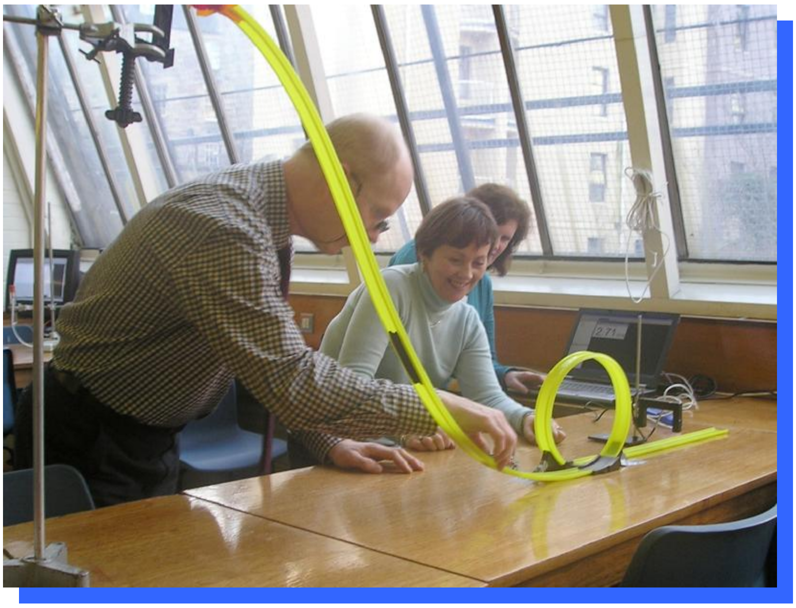
Education and Culture

Socrates

# Effective use of ICT
# in Science Education



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# Effective use of ICT in Science Education (EU-ISE)

Socrates

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Effective use of ICT in Science Education

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## Preface

The idea to bring together the international group to share experiences and work together in the field of effective use of ICT in science education arose during Comenius 2.1 Contact Seminar in Copenhagen in October 2003. Bob Kibble from the University of Edinburgh, Jari Lavonen from University of Helsinki, Josefa Guitart Mas from the Government of Catalonia, Jozefina Turlo from Torun University and I saw a common interest in discussing lot of open problems in effectiveness of using ICT tools in schools and we had interest in comparing situations in different European regions.

In preparing the strategy of our common work we clearly saw that the situation in our countries is very different in terms of the level of equipment in schools, in the level of teacher's competencies relevant to ICT use, and also in the level of teacher's attitudes to ICT. But at the same time we saw lot of common issues. The investment to hardware and software tools for science education, in some regions at a high level, do not automatically lead to noticeable progress in quality of science education. We have focused our interest upon the effectiveness, to the teachers, of raising the quality of science education and evaluation of the situation in this narrowly focused area.

After one year of informal communication and looking for a strategy of our common work our project proposal has been approved. This book brings a selection of the outputs of this project. We can read here about the results of our international questionnaire, about the situation in the field of ICT tools in our countries, and about how in different circumstances the ways of bringing about teacher training for effective use of ICT are realised.

This book brings also some new views to the classification of ICT tools and related methods in science education, proposed by Jari Lavonen, examples of experiments planned by students in an MBL laboratory by myself, and examples of interesting sophisticated experiments in an MBL laboratory by Jozefina Turlo.

After this project we are still working in this area and 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.

Peter Demkanin, May 2008

## Learning and the use of ICT in Science Education

*Jari Lavonen*

### Abstract

*In this introduction chapter use of Information and Communication Technology (ICT) in science education is analysed from the point of view of learning and interest. Examples of ICT use described here have been developed in the project Eu ISE –Effective use of ICT in Science Education (226382-CP-1-2005-1-SK-COMENIUS-C21). Firstly, students' interest in science and science learning is analysed in the context of ICT use in science education. Secondly, possible ICT use, examples of best practices, in science education are described. Thirdly, ideas how ICT can be integrated to some basic teaching methods are presented. Finally, a summary where ICT use from the point of view of learning and interest is presented.*

### Introduction

At the same time when the project *Eu-ISE (Effective use of ICT in Science Education* 226382-CP-1-2005-1-SK-COMENIUS-C21) was started the Organisation for Economic Co-operation and Development (OECD, 2004) published a survey "*Completing the Foundation for Lifelong Learning: An OECD Survey of Upper Secondary Schools"*. This survey recognises that there have been large in-service training programs and large sums have been spent on Information and Communication Technology (ICT) and still the OECD identifies use of ICT in schools as disappointing. Adequate guidance and in-service training or professional development of teachers is still a major problem in all OECD countries. The use of ICT in education in most countries concentrates on routine type tasks, like sporadic and mechanical information retrieval from the Internet.

However, teachers and students have high expectations for using computers in their classrooms. This is because ICT can make science teaching and learning more versatile and goal-oriented, motivate and activate students, and promote co-operation, study in authentic contexts, and creativity in learning (Knezek & Christensen, 2002; Lavonen, Juuti, Aksela & Meisalo, 2006). Moreover, the infrastructure for using ICT is working well in many areas of society.

The OECD survey and the experiences of science teachers' in-service training, organised by the partners of *Eu ISE* project, (e.g., Lavonen et al. 2006), show that many science teachers feel themselves insecure to use ICT in education. ICT can not be simply added to teaching and learning activities, because the goals and the way of teaching and learning science will change when ICT is used in education. Instead of following routines with ICT students should be led to active learning and collaboration. Consequently, it can not be assumed that the use of ICT transforms science education in all cases for the better. Osborne and Hennessy (2003) emphasise the role of the teacher, in creating the conditions for ICT use and for selecting and evaluating appropriate ICT tools, and, moreover, in designing teaching and learning activities. Osborne and Hennessy (2003) identify ways in which teachers might make effective use of ICT:

- ensure that ICT use is appropriate and 'adds value' to learning or "new" goals are activated for teaching and learning science,
- build ICT use on teachers' own existing skills and practices and on students' prior skills and conceptions,
- plan activities or tasks for offering students responsibility, choice and opportunities for active participation,

- prompt students to think about concepts and relationships,
- create time for discussion, reasoning, analysis and reflection,
- focus on goals and tasks including goals dealing with ICT skills,
- develop students' skills for finding and critically analyzing information.

In this introduction a first a look for students' interest in science and science learning is done in the context of ICT use in science education. Secondly, possible ICT use and examples of best practices in science education are analysed. These examples were presented and discussed during the teachers' in-service training sessions within our *Eu ISE* project. Thirdly, we present some ideas for how ICT can be integrated to some basic teaching methods. Finally, we present a summary where we look at ICT use from the point of view of learning and interest.
However, firstly we shortly explain what we mean by Information and Communication technology (ICT). The artefact which is used in acquiring, processing, integrating and analysing information and is used as a mediating tool in communication is a computer. Computers have made information processing fully automatic. Therefore, the term "computer" should rather be understood as "modern, fully automated technology for information procession (gathering, storing, processing and sending data)" than what we usually deal with – the hardware of a personal computer. Single software is called in some cases an ICT tool because a tool describes better, for example, the use of software and a sensor than single software.

## Student Learning and Interest in Science

### 1. Features of Effective Teaching and Learning

According to the book "*How People learn: Brain, Mind, Experience, and School*" (Bransford, Brown & Cocking, 2000) meaningful learning engages students in tackling the topic to be learnt in such a way that they create meaningful and understandable knowledge structures on the basis of a goal for learning. Based on their ideas, it is possible for us to present an outline of science learning with a focus on ICT use in learning. Learning represents each individual learner's own personal knowledge construction process which presupposes each learner's active, goal-oriented and feedback-seeking role. The constituents of meaningful learning are the following: activity, intention, contextualization, construction, collaboration, interaction, reflection, and transfer. These serve as development and selection criteria when choosing teaching and learning activities emphasising ICT use.
*Activity and intention* mean that students take responsibility for their own learning. Thus they set, together with a teacher, their learning goals and proceed according to a plan to reach the goals they set. This process may be facilitated, for example, by guiding students to plan by themselves or in small co-operative groups. On the other hand, students neither master the logical structure of a subject nor recognise their own biased preconceptions, and therefore students' goal setting needs to be supported and guided by the teachers. Thus, activities that support co-operative planning and evaluation are important for learning.
Learning could also be enhanced by *self-evaluating* activities. Bransford and Donovan (2005) emphasise the role of self evaluation in science learning. They suggest that a teacher should provide support for students self-evaluating for example by giving them opportunities to test their ideas by building things or making investigations and seeing

then whether their preliminary ideas were working. Different kinds of feedback are important for learning.

*Reflection* means that students examine their own learning and develop metacognitive skills to guide and regulate their learning. Metacognitive skills are necessary for planning and evaluating one's own work. These skills make also learning a self-regulatory process in which the student becomes less dependent of the teacher. For example, self-evaluating or evaluating in a small group, taking multiple-choice tests, doing exercises and consulting answer keys support developing reflective and, moreover, metacognitive skills.

*Collaboration and interaction* mean that students actively take part in group activities and support each other by discussing and sharing knowledge. Learning new concepts presupposes a dialogue both between the teacher and the students and amongst the students (explaining, debating, questioning). In addition to face-to-face interaction ICT offers several possibilities to share ideas through newsgroups, e-mail or through a Learning Management System (LMS).

*Construction* means that students combine their earlier knowledge with the new topics to be learnt and thereby tailor information structures that they can comprehend. Therefore, the teacher should encourage students to bring up their previous views and beliefs and thereby construct new knowledge on the basis of this shared information. For example, prior to starting reading or writing, students need to be guided to bring up their prior views on the subject to be dealt with. Respectively, before an investigation or other practical activity students should be encouraged to present his or her prediction or even supposition.

*Contextualization* means that learning takes place in real life situations or in situations simulating real-life instances. This in turn presupposes that the learning setting allows for authentic and real-life learning experiences. For example, when using a search machine (Google), students should be encouraged to look information from different sources. This enables the students to treat the concepts in various contexts and thereby deepen the meanings these concepts acquire. It pays off also to keep in mind that the quality of all internet-based sources need to be checked carefully to ensure that the facts are reliable (source criticism). From the point of view of interest, the context in which science ideas are learned, rather than the ideas themselves, has important influence on learning. For example, when writing it is crucial that students write to prospective readers other than the teacher.

Learning is *cumulative* and, therefore, students are aided in noticing how a new concept or skill is related to other already familiar concepts or the network of concepts or skills. Learning of science process and ICT skills are similar processes. In both areas there are low level and high level skills. For example, before a student learns to use a LMS he or she should learn to use a word processing and a search machine. Consequently, students should be supported in learning new skills and in internalising the new concepts and in building conceptual networks in the given field.

Previous characteristics of learning activity may be realized through the use of ICT. For example, by employing the Internet in the planning phase of the project, students have access to meaningful information of the topic. When looking up information from varied sources, students at the same time actively structure the flow of information they encounter into meaningful entities in order to be able to complete tasks. Similarly, this exploration of information from varied sources forces students to evaluate the reliability of both the information and the sources they use. During science investigations similar procedures can be followed in planning and in repeating the measurements or investigations. In both activities the students can be encouraged to work together and also actively evaluate their activities. Several studies have indicated that information processing, inquiry-based learning, and exploring resources via networks, are beneficial for science education (Linn, 2003).

## 2. Student Interest and Learning

There are many concepts that can be used to describe *motivational aspects of science teaching and learning*. Here we base our analysis on Self Determination Theory (SDT) and theory of Interest. According to Ryan and Deci (2002), a student's way of thinking has an important role in the process of motivation. Motivated behaviour may be (i) *self-determined* or (ii) *controlled* and they involve different reasons for behaving. Self-determined or autonomous behaviour is behaviour which arises freely from one's self. Controlled behaviour, in contrast, means that the behaviour is controlled by some interpersonal or intrapsychic force, like a curriculum or a task. The motivation styles in SDT are: (i) *amotivation*, (ii) *extrinsic motivation* and (iii) *intrinsic motivation*. Intrinsic motivation has positive effects on learning, in particular, to the quality of learning. Intrinsically motivated behaviours are based on the need to feel competent and self-determined (Deci & Ryan, 2000). Extrinsically motivated behaviour is instrumental in nature. Such action is performed for the sake of some expected outcome or extrinsic reward or in order to comply with a demand.

Although students primarily produce their motivation, it can be enhanced and learned. In practice, a science teacher can offer optimal challenges and rich sources of motivating stimulations through choosing the learning activities. Therefore, in addition, to previously discussed features of self-determined and controlled behaviour of a learner, it is appropriate to analyse also features of a learning activity which could increase the motivation of a learner. This is because self-determined learning occurs when a learning activity itself is considered as interesting, enjoyable or personally important by a learner. From the point of view of the SDT, the motivational features of the learning activity could be classified in five categories:

- *autonomy-supporting activities/teacher*, through
  - choose of student-centered learning methods like "open ended" inquiry (Wellington, 1998) and other tasks where students have some choices how to plan or study,
  - collaborative learning activities which support feeling of autonomy,
  - co-planning of the learning activities,
  - use of ICT where students have choices, possibilities for planning and evaluating ones own activities and
  - support to the feeling of effectiveness and importance of working;
- *support to students' feeling of competency,* through
  - choice of inquiry and other tasks, which are possible for the student to solve;
  - choice and use of constructive evaluation methods, like self assessment, portfolio evaluation, informal discussions, which help students to recognise that they are good at an activity or do the activity well and
  - support for the feeling that the activity has some value or use for the student.
- *support to students' social relatedness,* through
  - choice of tasks, collaborative learning activities, co-planning and ICT use which help students to feel close to peers and
  - support to the feeling that the students can trust each other and feel themselves close to each other.
- *support to interest and enjoyment,* through

  - waking up of curiosity by choice of surprise-evoking inquiry and other activities or tasks,
  - enjoyable, fun and interesting activities, like through choice of interesting web pages or simulations,
  - choosing activity which hold attention;
- *science content* (new materials or new knowledge in science) and *context* (human being, occupations, technology or history).

Interest is a content-specific motivational variable (Krapp, 2007). Interest is approached from two major points of view. One is interest as a characteristic of a person (p*ersonal interest*) and the other is interest as a psychological state aroused by specific characteristics of the learning environment (*situational interest*). Personal interest is topic specific, persists over time, develops slowly and tends to have long-lasting effects on a person's knowledge and values (Hidi, 1990). Pre-existing knowledge, personal experiences and emotions are the basis of personal interest (Schiefele, 1991). *Situational interest* is spontaneous, fleeting, and shared among individuals. It is an emotional state that is evoked by something in the immediate environment and it may have only a short-term effect on an individual's knowledge and values. Situational interest is aroused as a function of the interestingness of the topic or an event and is also changeable and partially under the control of teachers (Schraw & Lehman, 2001).
According to Hoffman (2002) an appropriate context where certain science content or topics are met or teaching and learning activity might have an influence on the quality of emotional experience, which is importance for the development of situational interest. Juuti, Lavonen, Uitto, Byman, and Meisalo (2004) surveyed Finnish 9th grade students' interests in physics in certain contexts. The most interesting things (especially for girls) were connected with human beings. Therefore, it is important to approach issues through the activities of human beings. Students' out-of-school experiences are different. Boys' experiences are more relevant to conventional physics and technical topics whereas those of girls are more closely related to everyday life and health (Uitto, Juuti, Lavonen & Meisalo, 2006). Therefore, human-related experiences during the science lessons are important especially for girls.
The *Self-Determination Theory* (SDT) and *Theory of Interest* are relative theories. Especially from the point of view of ICT use, similar conclusions can be made based on both theories. For example, it is important to support student autonomy and curiosity for increasing his or her interest or motivation to learn. Both, autonomy and curiosity are possible to support by choosing the activities in a versatile way. ICT use as such can support both feelings. For example, Dori, Barak and Adir (2003) found that ICT-enhanced learning motivates and engaged students on learning.

**Roles of ICT Use in Science Education**

Computers have been used in education in many ways from the very beginning of their history. Several ways to analyse use of computers or ICT in education have been suggested. In the 1980s use of computers was typically divided to technological and pedagogical use. ICT use was classified based on the type of interaction in two categories: either a student or a computer leads the interactive learning process (Brownell, 1992). In 1980s a lot of governmental money in several countries was used for the *educational software production*. This software was used, for example, for training a single skill or learning scientific terms. In the 1990s the use of ICT was increasingly analysed from a pedagogical point of view and ICT use was typically divided into IT assisted learning, tool applications, and computer science (Moursund & Bielefeldt, 1999). In the first category ICT is used as an agent for interaction in many ways. In the second category the computer is a tool. The third category is dedicated for computer science perspectives (look more Lavonen, Meisalo, Lattu, Leinonen & Wilusz, 2001).

