Fig. 8.

![Fig. 8 CMA Coach System](image)

We would be pleased, if readers do not hesitate to contact us with comments and new ideas to raise
the quality of science education in our schools.

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REFERENCES

[1] Demkanin, P.et al. (2008), Effective use of ICT in Science Education, Univ. of Edinburgh, pp. 120-140


[10] Baník, R. et al. (2007), Fyzika netradične (Unconventional physics), STU, Bratislava


[14] Marzano, R. Integrating Technology into the Classroom using Instructional Strategies based on the research from: Classroom Instruction that Works, available at: www.tltguide.ccsd.k12.co.us