ICT use in science education is appropriate to classify here into (A) *tool applications (use of tool software)* and (B) *ICT use in learning (learning through ICT)* (Webb, 2002; Lavonen, Juuti, Aksela & Meisalo, 2006). In the *tool category* (A), ICT is treated as a set of available software enabling students to accomplish their tasks in an effective way. To this category belongs for example the use of word processing and spreadsheets in science learning activities. A teacher can use a Power Point presentation or a whiteboard when he or she explains a science model. Publishing and web-publishing tools are also examples of teacher's tools. Furthermore, databases, spreadsheets, graphing tools and modelling environments can be used as tools in science education.

The main uses of *ICT in learning* (B) can be divided into three different categories for directly supported learning: (B1) *Computer-assisted learning (CAL)* is any interaction between a student and a computer system designed to help the student learning. A student can, for example, learn with an interactive educational software or training software or computer tutorials.

(B2) *Computer-assisted inquiry* is the use of ICT as an aid in collecting information and data from various sources to support scientific reasoning (McFarlane & Sakellariou, 2002). Typically ICT is used as an agent for interaction with the information source (nature or written source), like the Internet or a Microcomputer-Based (school) Laboratory (MBL) (Wiesenmayer & Koul, 1998; Lavonen, Juuti, Aksela & Meisalo, 2006).

Electronic mail, newsgroups, chat rooms, blogs,Wiki, and videoconferencing are used for educational purposes in the (B3) *distance learning approaches*. For example a newsgroup can be used for facilitating students' homework. A large number of websites that focus on chemistry topics were developed for academic purposes by their instructors. Lecture notes, homework projects, online books and complete courses in science, physics, chemistry or biology are available on the Web (Lui, Walter & Brooks, 1998; Tubi & Nachmias, 2001). The whole course can be managed through a Learning Management Systems (e.g., Moodle or Blackboard).

Previous classification was done from the point of view of ICT use – not from the point of view of a single software or ICT tool (look a description of ICT tools in science education by Denby & Campbell, 2005). For example Microcomputer-Based (school) Laboratories (MBLs) can be used as tools and also in a Computer-assisted inquiry project. In the tool category MBL is a tool for data capture, processing and interpretation. Educational Multimedia software can be used for single simulation of a processes or carrying out 'virtual experiments'. First example belongs to *CAL* category and the previous one to the *computer-assisted inquiry* category.

In several situations, not only a computer and software are used in science teaching and learning, but digital equipment is connected to the computer and used. When a digital recording is made, a microphone, digital camera, web cam, computer-controlled microscope or a video camera is connected to the computer. A video or LCD projector is an example of computer projection technology. Microcomputer-Based Laboratory tool is a combination of the Interface, sensor and a software. Moreover, scanners and printers are used as tools in science education. Mobile technology and portable MBL tools offer totally new possibilities for science education.

## Tool applications

Any particular technology is often treated as a set of available tools enabling people to accomplish their tasks in a more efficient way. The same applies to the ICT, which by its nature can be understood as a large array of hardware and software. Some commonly used "ICT tools" are tool applications: word processing (Baker, 1991), graphics packages, scanner, digital camera, video, presentation applications, databases, spreadsheets (Webb, 1993).

In science learning, students can use different tool applications and also learn what needs are met by these application and when and how to use their different features. For example following tool applications can be used in science learning: word processing, publications and presentation software, spreadsheets, databases, multimedia, web browsers and e-mail. Word processing software can be used, for example, for organising ideas, writing home works and project works. Spreadsheet can be used, for example, for analysing data and modelling. To select the right tool application it is important to understand what types of thinking, learning experiences and experiences of ICT use each ICT tool supports.

A teacher can use tool application is several way. In addition to previously mentioned, he or she can prepare assignments, tests, and other resources for science teaching and learning. Video or LCD projector can be used as a tool in several ways presentations and it can be connected to MBL-tool or a microscope. Tool applications may, however, also be potential drawbacks to this development as it can easily reinforce a didactic style of teaching in which students are the passive receivers of teacher generated ideas and information, albeit, rather more richly illustrated with images. One new interesting tool science teachers have started to use is an *interactive whiteboard* (White board, SMART Board). Whiteboards operate analogously to chalkboards in that they allow markings to temporarily adhere to the surface of the board. The touch-sensitive display connects computer and digital projector and then computer applications can be controlled directly from the display, write notes in digital ink and save work to share later. Most white boards also have specially designed software that includes a range of useful tools. Advantages of the interactive white board are: documents and software can be access from the screen without having to move away to a laptop, it is easy to move between screens to return to earlier work; the drag and drop facility can be used to windows.

### *Word processing*

*Reading and writing* represent well-established approaches to studying and learning sciences. However, studying that centres on reading and writing faces new challenges when learners look up information on the Internet and use word processing. For instance, reading may entail copying web-based information on the notepad and writing in turn entail pasting this information on the document-in-progress. In such cases, learners neither process information nor understand the meanings of new concepts not to mention integrating these concepts within their own existing knowledge structure. Thereby learning presupposes processing the available information by, for instance, reading and writing. In addition, mindmaps and knowledge structuring serve as effective means to process information (Bentley & Watts 1989). In fact, by processing information learners learn the skills and thinking necessary for information processing to take place. Moreover, when processing information in small groups, learners practise collaboration and communication skills as well. These skills are a pre-requisite for professionals serving in various fields of expertise. Students may be encouraged and inspired to read and write by using information and communication technology and by choosing an appropriate teaching method. By employing the Internet, students have access to meaningful information by consulting, for example, electronic books, hypertexts and hypermedia in the CD-rom format or diverse web-based hypermedia documents, such as www-pages. When looking up information in varied sources, students at the same time actively structure the flow of information they encounter into meaningful entities in order to be able to create a report on a given topic. Similarly, this exploration of information in varied sources forces students to evaluate the reliability of both the information and the sources they use. (Lavonen, Juuti & Meisalo, 2007)

Misner and Cooney (1991) present in their book *Spreadsheet Physics* use of spreadsheets in science education. The numerical display of the spreadsheet enables students to understand how simple arithmetic can be used repeatedly to solve relatively complex physics problems. Moreover, the spreadsheet has been used in data presentation, modelling and simulations in science education in different levels.

*Concept mapping*

Referring to Bransford, Brown and Cocking (2000, 31) a person who has developed an expertise in a particular area of knowledge is able to think effectively about problems in that area. Therefore, a teacher should help students to develop expertise. Bransford et al. (2000, 9) suggests that experts' abilities to think and solve problems owes to a rich body of knowledge about subject matter. Furthermore, Bransford et al. (2000, 36-37) had argued that content knowledge of experts in physics is organised around core concepts or "big ideas" that guide their thinking about their domains Learning activities that help students to create a network of concepts seem to be advantageous to learning (Trowbridge & Wandersee, 1989, 117). *Network representations* are two dimensional, hierarchical, node-link representations that depict the major concepts found in domain knowledge. The concepts are linked by lines and those links are labelled with connecting words that explain the nature of link. Network representations in certain domains of science are similar to concept maps, introduced by Novak (Mintzes & Wandersee, 1989, 69; Trowbridge & Wandersee, 1989, 115-123). *Mind maps* are closely related to concept maps. In mind maps related ideas radiate out from the one central idea. Mind mapping is a useful tool for students to share prior knowledge, to establish connections between ideas and to list ideas quickly without judgment.

Concept and mind mapping tools support the developing of diagrams in which teachers or students illustrate concepts and the relationships between them. Cmap Tools is one free software which is very suitable for making concept or mind maps based on our in-service training activities. It can be downloaded from the website of IHMC, A University Affilitated Research Institute of the University of West Florida http://cmap.ihmc.us/download/. More information about the product, including examples of its use can be found on the website at http://cmap.ihmc.us/

*Modelling*

In "real" sciences, there are three approaches to new knowledge: theoretical, experimental and computational. One interesting example which has come from computational chemistry to science education is visualisation of chemical compounds and reactions. There is evidence that use of visualisation tools in problem solving enhance conceptual understanding among students (Barak & Dori, 2005). The advantages of use of these tools is visualisation of the micro and macro world. Static graphics of chemical structures, found in textbooks, may help learners to form two dimensional mental images, but tools such as 'ISIS-draw', 'MDL Chime' and' DS ViewerPro 5.0', enables dynamic, interactive, 3D visualisation of molecules. They allow students to view, rotate, measure molecules, as well as modify or construct new molecules. These visualization tools could make the abstract real, and thus help students understand chemical concepts (Dori & Barak, 2001; Dori, Barak & Adir, 2003).

*Microcomputer-Based Laboratory*

Microcomputer-Based Laboratory (MBL) (in UK data-logging) tool is a combination of the hardware and software that are used for collecting data (data acquisition) using sensors/probes (such as temperature or pH sensors) connected to a microcomputer through an interface. These collected data can be analysed and displayed in graphic form, in real or delayed time. The MBL package is a set of mutually compatible MBL tools (usually with a marketing name such as 'Vernier', 'LabQuest' or 'COACH' (Tinker, 1996).

The MBL package can be illustrated as a large marketplace with different tools and environments for the user to take advantage of when studying natural phenomena. According to the Marketplace metaphor the user makes the necessary choices concerning his measurements much in the same manner as a family mother gets groceries from the marketplace. The Marketplace metaphor also means that the user can for example perform complicated scaling of axes or choices concerning linearity either before or after the measurement. After the measurement a curve can be applied to the results or the axes can be renamed. The measurement file can conveniently be transferred to other programs for further manipulation. The essential point is that tools for displaying measured data can be chosen at any time. Moreover, it is possible to a new measurement in the same window (Lavonen, Aksela, Juuti, & Meisalo, 2003). Here we shortly describe typical properties of a MBL tool from the point of view of science education.

Hardware of a MBL package consists of an Interface and collection of sensors. Typically an Interface has four analog and four digital channels and 2 DA- converters. The sensors are connected to the Interface and the Interface is connected to the USB-port of the computer. The Interface can also be used as a datalogger which is operating without a computer. With the MBL package and an appropriate sensor several entities can be measured, like time, frequency, velocity, acceleration, strain, mass, voltage, current, resistance, electric energy, electric power, temperature, illumination, pressure, acidity (pH), conductivity, oxygen content, absorbance, humidity, the density of the magnetic flux, and number of electrical pulses. It is very common with MBL packages, when a sensor is connected to an input the Interface recognises the sensor automatically and downloads the calibration of the sensor.

Measurement results can be presented numerically or graphically on the screen, or they can be printed or saved. Files can be transferred to spread sheet or word processing programs. The MBL package has a package of tools, which allows the zooming of graphics and the addition of text, curve fitting to the data (ax, $ax^2$, ex, log x etc.), scaling of axes (LOG, INT, 1/x, 1/y, x2 etc.) and graphic integration and derivation of data. Furthermore, a package include a possibility tm make different kind of setups for the measurement.

A user of the package can setup sampling collection parameters such as rate, experiment duration, and triggering. The default measurement is typically a measurement where the collected data is presented graphically and the curve is presented simultaneously with the measurement. In a"Buffer measurement" the results are displayed on the computer screen after the measurement is performed. Trigging is a method to start the measurement automatically. Errors caused by the experiment set-up or excess vibrations can be smoothed out by filtering the results. Fourier transform is used for breaking up dependencies into a spectrum consisting of sums of sine functions. One can for example

study the change in amplitude for sound as a function of time using a microphone. By Fourier transforming the results in the time space, we receive the frequency spectrum in the frequencyspace. From the frequency spectrum, the frequencies at which the source emitting the sound is vibrating are read. Set up can be opened also by opening an appropriate experiment file. An experiment file is a record of the configuration of the sensor settings, calibrations, sampling setup (data collection rates and conditions), desktop settings or graph configurations and data acquired during the measurement.
Spreadsheet properties of the MBL packages are similar to spreadsheet application, like Excel. User can make changes to cells by first pointing it and then writing. For example, by writing a new formula (e.g. =A4*B4) to the cell a calculated value will be get to the cell.

**Computer-Assisted Learning, CAL**

Computer-Assisted Learning (CAL) is any interaction between a student and a computer system designed to help the student to learn. CAL includes drills, tutorials, simulations including applets in the Internet and virtual-reality environments that can present complex learning situations. CAL includes sophisticated and expensive commercial packages to applications developed by projects in educational institutions or national initiatives to simple solutions developed by individuals with no funding or support to tackle a very local problem. Unfortunately, it is not possible to go through here all different kind of software which has been developed in the framework of CAL for science education.
One widely used simulations in science education are Java applets/physlets which can be found in the web-pages (Christian & Belloni, 2001. An applet is a software component that runs in the context of another program, for example a web browser. Applets are most often used ICT applications in the explanation or interpretation of processes in nature or in technological environments (McFarlane & Sakellariou 2002). For example in the web page of the University of California (http://www.chem.uci.edu/undergrad/applets/), is a nice collection of applets that give students a chance to explore some scientific principles which simulate the way a professional chemist does. A similar collection of physics applets can be found from the web page of University of Oregon (http://jersey.uoregon.edu/vlab/).

**Computer-assisted inquiry**

Computer-assisted inquiry is the use of ICT as an aid to collecting information and data from various sources. For example Microcomputer-Based Lab (MBL) tools can be used in science inquiry and nature as a source of information. MBL can help in data acquisition and data processing in laboratory. Science inquiry is of course very similar with or without MBL tools. Therefore, a short overview of science inquiry is presented in this chapter. Another example of computer-assisted inquiry is an inquiry where internet or a Web Based Learning Environment (WBLE) is used as a source of information. In both cases it is important that also a student - not only a computer – is processing acquired information so that the student learn new knowledge and become familiar with the principles of scientific reasoning (cf. Millar, 1996, p. 15).
In a *science inquiry* students begin with a question, design an investigation, gather evidence, formulate an answer to the original question, and communicate the investigative process and results. In partial inquiries, they develop abilities and understanding of selected aspects of the inquiry process. Students might, for instance, describe how they would design an investigation, develop explanations based on scientific information and evidence provided through a classroom activity, or recognize

and analyze several alternative explanations for a natural phenomenon presented in a teacher-led demonstration. Experiences in which students engage in scientific investigations provide the background for developing an understanding of the nature of scientific inquiry, and will also provide a foundation for appreciating the history of science described in this standard. Of course, MBL and other ICT tools do not give explanations – only the evidence or data. Students should understand that background knowledge and theories guide the design of investigations, the types of observations made, and the interpretations of data. In turn, the experiments and investigations students conduct become experiences that shape and modify their background knowledge.
In science education literature *models and modelling* are connected to learning. By a model is meant "a representation of an idea, object, event, process, or system". The purpose of any model in science is to simplify a phenomenon and to make an explanation of it. Consequently, models have several tasks in science education: they help pupil to learn sciences, to learn about science, the history of science and methodology and, moreover, to learn to do science. (Gilbert & Boulter, 2000). One essential purpose of science education is to help students to gain an understanding of basics of science models or knowledge as is appropriate to their needs, interests and capacities. Rogers (2006) analysed use of simulations and modelling software in science education. He claims that science teachers have embraced the use of simulation software more enthusiastically than modelling software. Some simulations are visual aids, chosen for their ability to help pupils visualise complex or abstract phenomena. Others feature virtual experiments which allow pupils to perform pseudo-laboratory activities and obtain quasi-experimental data. In both cases it is common for the software to facilitate activities which support the development of valuable skills for scientific investigation. However, Rogers (2006) argued that modelling software has even greater potential for developing these skills towards a deeper level of scientific understanding. However, many modelling software, like Stella, developed for dynamic modelling, appears to be less accessible than graphically-rich simulations.
In the end of the previous millennium, there was wide interest towards learning or *inquiry in WBLE.* The interest was not just how to share information or activate students to perform several tasks, but how to help students to share their knowledge and how students learn to improve their existing knowledge. Canadian researches Carl Bereiter and Marlene Scardamalia, founders of the *CSILE* (Computer-Supported Intentional Learning Environment) project, stressed that students should be able to participate in scientific process. With scientific process, they mean shared, progressive discourse that advances students' mutual understanding of science (Bereiter, Scardamalia, Cassells, & Hewitt, 1997). Another well known model for inquiry learning is based on a theoretical framework called "Scaffolded Knowledge Integration" developed by researchers at the University of California, Berkeley. (e.g., Linn & Songer, 1993; Linn, Eylon & Davis, 2004). In this framework, inquiry is understood as "*engaging students in the intentional process of diagnosing problems, critiquing experiments, distinguishing alternatives, planning investigations, researching conjectures, searching for information, debating with peers, seeking information from experts, and forming coherent arguments.*" (Linn, Davis & Bell 2004a, p. xvi). Several ICT tools learning platforms have been developed for inquiry in WBLE. One well known platform, developed in Berkeley is WISE, the Web-based Inquiry Science Environment (Linn & Slotta, 2000). WISE provides an Internet-based platform for science activities where students work collaboratively on inquiry projects, making use of resources drawn from the Web. In one project, for example, students design a house for the desert climate by critiquing energy efficient

house designs found on the Web, completing design worksheets, and discussing their design ideas online (Cuthbert & Slotta, 2004). The scaffolded knowledge integration framework where students participate in diverse inquiry tasks and practice productive inquiry contains four metaprinciples:

- learning should be build on student ideas and the problems should be personally relevant for the students; teacher should scaffold inquiry (making science accessible),
- learning involves modelling and evaluating how ideas are connected and sorted out to form new knowledge; teacher should scaffold students to make their thinking visible by explaining their ideas to teachers, peers, and experts; and to provide multiple representations of the phenomenon under study (making thinking visible),
- learning from others takes advantage of the collective knowledge of the classroom; teacher should scaffold students by encouraging them listening to others; by designing discussions; by highlighting cultural norms; and by employing multiple social structures,
- promotion of autonomy and lifelong learning, involves encouraging monitoring activities, and engaging students as critics of diverse scientific information that help to establish generative norms and a perspective of lifelong learning.

In both cases, nature or internet as a source of information, of inquiry or inquiry based learning there are similarities. Following characteristics of inquiry-based learning can be emphasised:

- Learning is an active process, rather than passive receiving of information. Students benefit from working on complex problems, which can be approached from different perspectives.
- Learning is co-operative process and, therefore, students should be encouraged in interaction with others working on the same problem. Language is the most important carrier of these inquiry-supporting interactions.
- Conceptual understanding takes precedence over procedural efficiency. Knowledge about how to carry out a procedure is of limited value if the students do not have an understanding of how and when to use them.
- Teacher must be sensitive to students’ previous knowledge of the phenomena under study. Some of these ideas might be a valuable for learning, but others might be unproductive.
- Learning activities occur in interesting context.
- Problems that are relevant to students' experiences outside of the school setting enable them to make connections between what they learn outside of school and in class.
- Development of metacognitive skills enables students to take responsibility for managing and monitoring their own learning activities.
- Preparing the students for lifelong learning. Formal education should make the students able to learn for the rest of their lives, meeting the demands of a rapidly changing society.

Schraw, Flowerday and Lehman (2001) review the history of research on interest and learning and summarize recent work. Based on their review and a summary presented by Mayer (2001, pp. 184-186) for multimedia or web based learning following characteristics for learning from the media can be suggested:

- *Advance organisers* are organisational cues which when opening the media, function as tools to help connecting the unknown to previously known as well as offering a framework for helping to understand what is to be learnt.
- Understanding *what is relevant to the learning task beforehand* increases interest and learning.
- *Choices* promote a greater sense of self-determination because it satisfies students' need for autonomy.
- *Well-organized media* is coherent and informationally complete.
- Texts in media are *vivid* if they contain rich imagery, suspense, provocative information that surprises the reader, and engaging themes. Illustrations can add the vividness of materials.
- *Simplified drawings* as illustrations may be better for learning than realistic photos.
- Students learn better when *illustrations and related text are close to each other* than when they are more distant.
- *Prior knowledge* is related positively to interest and deeper learning.
- Students learn better with *animation and narration* than with text, especially when reading on-screen.
- Students who *actively make meaning* learn more information at a deeper level.
- *Constant feedback* is efficient.

**Distance learning approaches**

Electronic mail, newsgroups, chat rooms, and videoconferencing can be intensively used for educational purposes (Madjidi & Hughes, 1999). They offers possibilities for learning and even electronic brainstorming and other forms of processes where social interaction is emphasized.

Email and mailing lists are the most popular Computer Mediated Communication (CMC) tools, used to exchange messages between individuals. A newsgroup allows users to read and contribute to special-interest 'newsgroups'. Computer conferencing (discussion board) enables groups of people to hold discussions by reading and posting text messages on a computer system. The advantages over mailing lists are that the messages are archived and the structure of the discussion is also recorded. Computer conferencing is widely used to support learning. Internet Relay Chat (IRC) allows users to chat 'live' (in real time) using text or audio. NSM messenger and Skybe are nowadays well known sophisticated chat tools. Through videoconferencing geographically distant people can hold discussions in real time, during which they are able to hear and see each other and share various other types of data.

All previously mentioned CMC-tools can be used several ways in science education. For example, students from a same school or from different schools can work and communicate together towards common goals in their project. It is also possible that older students supervise younger students projects through CMC tols. Students can take contact to experts in universities or industry through CMC tools.

Distance learning in natural way has evolved from using regular CMC tools and Web pages (Gordin, Gomez, Pea & Fishman, 1996).Thus distance learning solutions are based on a wide range of communication technologies like a newsgroup and a combination of Web pages. These separate CMC tools and Web pages are combined in a Learning Management Systems (LMS), like Blackboard and Moodle (Davis, 1998). Currently, several teachers are slowly looking for light distance learning tools, like Wiki and blogs, instead of LMSs. For example, a teacher can publish interesting problems through a course blog and students can create common Wiki during the science course or as a product of a project. The direction is towards learning networks (Rudd, Sutch & Facer, 2006).

LMSs, like Moodle, allows a combination of versatile CMC tools for organising course materials and establishing whole science courses. A science course in a LMS can consists of number of lessons and activities. A lesson can consist of simulations, videos, web pages and web lectures. After each lesson there can be assignments which are returned to the LMS. After the lesson there can be also group discussion or a group activity in a special workspace in the LMS. In the countries where are small school and few students in a school, neighbour schools can have a common course in the LMS and students from the separate schools can join the common course.

Science teachers are showing growing interest to previously described variation of in Web-Based Learning (WBL). Lectures notes, homework assignments, online books, and complete courses in science topics, can now be found on the Web (Berenfeld, 1996; Berge & Collins, 1998).Web-Based Learning Environments (WBLEs) offer inspiring possibilities in science teaching. Online discussions, information distribution via WBLE and the opportunity for students to learn from one another through exercises jointly treat the topics to be learned, evaluate information and learn new things. However, ICT in itself does not ensure alone help students to learn. Promoting learning by providing support to the learning process is essential to teaching. Teaching in WBLE emphasises study guidance more than ever: teachers and students may not meet in the course of the learning process, and students are expected to work more independently. Interaction in WBLE differs from that in contact teaching, presenting challenges to the teacher in charge of guidance. Well-designed teaching and educational solutions that help to achieve the learning objectives enable ICT to be used successfully to support learning and teaching. In practice, WBLEs are often used to refer to a combination of face-to-face and online learning. (Brooks, Nolan & Gallagher, 2001; Graham, 2005)

### Integrating ICT into teaching methods

Teaching methods are typically goal oriented and emphasise social interaction between pupils and between pupils and a teacher. The learning strategies are not necessarily the same as the teaching methods used, although there is some overlap, especially when there has been effective co-operative planning or pupils have studied, for example, in small co-operative groups or made concept maps (Joyce & Weil, 1996; Fairbrother, 2000, p. 7; Oser & Baeriswyl, 2001). However, teaching-learning-process in science is complex and, therefore, cannot be reduced to well designed algorithms or a string of sequences of specific teaching methods (Leach & Scott, 2000, p. 54). On the other hand, during a single lesson several different kinds of teaching methods can typically be recognised. We take a look for ICT use from the point of view of teaching methods emphasising learning in a small group, reading and writing and, moreover, practical work.

### Integration of ICT into teaching methods: learning in small groups

Research in science education suggests that communication between students is important for learning (Mildenhall & Williams, 2001). In their systematic review of small-group discussions in science education, Bennet, Lubben, Hogarth, and Campbell (2004) suggested that successful communication within a group is based on intragroup conflict (diversity of views) and external conflict that a teacher could facilitate. Basic teaching methods are small group discussion, problem-solving, and project work. Further, now and then during the lessons, pupils may learn by oneself solving problems, reading textbook or other references, or writing, for example, essays (Rivard, 1994).

Terms like "group work", "teamwork", "co-operative learning", and "collaborative teaching" are used when students work together in groups of two or more with active social interaction. Both face-to-face interaction and mediated interaction using ICT such as e-mail or an LMS can be used.. In this kind of learning, five elements Johnson and Johnson (1994), have introduced. These elements, typical in co-operative learning, are: positive interdependence of the group members, individual accountability, face-to-face interaction, development of social skills (e.g., communication, trust, leadership, decision-making, and conflict management), and assessment of collaborative efforts by the group members.

The Internet can be used for data retrieval in learning in a small group. For example jigsaw method (Sharan 1994) foster use of Internet and learning in a small group. In the jigsaw classroom the students are first divided into *4-person jigsaw groups*. The groups should be diverse in terms of gender and ability. One student is appointed from each group as the leader. Initially, this person should be the most mature student in the group. The lesson is divided into 5-6 segments. Each student are assigned to learn one segment, making sure students have direct access only to their own segment. The students should be given time to read from the Internet over their segment at least twice and become familiar with it. There is no need for them to memorize it. In the next stage *temporary "expert groups"* are formed by having one student from each jigsaw group join other students assigned to the same segment. The students in these expert groups are given time to discuss the main points of their segment and to rehearse the presentations they will make to their jigsaw group. In the next phase, the students are brought back into their jigsaw groups and asked to present her or his segment to the group. Others in the group are encouraged to ask questions for clarification. The teacher should float from group to group, observing the process. If any group is having trouble (e.g., a member is dominating or disruptive), the teacher should make an appropriate intervention. Eventually, it's best for the group leader to handle this task. Leaders can be trained by whispering an instruction on how to intervene, until the leader gets the hang of it. At the end of the session, a quiz on the material is given so that students quickly come to realize.

MBL, Microsoft Word, and Microsoft Excel can be used to analyse and report laboratory experiments in a group investigation in the co-operative classroom. Again, the jigsaw method can be used in a number of different ways. For example, students could summarise organic chemistry concepts with CmapTools, design and perform experiments using both the Internet and MBL, and co-operate with students from other schools by using E-mail or a newsgroup.

### Integration of ICT into teaching methods: reading and writing

Several types of texts, such as texts in the Internet, can be used as sources of information in science learning activities. Once readers understand the meaning of a given text, this text first activates the previous knowledge they have in mind on the subject and then initiates the learning process. This leads into constructing previous knowledge and new information to form a new combination altogether. Previous knowledge affects reading, and it is easier to understand a text that deals with a familiar topic. Moreover, contexts, topics and discussions affect interest and learning. For instance, when discussing, readers can be asked to tell what they already know about the topic and thereby design reading activities that foster learning both concepts and social skills.

Reading represents an active process in which the reader constructs new knowledge by processing the text. At the first time when glancing over a text, the reader creates the 'first interpretation' that keeps being reinterpreted on subsequent readings. Both reading and writing involve creating and modifying meanings. For instance, Tynjälä (1999) states that learning by reading, creating meanings, may be facilitated by carrying out writing exercises and discussions. Moreover, learning by reading requires distinctive cognitive activities that enable the reader to interact with the text to be read. This in turn is the only way to learn to understand a text even when the contents are very far from the reader's daily life. The exercises intended to support learning may include the following:

- activating students previous views and knowledge
- comparing students previous views and knowledge with the information featured in the text
- dissecting the views presented in the text
- applying the general principles presented in the text to imaginary practical settings
- voicing critical opinions
- writing a summary.

By memorizing texts students develop into skilled readers and writers of exam answers but these types of skills are rarely needed in further education and at work places. Thus instead on asking students to memorize texts it is more useful to guide them to manage information; critically evaluate information; apply and develop the information available and create new knowledge on the basis of this information.

Learning by reading is affected both by the reader's strategies and the text to be read. The types of problems that students encounter when reading science texts can be listed as follows (cf. Baker , 1991):

- Texts are abstract having a complicated structure of sentences and are difficult to understand.
- Texts neither encourage readers to identify new things on their own nor guide to problem solving.
- Texts start by explaining concepts and phenomena, established information.
- The number of new terms and concepts (information density) is high and introduced concepts are vaguely explained.
- Introduced concepts do not draw from the previously discussed ones.
- The information structure in texts is blurred.
- Students lack substantial previous knowledge in comparison with what understanding a particular text presupposes. The extent to which students have previous knowledge varies depending on a student.
- Students have several preconceptions on concepts and these conceptions often contradict what the text states.
- Students have never been guided to learning by reading.

During the writing process, the writer develops both as a writer and a human being. Furthermore, expressing one's ideas, even by just keeping a journal, serves an effective way of testing how convincingly one is able to argue for one's points. This in turn enables the writer to retrospectively examine the development of the thinking process. In essence, developing one's thinking entails being conscious of one's thinking process. Writing inextricably involves thinking, which secures it as a cognitive activity. It is common for writing to be a solitary activity by individuals since writing usually demands a high level of concentration. It is also a linguistic activity because the writer has to think about and be careful in selecting grammar structures and vocabulary, especially in interpreting "scientific" ideas. Overall, a teacher should consider that creating a written piece of work is a whole process which involves learners in: gathering ideas - through reading, for example; organizing ideas into sentences and paragraphs; ideas need to be put into a logical order, paragraphs need a main idea and supporting points with a few details; drafting; and editing

Rivard (1994) has pointed out several factors that are crucial when trying to develop learning by writing. These factors involve, for instance, the requirements set for the student by the writing exercise, the learning atmosphere in class and the students' metacognitive knowledge and skills. Thus such writing exercises that facilitate learning require the student to reprocess, question, interpret and synthesise issues and principles already learnt. In contrast, traditional exercises only orient students to represent previous information, copy ideas directly from a source, such as, for instance, a course book or a website.

Process writing is greatly facilitated by using modern word processing technology, when ICT facilities are available. It is not only the information sources brought available by using Internet that are important. Crucial is also the possibility to easily change, correct and rewrite, even completely restructure written text during the process. Quite often it is useful first to outline the synopsis of the text and then proceed starting from any piece of content which seems easy to produce. In modern learning environments it is also easy to organize process writing as team work.

Although writing serves as a natural way of creating meanings and viewing the world, writing tasks at school rarely motivate students. We all remember these all too familiar questions "How many pages?", "Do I have to use full sentences?", "Are bulleted lists allowed?" This apprehension to learning may also stem from how writing is equated with taking a test. The most crucial issue in bringing about the motivation for writing is to have a recipient or at least an intended recipient and the means to publish the writings. Thus the texts are created for classmates or other potential readers rather than the teacher. The publication may take the form of a school bulletin, a booklet, or a website. Furthermore, the texts may be displayed in the science class, published on an online learning environment or on the Internet. During the writing process, writers can be supported by giving them the following questions for reflection:

- What else do I know about this issue?
- Shouldn't I try to explain some concepts?
- Am I proceeding in the right direction?
- Does this take me to the conclusion that I want?
- Have I provided enough evidence to convince an ignorant reader?

**Integration of ICT into teaching methods: practical work**

Teacher demonstrations and student practical work have long been accepted as an integral part of teaching and learning science. There are various classifications of the teaching methods where experiments are essential. From the point of view of type of activity they can be classified to practical work, teacher demonstrations, class practicals, small group activities etc. (Wellington, 1998, 12).

The importance of the teaching methods in school science, where experiments are essential, is argued for (i) better acquisition of scientific knowledge, (ii) better understanding of the nature of natural sciences, and (iii) the development of working or process skills. Moreover, the student's (iv) attitudes and motivation to study science become more positive and (v) personal growth is enhanced (Wellington 1998, 6). Nevertheless, researchers do not agree on the significance of experimental methods in

physics education. For example, Watson, Prieto, & Dillon (1995) found out that extra time on practical work had little impact on student understanding. It is claimed that experiments are valuable if both students and teachers have recognised the goals for experiments (Hodson, 1990, 1996).
ICT can be used in several ways with teaching methods emphasising experiments. Most useful ICT tool is MBLs. Furthermore, basic tool applications, like Excel, can be used with experiments.

**Conclusions**

Although, we have described here several examples and some of the examples sound real success stories, it is difficult to say that certain way of use ICT in science education is more effective than another or even most effective. How effective a single ICT tool (a word processing, a single web page, a database, a web encyclopaedia, educational multimedia, MBL, simulation, etc.) is for science teaching and learning depends on properties of the tool itself. Secondly, effectiveness of a ICT tool depends on users or local characteristics, such as the pedagogical orientation of the user and his/her beliefs about the usability of the tool, and support available. Thirdly external factors such as in-service training and the curriculum and curriculum materials have an influence to the usability of the ICT tool. An "effective use of an ICT tool" is a complex concept and it can not be analysed without the knowledge of users of the tool or a context where it used.
We are living in a very rich digital world. Because of the important and integral role of digital technology in society, science teachers should also reconsider their attitude to use of ICT and other digital devices. Otherwise science teachers are supporting inequalities in individuals' ICT use or e so-called 'digital divide'. Therefore science teachers have a part to play in ensuring that all members of society are able to access the opportunities afforded by ICT use (Selwyn & Facer, 2007)
Based on previous analysis ICT use in science education can enhance practices and quality of learning in science. The potentials of ICT use in science education can be summarised as follows. Newton and Rogers (2001), Osborne and Hennessy (2003), Wellington (2003), Denby and Campbell (2005) present similar lists of ICT use potentials and present also references where more evidence about the realisation of potentials are presented. ICT use in science education can

- make learning active, constructive, contextual, co-operative, self-regulated, reflective and cumulative and engages students in tackling the topic to be learnt in such a way that they create meaningful and understandable knowledge structures on the basis of a goal of learning,
- increase interest, motivation and engagement in activitie,
- provide access to resources (web pages, texts, databases, videos, demonstrations, applets) that are of high quality and relevant to scientific learning,
- help students focusing attention on over-arching issues, increasing salience of underlying abstract concepts,
- enable visualisation and manipulation of complex models three-dimensional images and movement to enhance understanding of scientific ideas,
- supporting exploration and experimentation by providing immediate, visual feedback,
- help students to learn to use ICT or increase their digital competence,
- expedite and enhance work production and offering release from laborious manual processes and more time for thinking, discussion and interpretation,

- increase currency and scope of relevant phenomena by linking school science to contemporary science and providing access to experiences not otherwise feasible.

ICT offers also teachers opportunities to use tools applications in preparing lessons and teach science.

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## A Pan-European perspective.

*Bob Kibble and Paul O'Hara.*

**Abstract.**

*As part of a Socrates funded European research partnership questionnaires were used to sample views of science teachers concerning the extent and the value of ICT in supporting learning in science. The partner nations were: Finland, Slovakia, Poland, Spain and Scotland. In total 468 responses contributed to the study. The responses offer an indication of the breadth of provision, range of teacher skills, training needs and attitudes towards the value of ICT. Overall findings indicate a positive disposition towards the value of ICT in learning science with three quarters of teachers questioned believing that ICT can have a positive effect on learning. However our analysis reveals significant national differences in the areas of the availability of resources, disposition towards the value of ICT to support learning in science and in training needs. We believe that these differences build a strong case for continuing partnership in this area with a view to supporting and shaping science education through sharing the best use of ICT on a European stage.*

### 1. The development if ICT in educational contexts across Europe.

The increased use of ICT technologies in schools mirrors the increase in use of such technologies in society in general. Indeed one of the arguments to support a greater use of ICT in schools is to prepare learners for adult experiences as users of technology, either in leisure, business or learning contexts. All of our respondents indicated that learners were most likely to be making use of ICT at home. It is generally accepted that ICT can provide powerful tools to support learning in schools. Government initiatives to furnish schools with computers, interactive whiteboards, digital microscopes and dataloggers (MBL) are widespread across Europe but, as the following overviews from Scotland and Finland illustrate, the journey to this position has been itself a learning process for policy makers and curriculum planners.

In Scotland, as in the whole UK, a significant programme of continuing professional development (CPD) for teachers, known as the New Opportunities Fund (NOF), ran from 1999 to 2003 with the aim of making every UK teacher competent in the use of Information technology. The success of this initiative as a strategy for educational change has been questioned (Conlon, 2004), (Oldham 2003). Conlon points to a number of reasons for what he describes as a 'shocking' failure of the NOF CPD programmes which cost £230 million. Two critical elements which are relevant to our study are i. the lack of teacher access to ICT technology in their workplace on which to practice and deliver their newfound skills and ii. the unreasonably high expectations of the knowledge and skills targets which the NOF programmes aspired to achieve. Oldham, looking at the effect of NOV training in the Wirrall, and concluded that the benefits were dependent not only on the training providers selected but also on the attitude and confidence of those teachers being trained. Oldham concluded that the impact of NOF training in her local area had been 'extremely variable.'

Key lessons have to be learned from early training initiatives in ICT Scotland. They include a realisation that:

i. the provision of a training programme will itself not ensure the desired effect of changes in pedagogy.
ii. the prior skills of teachers, and the particular subject ICT requirements need to be recognised and built upon
iii. the hardware and software to enable the training to be practised needs to be available as part of the training and development initiative.
iv. the installation of new technologies without the immediate support of training in their use and application will result in underused resources, often left to gather dust and become obsolete before even being used.

There have been three official national ICT strategies in Finland. *The year 1986 strategy* stated for instance that information technology (IT) should be integrated in school work so that it helps students in their daily work and thereby supports reaching some general goals of education. The project plan emphasised that the responsibility of the school is to train students as active workers of the information society. A new optional subject, Information Technology (IT), was introduced. This subject concentrated on the skills of computer use both in comprehensive schools and in upper secondary schools. The use of different tool applications or tool software, like word processing, was emphasised. IT was treated as a set of available software enabling people to accomplish their tasks in a more efficient way. However, in many schools also elements of programming, using for example different versions of BASIC, PASCAL or LOGO, were studied. However, in practice the implementation of the project plan was pedagogically very one-sided in many schools. Teachers were not able to utilise sufficiently the new possibilities offered by the information technology.

In 1995 general national guidelines, *Education, Training and Research in the Information Society,* for ICT use in education were published in the strategy document of the Ministry of Education. The Finnish Framework Curriculum for the Comprehensive School introduced ICT as an intercurricular subject – not any more as a IT subject. It was mentioned in the curriculum that ICT should be used in teaching of all subjects based on the goals of the subject.

At the end of the 1990s there was a lot of discussion about integration of Information and Communication Technologies (ICTs) into science and science teacher education and how this integration can motivate students and teachers and improve both science teaching and learning. This integration of ICT was supposed to make science education more versatile and goal-oriented, inspire students to be more active in their own education, and promote co-operation, study in authentic contexts, and creativity in learning. Because of the huge potential for ICT in education and the problems teachers have in using it, there was a lot of discussion also in Finland concerning how to help teachers use ICT in science education. Therefore, the Finnish Ministry of Education published in the beginning of new millennium their second Strategy for Education, Training and Research in the Information Society (SETRIS, 2000), which aimed to promote the pedagogical use of ICT. Therefore, in the strategy visions how teachers' ICT competence and ICT infrastructure in all levels should be developed was described. Especially, it was described in the strategy how the use of ODL approaches can be developed as a part of science teaching. The strategy emphasised virtuality and covered

ICT at general level fusing it with technology education.

**2. Rational for this work.**

This paper explores some key messages which have emerged from a survey of science teachers across five European partners; Finland, Slovakia, Poland, Spain and Scotland. The survey forms part of a three year international collaboration into the use of ICT in science education. Funded through the Comenius II initiative, the project, EU-ISE[1], commenced in 2005. The project partners attended a Comenius partnership convention in 2003 and decided to work together on a common focus. The EU-ISE team chose to design a questionnaire which would be given to teachers of science in the five partner countries. Individual papers are being considered which look more closely at messages from within a single nation. This paper will consider comparative messages. We are aware that self report questionnaires have inherent uncertainties relating to reliability. Our data reveals sufficient internal consistency to enable us to offer secure messages from the results, aware as we are of the limitation of over generalising.

We recognise that the views of the teaching profession are important in helping to reflect on the relationship between training needs and the expectations of the technology and of the learners. Teachers will hold the key to the decisions as to when and how to employ new technologies in their lessons. The availability of technologies, technical competence and associated pedagogy will determine just how teachers manage learning through ICT. We therefore wanted the fruits of our European collaboration to be informed by practising teachers. A questionnaire has enabled us to sample the opinions of large numbers of teachers working in schools across Europe. The design of our questionnaire enabled us to investigate several dimensions of the ICT – schools landscape. These dimensions can be articulated through the following research questions:

- What are the attitudes towards the use of ICT in science teaching?
- What is the pattern of provision of ICT resources in schools?
- How are teachers using ICT resources to support learning?
- What messages might be given to teacher trainers about how best to prepare and support teachers in the best use of ICT?

One dimension of the EU-ISE project was a commitment to review what is seen as ‘best practice’ across Europe and then to devise and deliver training activities to teachers and trainee teachers. These activities would be informed by the research outcomes. The questionnaire has therefore become a pivotal component in our research methodology.

In 2005/2006 each partner country issued questionnaires to teachers in their own country. Some were sent by post, others used an electronic response system. A sample of schools and teachers was used to represent a broad range of types of school. The sample included both independent and state funded schools. This paper is based on the data contained in 468 returns (Scotland 70, Finland 101, Slovakia 73, Spain 127, Poland 97.)

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[1] EU-ISE project code:226383-CP-1-2005-ISKCOMENIUS-C21

**3. Data processing of raw scores to create a positive index.**

The questionnaire collected data which would be used as independent variables. We were interested in national location, age and gender of respondents as well as their subject affiliation and type of school. Other data explored responses to a large number of statements (items) regarding ICT and its value in enhancing science education. Most items used a four point Likert scale with the high score , 4, being the 'strongly agree' response although item 12 offered only three choices, with a '3' being 'strongly agree'. We decided that for almost all items, the high scores were synonymous with what we refer to as a 'positive disposition' towards the use and value of ICT in science education. For example, item 9.22 'ICT helps teachers to deliver the school curriculum'. A score of 4 on this item reflected a positive disposition towards the use of ICT.

(Three items, 9.2, 9.4, 9.19 were worded such that a positive disposition was synonymous with a 'disagree', score = 1 response. For example item 9.19 'ICT disturbs the learning process'. For such items we reversed the scoring so that positive disposition equated with high scores in keeping with the remainder of the questionnaire.Inspection of a sample of respondents showed that those with generally high positive disposition on other items did indeed chose to score these three 'negative' items with low scores.)

Raw Likert scores, 1 to 4, or 1 to 3 were mapped to a 100 point scale. The 4 Likert points mapping as: 1 = 0, 2 = 33, 3 = 67 and 4 = 100 on the new scale. The three Likert points mapping as 1=0, 2 = 50 and 3 = 100. On the resulting 0 – 100 scale, each item secures a score which we will call a '**positive disposition index'** for that item. For each respondent, their responses, on the 0-100 scale, for each item can be averaged to offer a personal positive disposition index. The independent variables allow us to consider these personal indices grouped by partner country. Table 1 serves to illustrate the result of this mapping analysis (fabricated data)

| | Item 9.x | Item 9.y | Item 9.z | etc | | | | Mean personal positive disposition index |
|---|---|---|---|---|---|---|---|---|
| Teacher A | 0 | 67 | 33 | etc | | | | 50 |
| Teacher B | 33 | 100 | 67 | etc | | | | 65 |
| Teacher C | 100 | 100 | 67 | etc | | | | 78 |
| etc | etc | etc | etc | | | | | |
| | | | | | | | | |
| Mean positive disposition index | 45 | 80 | 60 | | | | | |

Table 1. An illustration of how positive disposition indices relate to respondents (read across) and to items (read down).

In this example teacher C might be described as having a positive disposition towards ICT in science. They are likely to see the value of ICT in supporting learners more than teacher A. Item 9.y seems to have a strong mean positive disposition index suggesting that it has a significant contribution to make in the story of ICT in science education. It is by using the disposition indices that we have been able to offer some significant messages concerning the availability, use and training needs associated with ICT across partner countries.

The following analysis explores how such independent variables as partner country, subject and gender relate to attitudes and use of ICT in science.

## 4. Data Analysis.

### 4.1 The general disposition towards ICT in science education.

Our first analysis was to rank all 468 respondents by 'personal positive disposition' towards ICT in science education. The range of scores went from the most 'positive' individual with a score of 85.5, a female from Spain, to the least positive, a female from Poland with a score of 17. Individual scores however are not of interest. What was interesting was that, of the top 10% of our sample, i.e. the 46 teachers most positively disposed towards ICT in science education, only two were from Finland whereas 13 were from Scotland. Table 1 shows the top and bottom 10% in terms of national background.

| Country | No within 10% of most positive respondents. | No within 10% of most negative respondents. |
|---|---|---|
| Finland | 2 | 19 |
| Slovakia | 5 | 4 |
| Spain | 12 | 4 |
| Poland | 12 | 7 |
| Scotland | 13 | 1 |

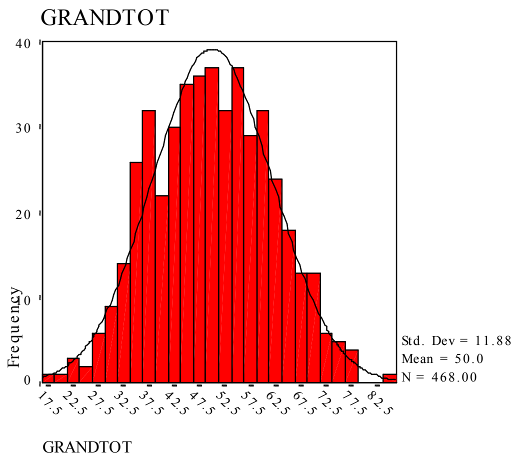
Table 2. Number of respondents within the 10% extremes of most positive and least positive. ICT disposition.

Table 2 reveals an interesting and unexpected range of attitudes. It is clear that teachers in Finland are least well disposed towards the value of ICT in science teaching. Teachers in Scotland seem to be disposed towards the value of ICT. The population as a whole offered us a bell shaped curve with mean value 50.0% thereby indicating that across our five partner nations there was no overall bias in disposition towards or against ICT in science education. The mean values for each partner country however, see table 3, serve to underline significant national differences.

| Country | Mean value of 'positive disposition' index. |
|---|---|
| Scotland | 56% |
| Poland | 52% |
| Spain | 50% |
| Slovakia | 48% |
| Finland | 44% |

Table 3. Mean 'positive disposition' index scores across all participants in any particular country.

Fig 3.a The symmetry of the whole cohort curve indicates that our sample overall displayed no bias in ‘disposition’ towards ICT.




**4.2 ‘Positive disposition index’ – analysis by country.**

The mean positive disposition scores by country were calculated for each item on the questionnaire. An inspection of these scores reveals several items where a significant difference has emerged between partner countries. Tables 4 to 7 offer extracted data to illustrate those questions where disposition scores appear significantly different across countries. Each table relates to one of the question sets. We have offered specific

| | Mean for all partners | Mean for Scotland | Mean for Poland | Mean for Spain | Mean for Slovakia | Mean for Finland |
|---|---|---|---|---|---|---|
| 9.05 Have the skills | 69 | 78 | ***79*** | 70 | 62 | ***58*** |
| 9.04 Don’t have the time | 67 | ***75*** | 70 | ***55*** | 65 | 74 |
| 9.23 Need to buy more ICT | 63 | 64 | ***76*** | ***48*** | ***76*** | 59 |
| 9.24 Management expects ICT in use. | 62 | ***83*** | ***53*** | 59 | ***53*** | 66 |
| 9.22 ICT helps to deliver the curriculum | 62 | ***76*** | 70 | ***48*** | 58 | 64 |

commentary following each table.

Table 4. Significant national differences relating to question 9 items (attitude towards ICT)

Commentary.

In table 4, item 9.05 has revealed a message about training of teachers. It appears that in Finland teachers see themselves as needing more training that those in other counties. Perhaps there is a national message for Finland here. Teachers in Spain seem to have sufficient ICT resources but need more time to make use of them. The story in Slovakia and Poland appears to be the opposite in that there is a need to secure more equipment but currently not a desperate need for time to use it. However these two issues are related, the more equipment there is available the greater the expectation that this is used and hence perhaps the feeling of time pressure through this expectation. Is there a message from Spain that, despite there being ICT equipment available it is not being used effectively to deliver the curriculum?

### 4.3 Access to ICT.

Question 10 included items which explored the extent to which ICT facilities were accessible to teachers and learners.

| | Mean for all partners | Mean for Scotland | Mean for Poland | Mean for Spain | Mean for Slovakia | Mean for Finland |
|---|---|---|---|---|---|---|
| 10.01 Have only one or some computers | 60 | ***79*** | 55 | ***48*** | 52 | 74 |
| 10.09 Have data projector and screen | 56 | ***80*** | 56 | 50 | 52 | 51 |
| 10.02 Almost enough computers | 32 | 40 | 33 | ***42*** | 24 | ***19*** |
| 10.05 Enough MBL | 27 | 36 | 22 | 41 | *7* | 21 |
| 10.06 Access to interactive whiteboard | 12 | ***40*** | 3 | 4 | 9 | 12 |
| 10.08 Access to digital microscope | 26 | 50 | ***4*** | ***54*** | 6 | 7 |

Commentary.

The availability of computers is an issue. Scotland and Finland appear to have access to at least one computer per room but in Spain, Slovakia and Poland ICT facilities are yet to be seen as adequate. No country assesses there to be sufficient computers. Digital microscopes and interactive whiteboards are relatively recent additions to the resource catalogue for schools. It is clear that the provision and use of these two technologies varies significantly across Europe. Behind this data lies a message about purchasing of equipment. Both Interactive whiteboards and digital microscopes require the availability of a computer. It is therefore unlikely that such equipment will be purchased before computers are in place. The sequential acquisition of equipment appears to determine the use of new technologies with sufficient computers being the priority target for funding followed by peripheral attachments such as digital microscopes and interactive whiteboards. It is worth noting that a projection system is required for interactive whiteboards, placing even greater demand on financial resources in order to establish this technology. Where funds are limited and where equipment is scarce, it is unlikely that expensive technologies such as interactive whiteboards will become established.

### 4.4 Frequency of use of ICT dimensions.

Question 11 invited respondents to assess the frequency with which they made use of different aspects of ICT.

| Summary of question 11 items | Mean for all partners | Mean for Scotland | Mean for Poland | Mean for Spain | Mean for Slovakia | Mean for Finland |
|---|---|---|---|---|---|---|
| 11.03 Use powerpoint/graphics | 53 | ***69*** | 59 | 51 | 65 | ***31*** |
| 11.02 Use of spreadsheets | 42 | 48 | 45 | 41 | ***61*** | ***23*** |
| 11.06 Interactive whiteboard | 11 | ***44*** | 2 | 2 | 4 | 6 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 11.20 Use software packages. | 40 | ***59*** | 44 | 40 | ***29*** | 31 |

Table 5. significant national differences relating to question 11 items (frequency of use of ICT)

Teachers make use of a variety of learning resources of which ICT is an option. It is not surprising that ICT appears to be used only a few times each year for many teachers. The results indicate that in most partner countries, apart from Finland, there is frequent use of powerpoint and graphics software. It appears that Scotland is a significant leader in interactive whiteboard use.

### 4.4 Perceived training needs.

Question 12 explored the degree to which specific training could be identified as a priority.

| | Mean for all partners | Mean for Scotland | Mean for Poland | Mean for Spain | Mean for Slovakia | Mean for Finland |
|---|---|---|---|---|---|---|
| 12.01 Don't need training on internet use. | 81 | ***95*** | ***67*** | 82 | 93 | 76 |
| 12.06 Have access to software packages | 56 | ***74*** | 60 | 58 | 59 | ***36*** |
| 12.04 Don't need training on digital camera/video | 51 | ***68*** | 52 | 60 | 40 | ***34*** |
| 12.02 Don't need training for datalogging | 41 | ***52*** | 47 | 49 | 29 | ***25*** |

Table 6. significant national differences relating to question 12 items (ICT training needs)

Commentary.

It appears that training needs are significant in most areas of ICT use, perhaps apart from the internet. The need for training is less urgent in Scotland but certainly appears to be needed in Finland. The emergence of new technologies brings with it the need for specific training. The internet made an early appearance in classrooms and it is not surprising that at the time of this study training on the use of the internet is seen as a low priority. Home use will also contribute to teacher confidence. The Future Learning and Teaching initiative in Scotland (2004) has revealed that, although internet skills *per se* appear well founded, there is need for training in the pedagogy of internet use. There is a significant difference between managing one's own personal internet engagement and the planning and management of internet as a learning resource.

### 4.5. Self assessment of teacher competence.

Finally we invited teachers to assess their own competence towards ICT.

| | Mean for all five partners | Mean for Scotland | Mean for Poland | Mean for Spain | Mean for Slovakia | Mean for Finland |
|---|---|---|---|---|---|---|
| 7. Evaluation of personal competence | 61 | 71 | ***74*** | 68 | 64 | ***32*** |

Table 7. Significant national differences relating to question 7 items (competence rating)

Commentary.
It is clear that the response from Finland is significantly lower than for all other partners. Finish teachers appear to have a low self assessment of their ICT competency. Behind this result may lie a real need to update and train teachers in new technologies. However is there evidence here of a cultural trait – a tendency to be self-effacing? Perhaps teachers in Finland don't recognise the skills they have. The message from the overall index of positive disposition suggests that there is a real issue emerging in Finland. Item scores for access and availability of ICT in Finland are generally lower than the mean for our partnership group and the results indicate that, apart from use of the Internet, there is a perceived need for training in most other aspects of ICT

**5. Summary.**
This project has offered messages which have the potential to influence ICT policy and practice not only across partner nations but across Europe. The process of collaboration, with the support of a Commenius 2 programme, has also been influential in particular through bringing teacher educators together to share best practice and ideas. The survey of teachers has revealed the following key messages:

i. The value of ICT in support of learning in science is not universally appreciated or agreed.
ii. There is significant variation among European member states in the degree of use and confidence to use ICT to support learning in science.
iii. The availability of ICT resources is no doubt on the increase. The study reveals a significant variation in the type of technology available to learners in science across partner nations.

Within this data reside messages for individual partner nations. Acting on these messages has been a feature of the joint project. A particular outcome has been the link between these research findings and the implementation of training programmes by partners. Within this publication are articles outlining specific national responses to training needs. They are not necessarily the same responses as the needs of partner nations varies. It has been instructive to share approaches and compare what is happening in schools across Europe. In one sense the questionnaire has been only one piece of a larger picture but it has been a unifying piece which serves to link the other components.

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## A Professional Development Project for Developing the use of ICT in Science Education in Finland

*Jari Lavonen, Annika Ampuja*

**Abstract**

*In the article use of Information and Communication Technology (ICT) in science education and a Professional Development (PD) project which introduced a versatile ICT use to Finnish science teachers is analysed and discussed. Moreover, teaching and learning in the context of ICT use in science education is described and analysed based on the reports written by the teachers participating the PD-project. Examples of integration of ICT use to Science education, described in the article, have been developed in the Finnish sub-project of the EU- ISE –Effective use of ICT in Science Education.*

### Introduction

The integration of Information and Communication Technology (ICT) into science education can motivate students and teachers and improve the quality of both Science teaching and learning. This is because ICT can make Science education more versatile and goal-oriented, inspire students to be more active in their own education, and promote co-operation, study in authentic contexts, and creativity in learning (Knezek & Christensen, 2002; Osborne & Hennessy, 2003; Hayes, 2007; Hennessy et al., 2007). However, according to an OECD (2004, pp. 91-95) survey, the use of ICT in education in most countries, regardless of subject, concentrates on sporadic and mechanical information retrieval from the Internet. Only a minority of teachers regularly use standard tool applications.

Because of the huge potential for ICT in education and the problems teachers have in using it, there has been a lot of discussion around the world concerning how to help teachers use ICT in science education. The project *EuISE –Effective use of ICT in Science Education* was started in 2005 with the aim to promote the pedagogical use of ICT in science education. However, it is not easy to help science teachers to develop versatile use of ICT in education. Many science teachers feel themselves insecure to use ICT in education. ICT can not be simply added to teaching and learning activities, because the goals and the way of teaching and learning science will change when ICT is used in education. Instead of making routines with ICT, the students should be lead to active learning and collaboration. Consequently, it can not be assumed that the use of ICT transforms science education in all cases better. Osborne and Hennessy (2003) emphasise role of the teacher, in creating the conditions for ICT use and for selecting and evaluating appropriate ICT tools, and, moreover, in designing teaching and learning activities. Consequently, organising an effective professional development programme or in-service training for the development of ICT in science education is not an easy task.

In this chapter, a professional development programme and development of support material for teachers of the Finnish sub-project of the *EuISE* are described. Over the three-year period of the sub-project, altogether 16 meetings with teachers from 3 schools within a Professional Development (PD) project were organised. Moreover, 21 one day in-service training courses were organised in different cities of Finland. The main aim of the in-service training was to emphasise use of ICT and Microcomputer Based Laboratories (MBLs) (in UK data-logging) in Science education. Within the PD project and in-service training self-evaluation reports were gathered from the participating teachers. Activities of Finnish *EuISE* are discussed based on the PD project data.

## Professional development programme of the Finnish EuISE project

The Finnish PD-project of the *EuISE*, was active over three years and in average 8 teachers participated the meetings. The teachers had an average of 25 years teaching experience. During the meetings the teachers become familiar with use of ICT and MBLs in science education, planned teaching experiments, reported the experiments and evaluated them. The developed teaching and learning activities were videotaped in real classroom situations and published in the Internet for local use. English sub-titles were added to the some of the videotapes[2]. The videos demonstrate effective ICT use in science education from the point of view of Finnsh perspective. A special web-page[3] was also developed which helps teachers to integate MBL to science education. These developed activities were introduced to Finnish teachers through 21 one day in-service training courses, organised in different cities of Finland.

The aim of the PD-project was to support the co-operation of teachers, to share knowledge and experiences with ICT use in Science education, present teaching practices, and plan and arrange small teaching experiments in their classrooms and evaluate them (cf. Solomon & Tresman, 1999). When teachers talk in small groups, they inspect, evaluate, and share their previous experience and knowledge about ICT use and learn from that experience (Eraut, 1994). Consequently, the PD-project activities were on two different levels: between teachers during face-to-face meetings, and between teachers and students in the classrooms.

The teachers applied their new pedagogical knowledge and skills considering use of ICT in real-life school contexts. Joyce and Showers (1995) argue that effective in-service education should consist of theory (lectures), demonstrations, practice, feedback and co-operative and reflective work or coaching of teachers at their schools.

In the next two subchapters it is described in detail how ICT use in Science education and integration of ICT to teaching methods were discussed with the teachers within the Finnish PD project.

## Roles of ICT use in Science education

ICT use in science education was classified in the Finnish sub-project of the *EuISE* into (A) *tool applications (use of tool software)* and (B) *ICT use in learning (learning through ICT)* (Webb, 2002; Lavonen, Juuti, Aksela & Meisalo, 2006). In the *tool category* (A), ICT is treated as a set of available software enabling students to accomplish their tasks in an effective way. To this category belongs for example the use

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http://kraken.it.helsinki.fi/ramgen/Content1/HY/SOKLA/LUOVI/sateily_verkko_oppimateriaalin_kaytto_peruskoulussa_entxt.rm
http://kraken.it.helsinki.fi/ramgen/Content1/HY/SOKLA/LUOVI/liikkeen_tutkiminen_videokameralla_lukion_fysiikassa_entxt.rm

3 http://www.edu.helsinki.fi/malu/kirjasto/mittausautomaatio/

of word processing and spreadsheets in science learning activities. A teacher can use a Power Point presentation or a whiteboard when he or she explains a science model. Furthermore, databases, spreadsheets, graphing tools and modelling environments can be used as tools in science education.

The main uses of *ICT in learning* (B) can be divided into three different categories for directly supported learning: (B1) *Computer-assisted learning (CAL)* is any interaction between a student and a computer system designed to help the student learn. A student can, for example, learn with an interactive educational software.

(B2) *Computer-assisted research* is the use of ICT as an aid in collecting information and data from various sources to support scientific reasoning (McFarlane & Sakellariou, 2002). Typically ICT is used as an agent for interaction with the information source (nature or written source), like the Internet or a Microcomputer-Based (school) Laboratory (MBL)[4] (Wiesenmayer & Koul, 1998; Lavonen, Juuti, Aksela & Meisalo, 2006). Concept and mind mapping ICT tools can support the developing of network presentations and thus in inquiry oriented learning. Cmap Tools[5] is one free software which is very suitable for making concept or mind maps based on our in-service training activities.

Microcomputer-Based Laboratory (MBL) tool is a combination of the hardware and software that are used for collecting data (data acquisition) using sensors/probes (such as temperature or pH sensors) connected to a microcomputer through an interface. These collected data can be analysed and displayed in graphic form, in real or delayed time. After the measurement a curve can be fitted to the data or the axes can be renamed (Lavonen, Aksela, Juuti, & Meisalo, 2003).

Electronic mail, newsgroups, chat rooms, blogs, Wiki, and videoconferencing are used for educational purposes in the (B3) *distance learning approaches*. For example a newsgroup can be used for facilitating students' homework. The whole course can be managed through a Learning Management Systems (e.g., Moodle or Blackboard).

Previous classification was done from the point of view of ICT use – not from the point of view of a single software or ICT tool (look a description of ICT tools in science education by Denby & Campbell, 2005). For example Microcomputer-Based (school) Laboratories (MBLs) can be used as tools and also in a Computer-assisted inquiry project. In the tool category MBL is a tool for data capture, processing and interpretation. Educational Multimedia software can be used for single simulation of a processes or carrying out 'virtual experiments'. First example belongs to *CAL* category and the previous one to the *computer-assisted inquiry* category.

In several situations, not only a computer and software are used in science teaching and learning, but digital equipment is connected to the computer and used. When a digital recording is made, a microphone, digital camera, web cam, computer-controlled microscope or a video camera is connected to the computer. A video or LCD projector is an example of computer projection technology. Microcomputer-Based Laboratory (MBL) tool is a combination of the Interface, sensor and a software. Moreover, scanners and printers are used as tools in science education. Mobile technology and portable MBL tools offer totally new possibilities for science education.

## Integrating of ICT to teaching methods

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[4] The MBL package is a set of mutually compatible MBL tools (usually with a marketing name such as 'Vernier', 'LabQuest' or 'COACH

[5] CmapTools can be downloaded from the website of IHMC, A University Affilitated Research Institute of the University of West Florida http://cmap.ihmc.us/download/. More information about the product, including examples of its use can be found on the website at http://cmap.ihmc.us/

It was discussed widely how use of ICT could be integrated to teaching methods during the PD project (Ruthven & Winterbottom, 2007). Definition of a teaching method in the context of the PD project includes the idea of goal orientation and social interaction between students and between students and a teacher. A learning strategy is not necessarily the same as the teaching method, although there is overlap, especially when there has been an effective co-operative planning or students have studied, for example, in small co-operative groups or made concept maps (Joyce & Weil, 1996; Fairbrother, 2000, p. 7; Oser & Baeriswyl, 2001). However, teaching-learning-process in Science is complex and, therefore, cannot be reduced to well designed algorithms or a string of sequences of specific teaching methods (Leach & Scott, 2000, p. 54). On the other hand, during a single lesson several different kinds of teaching methods can typically be recognised.

Research in science education suggests that communication between students is important for learning (Mildenhall & Williams, 2001). In their systematic review of small-group discussions in science education, Bennet, Lubben, Hogarth, and Campbell (2004) suggested that successful communication within a group is based on intragroup conflict (diversity of views) and external conflict that a teacher could facilitate. Basic teaching methods are small group discussion, problem-solving, and project work. Further, now and then during the lessons, students may learn by oneself solving problems, reading textbook or other references, or writing, for example, essays (Rivard, 1994).

Demonstrations and practical work have long been accepted as an integral part of teaching and learning science (Duit & Confrey, 1996, pp. 86–87). Classification of the teaching methods where experiments are essential varies. For example from the point of view of type of activity they can be classified to practical work, teacher demonstrations, class practicals, small group activities, inquiry activities etc. (Wellington, 1998, p. 12).

Referring to Bransford, Brown and Cocking (2000, 31) a person who has developed an expertise in a particular area of knowledge is able to think effectively about problems in that area. Therefore, a teacher should help students to develop expertise by choosing an appropriate teaching method, like concept mapping. A concept map is two dimensional, hierarchical, node-link representations that depict the major concepts found in domain knowledge. The concepts are linked by lines and those links are labelled with connecting words that explain the nature of link (Mintzes & Wandersee, 1989, 69; Trowbridge & Wandersee, 1989, 115-123).

## Integration of ICT into learning in a small group

Terms like "group work", "teamwork", "co-operative learning", and "collaborative teaching" are used when students work together in groups of two or more with active social interaction. Both face-to-face interaction and mediated interaction using ICT such as e-mail or an LMS can be used. Although, we mainly use here the terminology introduced by Sharan (1994) in his *Handbook of Cooperative Learning Methods* all ideas can be used in *learning in a small group.* In this kind of learning, ideas of Johnson and Johnson (1994) about co-operative learning situations and the five elements typical in co-operative learning is appropriate to emphasise in small group learning. These elements are: positive interdependence of the group members, individual accountability, face-to-face interaction, development of social skills (e.g., communication, trust, leadership, decision-making, and conflict management), and assessment of collaborative efforts by the group members.

In the PD-project, organised during *EuISE,* the teachers were encouraged to follow the ideas of co-operative learning when using ICT in science teaching. The Internet can be used for data retrieval in the jigsaw method; for example, to find more information about different topics or on experiments. MBL, Microsoft Word, and Microsoft Excel can be used to analyse and report laboratory experiments in a group investigation in the co-operative classroom. Especially, the jigsaw method could be used in a number of different ways. For example, students could organise concepts of a specific area in a small group with CmapTools, design and perform experiments using both the Internet and MBL, and co-operate with students from other schools by using E-mail or a newsgroup. Within the PD project, the teachers were asked to write a summary describing the small group activities emphasising ICT use and organised at school with the students.

### Integration of ICT into teaching methods emphasising reading and writing

In the beginning of the Finnish PD-project of the *EuISE*, one of the main aims was to foster the ability of science teachers to guide their students to utilise the Internet, to write analytically, to improve students' reasoning ability, and to enhance their knowledge and interest in science. While developing this ability it was discussed that students should not copy the information directly from its source or leave it unprocessed, but acquire information a number of sources and develop skills to outline, plan, draft, revise, and edit writing. Therefore, we concentrated on teaching methods that would help students to express their own ideas, criticise and challenge the views of others, and reflect, through discussion, on changes in conceptual understanding that have occurred (Hodson, 1998, 34-43).

Within the meetings, several different teaching methods where reading and writing was essential were introduced to the teachers, discussed with them and applied in the classroom. Some examples of these methods were different techniques of note-taking and structuring information (e.g., concept maps), co-operative or reciprocal reading, process writing, and writing poems (for more on these, see Bentley and Watts, 1989; Lavonen, Juuti & Meisalo, 2007). Within the PD project, the teachers were asked to write a summary describing the reading and writing activities emphasising ICT use.

### Learning by science inquiry and ICT use

Inquiry-based or oriented science instruction has been characterised in a variety of ways over the years (DeBoer, 1991; Andersson, 2007) and promoted from a variety of perspectives. Some have emphasised the active nature of student involvement, associating inquiry with "hands-on" learning and experiential or activity-based instruction. Others have linked inquiry with a discovery approach or with the development of process skills associated with "the scientific method." In this chapter, a short description is given what is meant by science inquiry activity.

In a science inquiry activity, students typically in small groups, begin with a question, design an investigation, gather evidence, formulate an answer to the original question, and communicate the investigative process and results. In partial inquiries, which are also science inquiry activities, the students develop abilities and understanding about the selected aspects of the inquiry process. Students might, for instance, describe how they would design an investigation, develop explanations based on scientific information and evidence provided through a classroom activity, or recognize and analyze several alternative explanations for a natural phenomenon presented in a teacher-led demonstration. Experiences in which students engage in scientific investigations provide the background for developing an understanding of the nature of scientific inquiry, and will also provide a foundation for appreciating the history of science described in this standard. Students should understand that background knowledge and theories guide the design of investigations, the types of observations made, and the interpretations of data. In turn, the experiments and investigations students conduct become experiences that shape and modify their background knowledge.

In the end of the previous millennium, there was wide interest towards learning or *inquiry in Web Based Learning Environments (WBLE)*. This is also an example of a *science inquiry* activity. In this framework, inquiry is understood as "*engaging students in the intentional process of diagnosing problems, critiquing experiments, distinguishing alternatives, planning investigations, researching conjectures, searching for information, debating with peers, seeking information from experts, and forming coherent arguments*." (Linn, Davis & Bell 2004a, p. xvi).

In both cases, nature or internet as a source of information, of inquiry or inquiry based learning there are similarities. In both cases learning is an active and co-operative process and, therefore, students should be encouraged in interaction with others working on the same complex problem. Language is the most important carrier of these inquiry-supporting interactions. During the inquiry activity a teacher should be sensitive to students' previous knowledge of the phenomena under study. Some of the students' ideas might be a valuable for learning, but others might be unproductive. Problems that are relevant to students' experiences outside of the school setting enable them to make connections between what they learn outside of school and in class.

Third aim of the Finnish PD-project of the *EuISE*, was development of use of Microcomputer-Based Lab (MBL) tools to support science inquiry activities. The aim was, especially, to develop use of MBL in data acquisition and data processing in laboratory. Science inquiry is of course very similar with or without MBL tools. Within the PD project, the teachers were asked to write a summary describing the MBL use with the students.

**Teachers experiences of using ICT in Science education**

During the PD-project, teachers' experiences were discussed within the meetings. During the meetings also the video clips, videotaped in real classroom situations, were watched and discussed. During the meetings a memorandum was written. Moreover, the participating teachers wrote reports based on their experiences. These experiences are discussed next.

**Experiences of small group activities**

The teachers, participating the PD-project, had a number of positive experiences with the jigsaw method. Some comments were: "*Students taught well other students*", "*It provided an opportunity especially for quiet students to be active and to get support from other students*", "*The students took seriously their teaching to their mates*." and "*It was an easy method for teachers after a good preparation*." However, the teachers had some problems. They found that the learning method had to be presented very clearly before starting, the different roles (leader, secretary, …) were essential to take care of timetable and different duties, and students needed support for their new roles.

Various ICT tools were used within the small group activities. For example, when students studied the movement of pendulums and optical lenses, they used Excel spreadsheets. The students searched for information on nuclear energy in the WBLE and wrote summaries within a nuclear energy project. The teachers found Moodle LMS within a small group activity particularly interesting. "*It provides new opportunities for*

*teachers and students to study physics.*" Common products were especially useful. However, it took time to learn to use the new learning environment. Teachers found it necessary to spend plenty of time teaching its use and encouraging students to use it. Teachers also facilitated the sharing of student ICT expertise during lessons. The students who had learnt to use programs like CmapTools, PowerPoint or LMS during their computing science classes were like mentors to other students.
One special type of co-operative learning method learned during the *EuISE* training were use of simulations or Java applets/physlets (Christian & Belloni, 2001) in small-group activities. These were most often used in the explanation or interpretation of processes in nature or in technological environments (McFarlane & Sakellariou 2002).
As a summary teachers found ICT useful for co-operative science learning. Some of their comments included: "*It has supported the teaching of the topic*", "*The students were very interested in it*", "*The students had lively discussions*", "*Everyone succeeded in their tasks*", "*The students were provided with an opportunity to get different views on a number of topics*", and "*I have also learnt something new*". The main problems lay in the huge amount of information available on the Internet and the timetable: how could one find enough time for working? The teachers found it useful to check student ICT skill levels before the task, in order to teach or have others assist in the teaching of ICT skills so they could actually complete the task. On the whole, the students found working with ICT interesting and useful. They made comments such as: "*When we learn to work like this, it could be easier to study later on*", "*Everything succeeded well, the work was interesting and fun and quite easy*", "*We liked the task because it provided an opportunity to use computers in a meaningful way.*" However, sometimes working in small groups was very demanding when compared with normal teaching. The role of the teacher became essentially facilitating support to ICT use. Moreover, the role of a teacher was important in facilitating successful communication and intragroup conflict (diversity of views) within a group (Bennet, Lubben, Hogarth & Campbell, 2004).

**Experiences of reading and writing activities**

Teachers organised several teaching experiments in which students in small groups used prewritten texts, then drafted, revised, edited, and published a paper together. Teachers emphasised the process of creating writing rather than the end product (White and Arndt, 1991). Some of the themes selected were: the greenhouse effect, radiation in society, kinetic gas theory. Students were required to explain their observations with models, and utilise textbooks, encyclopaedias, newspapers, electronic databases, and the Internet as information sources. The teachers' general opinion was that their process-oriented approach helped students to plan their writing, generate ideas, and encapsulate diverse ideas. Drafting and revising helped students to analyse and structure the information available and prevented them from just copying the text from written sources or from the Internet using copy-and-paste. The teachers clearly stated how their process-oriented approach activated and motivated students: "*Students were enthusiastic*", "*They were more interested in science than before*", "*All students were active*", and "*Even shy students demonstrated creative behaviour*". Based on the products of their work, the teachers thought that it was difficult for students to check the veracity of their information, especially if their source was on the Internet. One teacher described this problem: "*The students were eager to find information very quickly. They did not refine their search – they were happy if they found something*". On the other hand, this process-oriented approach helped students avoid copying. Some problems connected with process writing were linked with the heterogeneity of the learning groups: "*Students' ICT skills varied a lot*", "*Not all students liked to reread* *their own work and share it with a small group of students or receive feedback from their peers*".

All teachers asked their students to read different sources of information, like the Internet. The teachers guided their students through activities typical of reciprocal teaching (Palincsar & Brown, 1984). One teacher wrote: "*I always emphasise activities supporting reading for understanding*". Students were required to check their understanding of the information available. They did this by such exercises as generating questions, summarising, graphical network presentations, and discussions with their peers. The teachers also used these techniques to develop comprehension skills with expository readings: the teacher and students took turns in leading a dialogue concerning sections of text.

One view to learning through reading and writing activities in the PD project was use of concept maps. Concept maps have been used in Science education in Finland since 1990s when several science textbooks introduced the concept map technique for science learning. Consequently the idea and use of concept map was not new for teachers participating the PD project. However, the new ICT tool, CmapTools, was new for the teachers. CmapTools was used in a several ways in the activities, organised by the teachers, like in outlining and structuring the information. One teacher wrote in her rapport about use of CmapoTools in learning use of radiation: "*I first introduced the CmapTools to the students through structuring seven familiar concepts about structure of the matter together. Simultaneously, I help students to remember, how concepts were connected in a concept map with links and how links were named and, moreover, how the ICT tool is used. I emphasise also the new possibilities to connect web-pages and other resources to the map. After about 20 min introduction I introduced the new topic, use of radiation, discussed about the goals of the activity and possible outcomes. The students work actively in small groups with the topic and build up different maps. The maps were presented to other groups, discussed and evaluated. In the evaluation discussion both, the content and structure of the map was discussed*."

The teachers were surprised by the influence of the different activities emphasising reading and writing in learning science. They were happy about the variation in activities: some were suitable for individuals and some for learning in small groups. It was also possible to adopt most activities as an essential part of working with an LMS, or to combine activities with different learning settings in a unique way. Some of the activities were creative. For example, upper-secondary school students guided an environmental project from primary school students through an LMS. Examples of writing activities were: to edit and write a booklet, such as a radiation-protection guide, or a guide for using an applet, or instructions for performing an experiment in the school laboratory.

Through the teaching experiments, the teachers noticed that in general, their students had a rather limited ability to write non-fiction and to understand what they had read. One teacher described her experiences in this way: "*The most valuable benefit of the training is that the newly-developed activities have increased the number of teaching methods and evaluation methods available to science education, and these methods can be used in a variety of ways*". On the other hand, the teachers were worried about how time-consuming process writing was, and how many documents had to be read and evaluated. Some were concerned about the copy–and-paste approach in working with the Internet: "*I have to be careful all the time to prevent copying text directly from the Internet without thinking themselves*". It was important to guide students to think for themselves, to work with what information was available, and to check the reliability of the information from different sources.

As a summary, common for all activities activating reading and writing was collaboration and process orientation. The students first become familiar with their own thoughts dealing with the activity and then the topic of the activity. This kind of constructivist view on is supporting learning. The collaboration facilitates the discussion, re-structuring or working with the theme and evaluation of the output.

**Experiences of use of MBL in Science inquiry**

The PD-project teachers organised several science inquiry projects emphasising MBL use. Teachers used MBL in various inquiry activities where the students in small groups begin with a question, design an investigation, gather evidence, formulate an answer to the original question, and communicate the investigative process and results. Teachers' have integrated MBL also to partial inquiries where the students develop abilities and understanding about the selected aspects of the inquiry process. The teachers were more frequently asking their students during a teacher led demonstration for example: "*How can I investigate this phenomena?*" or "*What is your hypothesis?*" or *"What do you think, what should happen?*" or "*How can you predict these results?*"

The teachers organised also whole inquiry process. A teacher describes students activities with a ultrasonic sensor: "*In the activity, students collect real-time data using ultrasonic motion detector probes and laptops. The students were walking according to a given graph and evaluating their walking style by use of ultrasonic motion detector. They could see from the laptop screen their real-time distance and velocity. The real-time graphical representations of students' motion allow them to build kinesthetic and cognitive connections between their actual physical motion and its representation on a distance versus time graph. These technologies allow the students the exploration of meaningful questions dealing with motion that would otherwise be impossible in a typical science classroom. In addition, these tools allow students to focus their attention on the interpretation of data they collect.*"

As s summary, based on the teachers descriptions and videos recorded during the experiments both teachers and students were satisfied with their working with the MBL during science inquiry activities.

During the PD-project we find especially useful our web-page, which help teachers in hardware and software use, and in integrating the MBL use in teaching methods. The web page guide teachers to use the hardware based on the "plug-and-play" idea and the software in easy set up and data processing. The web page include background information about phenomena and how the phenomenon is seen in the environment; idealisation tips with photos, video clips, and graphs using real measurements, as well as interpretation and further study suggestions. Terms, such as "classifying" and "preconceptions" lead trough hyperlinks to the hypertext teaching methods guide. Moreover, terms, like "calibration" and "curve fitting" lead through the hyperlinks to the operating manual for the MBL-tool.

**Conclusions**

Although, we have described here several examples and some of the examples sound real success stories, it is difficult to say that certain way of use ICT in science education is more effective than another or even most effective. How effective a single ICT tool (a word processing, a single web page, a database, a web encyclopaedia, educational multimedia, MBL, simulation, etc.) is for science teaching and learning depends on properties of the tool itself. Secondly, effectiveness of a ICT tool depends on users or local characteristics, such as the pedagogical orientation of the user and his/her beliefs about the usability of the tool, and support available. Thirdly external factors such as in-service training and the curriculum and curriculum materials have an influence to the usability of the ICT tool. An "effective use of an ICT tool" is a complex concept and it can not be analysed without the knowledge of users of the tool or a context where it used.

We are living in a very rich digital world. Because of the important and integral role of digital technology in society, science teachers should also reconsider their attitude to use of ICT and other digital devices. Otherwise science teachers are supporting inequalities in individuals' ICT use or e so-called 'digital divide'. Therefore science teachers have a part to play in ensuring that all members of society are able to access the opportunities afforded by ICT use (Selwyn & Facer, 2007)

Based on our experiences and previous analysis of ICT use in science education, ICT use can enhance practices and quality of learning in science and, moreover, increased student interest in learning science. This kind of ICT use is efficient. The potentials of ICT use in science education can be summarised as follows (compare Rogers, 2006; Osborne & Hennessy, 2003; Wellington, 2003; Denby & Campbell, 2005). ICT use in science education can make learning active, constructive, contextual, co-operative, self-regulated, reflective and cumulative and engages students in tackling the topic to be learnt in such a way that they create meaningful and understandable knowledge structures on the basis of a goal of learning. This happen especially if a teacher plan together with students and clarify the goals of the activity. Moreover, use of ICT can increase interest, motivation and engagement in science activities. Especially feeling of autonomous learning and support to students' feeling of social relatedness and competence during the activity could increase interest and motivation.(e.g., Deci, Eghrari, Patrick & Leone 1994).

Furthermore, use of ICT in science education provides access to resources (web pages, texts, databases, videos, demonstrations, applets) that are of high quality and relevant to scientific learning. It enables visualisation and manipulation of complex models three-dimensional images and movement to enhance understanding of scientific ideas. Use of ICT support teaching and learning activities, like exploration and experimentation by providing immediate, visual feedback, science inquiry, learning in a small group and activities where reading and writing are essential. In these activities ICT use expedite and enhance work production and offer release from laborious manual processes and give more time for thinking, discussion and interpretation. Finally, use of ICT help students to learn to use ICT or increase their digital competence.

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## ICT and Science - Training for teachers in Scotland.

*Bob Kibble*

**Abstract.**

*This work forms part of a European collaboration, EU-ISE, funded under Comenius II*[6]*. The focus of the collaboration was best practice in the use of ICT to support learning in Science and looked in particular at initiatives in the training and development of teachers. The training model operating at Edinburgh was of a short intensive courses of from two hours to one day course for small groups of teachers. This report looks at the materials used for the programme and the teaching ideas which were presented to teachers. The course deliberately allowed time for teacher input but was based on a philosophy of giving engaging ideas to teachers which they would be able to use in their classrooms the following week. The teachers role-played the part of learners, conducted experiments and so became familiar with the ICT and with the challenges facing learners. Four courses have been offered: the first was run with initial teacher trainees (n=32) preparing for secondary teaching in science, a second identical course with practising secondary teachers (n=19) and a third with Primary teachers (n=75) and a fourth course with trainee Primary teachers (n=150). The courses were designed and supported as part of the EU-ISE project. This report outlines the structure and design of the courses and includes examples of activities which were offered to participants.*

### 1. Background.

The School of Education at the University of Edinburgh runs undergraduate and postgraduate programmes for training new teachers and also offers courses for practising teachers. It is typical of many university Education departments across the UK. ICT has been an area in which the School of Education saw a need to develop and so it was natural that I should seek collaboration to help steer our science courses towards a greater ICT presence. The EU-ISE funding enabled me to create and deliver a new type of course to trainee and to experienced teachers. We focused on two areas which were seen to be in need of support[7], datalogging and the use of an interactive whiteboard. At the same time I was aware of the need to integrate ICT training into our undergraduate courses for primary teachers. I made use of the new resources to enrich our primary teacher programmes and will describe one such course. Finally I will outline a course which was designed with a commercial partner who had been working with me to design ICT materials based on the Beebot, a programmable robot used for younger learners. All these courses were advertised to participants through electronic and paper channels. Participants paid for refreshments but paid no fees.

Partners who worked with me in Scotland were:

- Paul O'Hara and Eric Martin – The University of Edinburgh
- Tom Dickson – Institute of Physics coordinator in Scotland
- Stephanie Robb – TTS and Promethean educational suppliers
- Rhona Goss – Monifieth High School

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[6] EU-ISE project code: 226383 –CP-1-2005-ISKCOMENIUS-C21

[7] See article on the EU-ISE questionnaire in this book

Nicola Jones – Balfron High School

## 2. The structure of courses.

Each course included an introduction and used small group strategies to allow participants to meet and speak to each other, to share perceptions of the tasks and to provide encouragement and support. A variety of tasks was presented in each session. Some tasks were extended experiments where ICT was used as a datalogging tool, some were based on using the interactive whiteboard in a demonstration mode before allowing for free hands-on, some tasks were based on scenarios to be discussed in groups. There were a few short presentations but these were limited to no more than ten minutes and included sessions on, for example, the use of video with an interactive board, the ways to programme a Beebot and how to incorporate animation in a powerpoint presentation. The examples offered at the end of this article draw on the full range of learner ages. Where possible, participants were encouraged to demonstrate their prior skills and knowledge by taking a lead in the small group tasks. In this sense teachers were teaching teachers and sharing their own good practice.

## 3. Pre-course preparation.

For the secondary courses I wrote a short paper to help teachers start to think about the issues before the course started. This was sent to all who had registered. In the case of students it was sent via an internal e-conference facility. The paper is included below.

### Pre-course stimulus paper.

**ICT – a new subject in its own right or an integrated facility?**

Whose responsibility is it to teach learners how to make the best use of ICT? This is a thorny whole school issue. There is no doubt that learners can't make best use of ICT until they are confident to engage, from the 'how to switch on' stage to the 'how to merge files' stage. How do they gain such confidence? Certainly there is much evidence that ICT is available and used out of school, particularly at home. Can we assume that skills learnt at home are developed sufficiently to enable learners to use ICT whenever they meet it in school? My research suggests that this is unlikely to be the case. Although many learners have a confidence with mobile phone technologies, digital cameras and computer games, a school can't assume that, for example, efficient internet searching, database interrogation, integration of graphics into word processing and datalogging skills are present in many learners. There is a need for a whole school approach to auditing ICT skills of the S1 intake and identifying just where in the first two years of secondary education learners will meet and learn how to manage particular skills such as those listed. Whole school curriculum planning, following a subject by subject audit, might result in an ICT strategy which sees S1 learners tackling internet search activities in french and geography, datacapture in science and maths, wordprocessing in several subjects etc. The strategy aims to equip all learners in a suite of ICT skills by the end of S2. This is just one approach. However I visit schools where there is little evidence of any joined-up planning about ICT across the curriculum. It is not uncommon for staff in science to know nothing about which other subject areas employ particular ICT strategies. This is a whole school issue with a responsibility resting firmly with school managers.

**Why should we bother with ICT in our teaching?**

This question ought not to be left to the sceptics among us. It is a critical question for all teachers. Part of the answer lies in the 'entitlement' curriculum – where ICT is seen as an essential feature of adult lives and more important of lifelong learning in adulthood. An education which fails to equip learners with good ICT skills is an education which has failed in a core skill. A second argument lies in the realisation that ICT can have a positive benefit to learners and learning. If used well ICT can enrich understanding, empower learners to move forward at a freer independent pace and open learning outcomes which hitherto had been deemed too demanding – for example some ideas relating to 3D images or to time related changes or related to very fast changes which only fast dataloggers can explore. It can also open up possibilities for collaborative learning across boundaries – perhaps with pupils in other year groups, in other schools or in other lands. The ASE 'Science across the World' initiative is an example of the latter.

So there are sound reasons for teachers to embrace ICT as a strategic feature to enrich learning and as a core life skill area.

**When should ICT be used?**
There is a real danger that the existence of an ICT facility in a classroom or in a school is used for the sake of using it. I have seen interactive whiteboards being used and overused when a more appropriate strategy might have been to use low technology – for example a group discussion task. The best practice messages which I have become aware of are when teachers make use of ICT in a planned and integrated way, building in the ICT experience to achieve a specific goal – on a task which benefits from the ICT capability. This is particularly important when we recognise that on so many occasions the failure of the hardware or software inhibits learning. An over reliance on technology can lead to a sense of overkill and also time wasted in getting the technology to work properly. Far better to use it little and often and only when you are sure of the value and justification and of course when you have had a chance to practise so you know that it will work.

My observations of ICT in science teaching started with the introduction of a BBC computer in the school where I was teaching in 1980. What has become clear to me over the years is that there are what I see as three stages in teacher competence with ICT.
Stage 1 is that of the initial confidence barrier. There are sceptics in staffrooms as I write this who simply refuse to engage with any ICT. They'll tell you that the technology can't offer anything more than they can do with a stick of chalk and a poster. And on many occasions they are right of course. Traditional methods work fine for much of the time. Most of us pass through the stage 1 confidence barrier some time or another.
Stage 2 is where we know how to switch on and engage with a piece of ICT. What we might typically do is use the technology in exactly the same way we would have used the old technology. So, instead of using a reference book to look up information, children would use the internet to do the same task. Instead of plotting a graph manually, children plot it using a spreadsheet. I think that the majority of teachers are within stage 2.
The progression to stage 3 is typified by those teachers who adapt their teaching to make the ICT work for them, often in innovative ways. Such teachers are the pioneers, they were the first to pass through stage 1 and 2 and they probably will be good at leading staff CPD sessions. You probably know who they are in your school. They will order a new piece of kit not simply to be able to say they have one of the latest gadgets but because they can see how it will change their teaching.

Of course I have described a simple model and it probably describes your school to some degree. An issue for managers is how to move their colleagues from stage 1 to 2 and then to 3. I have no doubt that pupils who meet teachers at stage 3 are advantaged in their learning. For them, their teachers will enrich their understanding of principles and processes by the imaginative use of ICT, using it occasionally but with skill.

**How can teachers gain in confidence with ICT?**
One thing we have learned is that a crash course in ICT, be it datalogging or web page design, is a wasted exercise if it isn't immediately followed up by the expectation and facilities to practise the new skills. Training ought to be designed so that it articulates with follow-up opportunities. An example of this working well is when a department with a new set of wireless laptops decided that all staff teaching in S2 would use the kit in a common research and present activity for all S2 groups. The training session which preceded the curriculum activities had an immediate relevance to the teaching of all teachers in the following half term. However, even if such training is well timed, the benefit to learners is severely diminished if the teaching staff don't manage to rise above the technology and consider their pedagogy. ICT does have the potential to change pedagogy.

Part of any training in ICT ought to be a discussion and exploration of the ways in which the new technology engages with learning, promotes new learning or changes the potential for learning. Without such discussions teachers are likely to make use of ICT but fail to raise their own professionalism above that of a technician, wheeling in a new toy, switching it on and using it to tell a story or whatever. I spent some time working alongside a science department who were getting to grips with a new ICT resource. Very few teachers in the team managed to rise above stage 2. They didn't seem to be able or willing to engage in any dialogue about teaching and learning. What I became aware of was that I was working with a team of teachers who were not used to discussing their pedagogy at all, ICT or no ICT. In such a pedagogical desert, it is not surprising that a new resource was embraced in no deeper way that at the level of technical competence i.e. learning how to book out the resource, plug it in and switch it on. The lesson here is that, if a school genuinely wants to become a learning community, with staff and students engaged in progressing skills and understanding on all fronts, there has to be a culture within that school whereby pedagogical issues, discussions about methods, teaching and learning are seen as having value and are encouraged. Managers need to create opportunities for teaching and learning to be placed on the agendas of staff development days.

Before leaving the issue of staff development, it is quite likely to be the case that the most skilled and confident users of a particular piece of ICT are the pupils themselves. Far from being intimidated by this superior know-how, teachers might consider ways in which pupils might make a contribution to ICT staff development. Might a group of pupils be invited to plan and deliver a session on webpage design or spreadsheet manipulation? If a school is to become a genuine learning community might it recognise that the student body is a huge potential training resource both for other young learners and for staff.

**New ways of learning?**

A survey I carried out of 70 teachers across Scotland revealed that a significant proportion agreed that the use of ICT had 'radically changed their teaching of science'. So just what is the added value of using ICT in science lessons? I suspect that this question will form the core of much of the dialogue in our CPD day.

Some messages from the collaborative European research survey which offer pointers towards answering this question are:

- ICT can offer better learning support for faster learners and also for slower learners.
- ICT can allow learners to work independently.
- ICT is motivational – learners seem to be switched on by new technologies.
- ICT allows better understanding of complex processes (3D representation, dynamic models etc)

Interviews with learners tend to support the teachers' positive outlook. The motivational element is very strong in pupil responses. However pupils also refer to the feel-good factor associated with virtual experiments – the way that they always work. It is not clear if we are still in a honeymoon period regarding the impact of ICT for learners. There is a danger of becoming ICT weary. How long will it be before we hear: 'Oh no, not another powerpoint / interactive CD / datalogging task' . There are dangers in the blanket application of ICT to all learning situations. One thread emerging from research in the field of formative assessment is that learners enjoy finding their known voice and listening to others. Dialogue between learners is a critical element in learning. In science, such dialogue could be engineered through formative assessment tasks such as card sorts, concept cartoons or board game tasks but equally through the collaboration on a practical investigation. So real hands-on, brains-on science and the softer side of interpersonal communication activities should not give way to ICT dominated learning. The trick is to blend the ICT into the learning experience so that it does nothing but add value.

This last point raises the issue of lesson planning. All teachers need to plan ahead, whether it be a formal plan such as those required of trainee teachers, or an informal plan residing in a notebook or in one's head. The way ICT is to be blended into a learning experience must be considered in such a planning process. At the very worse end of practice I have seen lesson planning being little more than remembering to book the ICT resource from the technician. The resource is then wheeled in to the lesson, pupils plugged in and the teacher wanders aimlessly with little on their mind other than chasing up the broken mouse. I would hope that this is a rare occurrence.

**Technical support.**
The introduction of new learning technologies places new expectations on technical support. What has become clear to me is that such support needs to be at two levels. The first is at a Local Authority level and involves advice to schools on the most suitable equipment for particular tasks, it involves trouble-shooting support for when systems go wrong. It might also involve training those in-house school lab technicians in the new technologies.

The second level is the support that is required in every school. Not only do new ICT items require special storage, often secure storage, they also require specific booking systems and particular maintenance and trouble-shooting skills. To invest thousands of pounds in ICT resources without updating technical support systems in a school is to ask for trouble. Things will go wrong, systems fail and hardware breaks on occasions. Having a reliable and skilled ICT technical service is essential.

**Summary messages to be taken back to schools.**

- Have you carried out a curriculum audit of ICT use and have you articulated what might be the minimum entitlement of ICT experiences across S1 and S2 for all learners?
- ICT might be seen as an area where core life skills reside. Have your pupils been exposed to and versed in the confident use of such skills before they leave?
- Is there a sense that ICT is assumed to be of value simply because it is there? The wise and sensitive use of ICT can be far more powerful than the blanket use of a resource simply because it is there.
- Staff training and development needs to be linked to real classroom tasks. Time to practise is critical to ensure that the investment in training secures real change.
- What role might pupils play in the training activities within a school?
- Does your school promote and encourage open discussion about teaching and learning? A successful learning community will make best use of new technologies if it can engage in a pedagogical dialogue about the value, use and abuse of such technologies.
- How good is your technical support for ICT?

## 4. Examples of activities which featured in the training courses.

There follows five examples of activities which help to indicate the sort of activities to be tried in Scottish CPD in Edinburgh.

# Scotland: ICT in Science. Activity 1.

## MBL: Investigating motion using a 'fast track' toy and a light gate.

A commercial fast track toy car and runway system can be bought for about 10 Euros. There are plenty of opportunities to explore the physics of this simple toy. Our CPD session covered the following activities.

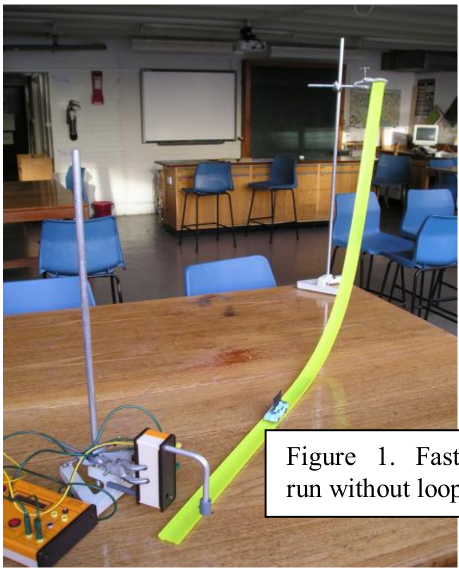


Figure 1. Fast track run without loop.

**Energy transfer.**
A 1 metre rule will offer a simple method of recording release height, loop height etc. (remember to measure to the centre of mass of the car.) The initial energy is stored as gravitational potential energy, $Ep = mgh$. Assuming all the transfer of energy is to kinetic energy, $Ek = 1/2\ m\ v^2$, you can predict the velocity of the car at any place on the track simply by calculating the transfer of Ep

The track can be arranged without the loop in the first instance, see figure 1. For release height of 77cm, the fall distance was 75cm. Repeated light gate measurements gave the final velocity of the car to be 3.7 m/s. (All our results were within a 3.6 to 3.8 m/s range.) This compares with the calculated value of 3.8 m/s. Such a small energy 'loss' was surprising but encouraging as it did mean that this simple slope could offer students a straightforward confirmation of energy transfer calculations without the complication of significant frictional 'loss'.

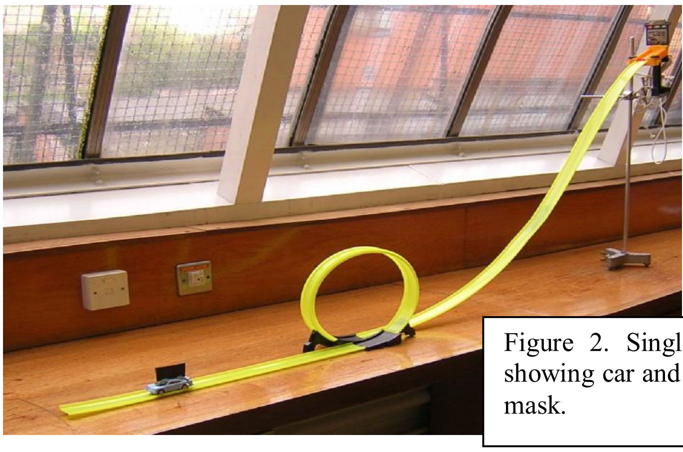


Figure 2. Single loop run showing car and timing gate mask.

**Adding a single loop.**
With a single loop in place we decided to record the velocity of the car at the top of the loop. A light gate suitably fixed enabled us to do this. Once again the simple energy transfer equations predicted that our car velocity would be about 3.31 m/s for the total fall distance of 56 cm. Actual values were about 2.1 m/s. Clearly the loop was responsible for energy transfer through friction and perhaps sound as well. Figure 2 shows the car and loop.

**Centripetal Forces.**
The analysis of forces which act during motion in a vertical circle is not trivial for students. The mass of the car, 0.036 kg, results in a gravitational force of 0.35 N acting during the journey, (and of course at all other times as well). The reaction of the track provides the second critical force acting to provide centripetal acceleration to the car. The diameter of the loop was 0.21 m. (This was taken as the diameter of the locus of the centre of mass of the car rather than the outer edge of the wheels.) At the top of the loop, with car travelling at a speed of 2.1 m/s, the force required to maintain circular motion can be calculated.

$$
\begin{aligned}
F &= mv^2/r \\
&= 0.036 \text{ x } (2.1)^2/0.105 \\
&= 1.51 \text{ N}
\end{aligned}
$$

It is evident that, at 0.35 N, the weight of the car is a significant fraction of the force required to maintain circular motion. A challenge for students might be to calculate the car velocity, and therefore the release height, which would result in the limiting condition where the weight of the car just matches the centripetal force at the top of the loop.

Such calculations and ensuing discussions help to establish a deeper understanding of forces, circular motion and energy transfer. They also show that physics can be applied in more everyday domestic contexts. In writing this I am aware that many teachers have been using such contexts extensively.

**Frictional forces.**
The cars run freely on a low friction track. However there is bound to be some energy transfer through friction and the difference between the measured and calculated final velocities will give a feeling for the proportion of the initial energy transferred through heating.

Assuming this transferred energy is dissipated uniformly along the track. By measuring the track length you can calculate the mean rate of energy transfer through friction (in J/m). This is a value which, with units of force (N), represents the mean frictional force acting on the toy car during the journey.
It must be said that, without the loop, our track was a notably low friction environment.

Energy is also dissipated when the track itself moves on a slippery surface. Taping the loop base to the table reduces this effect.

**Teachers and CPD.**
Small groups of teachers were introduced to the equipment and left to make their own measurements. The discussion which followed considered uncertainties, practical considerations such as setting up the equipment and the use of software by students. We allowed about 30 minutes for teachers to complete the task. There was general agreement that the car and track would be enjoyed and would motivate learners. The results were good enough to illustrate conservation in a quantitative way.

## Scotland: ICT in Science. Activity 2.

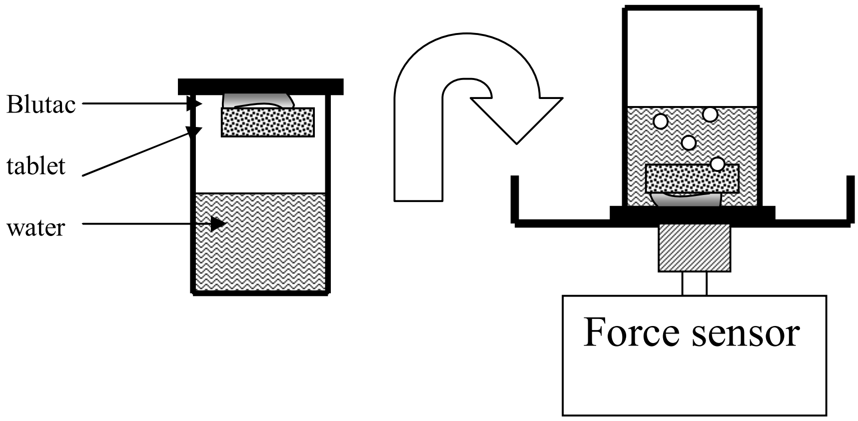
## MBL: Investigating motion impulse using a commercial force interface.

The use of plastic film tubs as rockets is common in many schools. The mix of water and a fizzy tablet produces corbon dioxide to ‘pop’ the rocket. I developed an experiment using this idea to illustrate impuse and change of momentum. It featured in the MBL CPD workshops. The ‘rocket’ was placed on the surface of a force datalogger and the launch force was recorded.

To give the experimenter time to set up the launch I used a small piece of ‘blutac’ (poster putty) to secure the quarter vitamin C tablet to the inside of the film lid. (see fig 1a). The other fuel component, water, was added to the film tub and the lid fixed on securely.

The force sensor ( our was a PASCO sensor) was held vertically with a plastic petri dish attached to enable a compression force to be read. (see photograph).

The data rate was set to a high frequency, typically between 200 and 1000 readings per second.




The results indicate a clear force/time relationship with a maximum force recorded of about 8N.

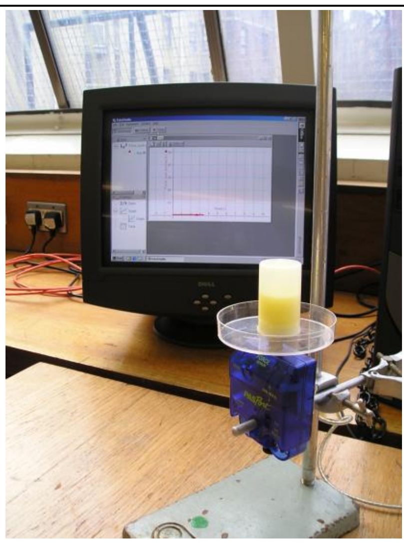
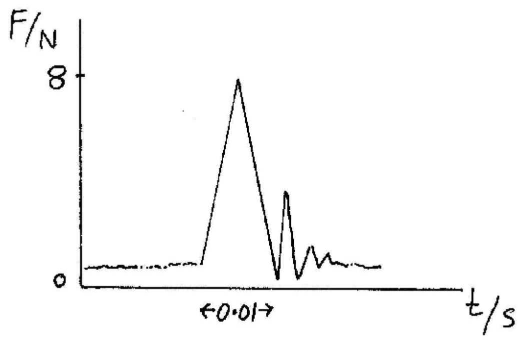


Figure 4. The fizzing film tub located on a force sensor. Below: A typical sketch of the MBL readout.



## Scotland: ICT in Science. Activity 3.

## MBL: Using sensors to explore environmental changes using a child's doll's house.

This activity was developed and used with trainee teachers. The use of sensors and dataloggers (MBL) in primary schools in Scotland is not widespread. Our undergraduate course has identified ICT as being an area which needs to find a stronger place in the programme. In response to this I developed a number of activities to incorporate into our Environmental Studies[8] workshops for undergraduates. We purchased a set of simple dataloggers ('Logbox' from TTS and 'Easysense Q' from Data Harvest) and developed some activities which gave students confidence to make use of these dataloggers in their own teaching. Each year the students spend an extended period of time in schools and are in a good position to take a lead in showing teachers how to use the new technologies. During the trial period we had only four dataloggers but since then have expanded our store to twelve loggers. This will enable students to borrow a datalogger and try it in schools

The 'Environmental Studies' curriculum structure suggests that we should try to locate our science in an environmental context. The idea to use dataloggers to monitor the local environment seemed a natural curriculum activity. I bought a dolls house ( about 70 Euros) from a high street store and we assembled it from a flat-pack box. This our technician about an hour.


In the first experiment a night light candle is used as an energy source. [Warning: candles should not be left unattended or placed near flammable materials]. Temperature probes from the dataloggers are inserted through holes drilled in the back of the dolls house. The windows were sealed and the internal conditions were monitored over a period of ten minutes.

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[8] In Scotland science resides within a broader curriculum heading of 'Environmental Studies'. This also includes history, geography and technology.

## Scotland: ICT in Science. Activity 4.

## MBL: Using sensors to explore environmental conditions.

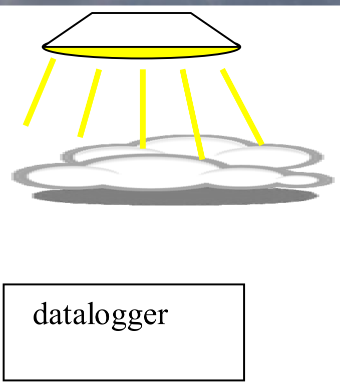
These activities were designed to introduce student teachers to using a simple datalogger. We have found that the majority of undergraduate students training to be primary school teachers are unfamiliar with dataloggers. Our experience has been that our workshops, which offer simple confidence-building tasks to be performed in small collaborative groups, encourage students to start to take the initiative in asking questions about the dataloggers and then in extending the tasks in their own ways.

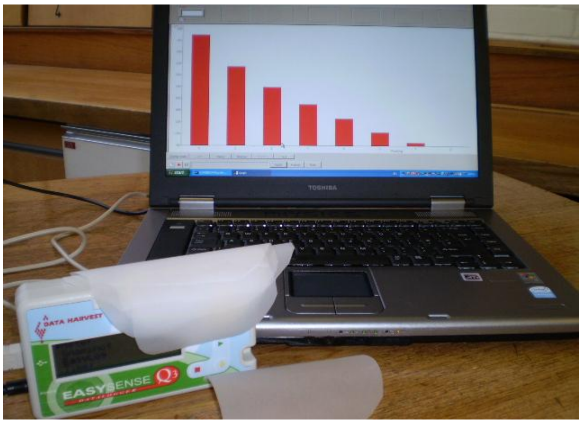
Our introductory workshops, offered to 150 student teachers in the second year of a four year undergraduate degree, used Logbox and Easysense Q dataloggers. The workshops lasted for 90 minutes and included the dolls house activity (see activity 3, above) as well as an outdoors activity where the dataloggers were taken into the Edinburgh city centre to monitor light, sound and temperatures in different locations. Here I will describe two simple investigations which were performed in the laboratory.

**Clouds that block the sunshine.**

This investigation uses home made model 'clouds' made from tissue paper or tracing paper. What effect does a cloud have on the passage of light?

Use the light from a table lamp to represent your 'sun'. The paper clouds can be laid upon the light sensor one by one. Record the effect that each cloud has on the light intensity.



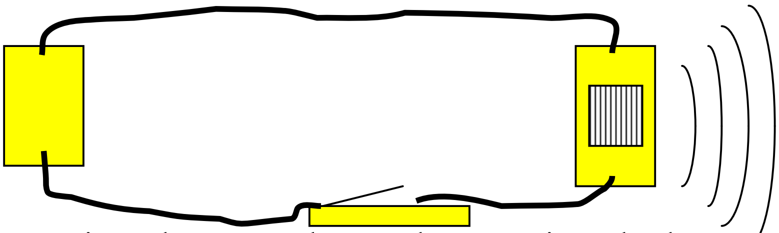




Above: Easysense Q datalogger and model clouds. The results show a gradual decrease in light intensity as each cloud layer is added.

Left: typical student worksheet.

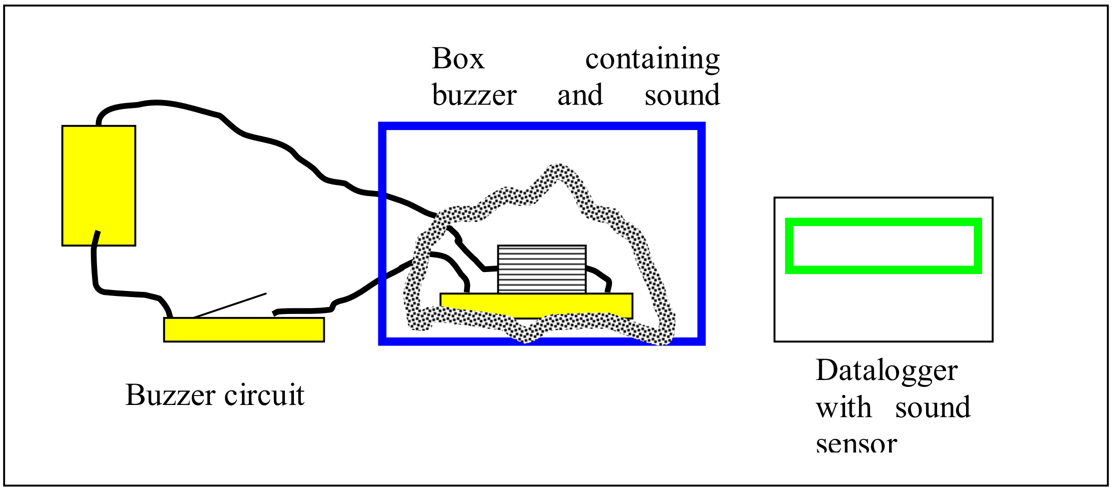
# That’s just too noisy!

The simple electric circuit allows a buzzer to sound.

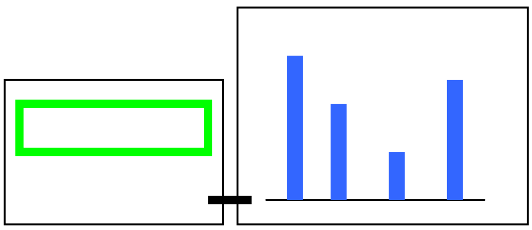


The datalogger microphone can be used to monitor the buzzer loudness in dB (decibels). The investigation invites learners to explore sound insulation by placing the buzzer in a box and investigating different types of sound insulation.

Use the datalogger to monitor the loundness of the buzzer. Note down this loudness. Then change the insulation and repeat your measurement.




You can also set up the datalogger so that it takes a reading each time you tell it to. It will display the sound loudness on a computer screen as a bar chart.



## Scotland: ICT in Science. Activity 5.

## A programmable robot workshop for Primary teachers.

I have been fortunate to have had the chance to work in partnership with a commercial company which specialises in educational materials for science and technology teaching. TTS retails the 'Beebot', a programmable robot in the shape of a bumble bee. It is aimed at younger learners and my task was to find ways of introducing Beebot to teachers and also to find ways of locating it within a science context. I worked with Stephanie Robb who was the Scottish representative of TTS. This was a purely educational partnership which I used to help me create new activities for my undergraduate workshops. I provided feedback to TTS about the value and development of their Beebot.

A particular training opportunity came in 2007 when I led the training of 75 experienced teachers in Falkirk, Scotland. The training model used by Falkirk Council was to release teachers for a half day event on a Friday afternoon. This happened at regular times in the year.

Our workshop was scheduled to last for 90 minutes. Stephanie Robb from TTS introduced the workshop plan and then I led the main training part. The activities included *Beebot Goes Shopping* (to introduce the programming functions), *Beebot on the Beach* and *Beebot in the Park* (to show how to teach science ideas). Each teacher was given a Beebot to take away from the workshop so that the activities could be started immediately. Many schools had already received a box of Beebots but most had never opened them nor used them. This is an example of the failed ICT strategy mentioned in a paper (Kibble and O'Hara) elsewhere in this book. By linking the free hardware with the training we hoped our ideas would find a place in classrooms the following week. Such is the benefit of organising training with a commercial partner.

One of the activities we used was reflective. We used a large sheet of paper for each group of eight teachers to use as a space onto which they shared their thoughts about the place and value of using the Beebot in their classroom. In particular we asked them to write about how the Beebot tasks linked with the new curriculum in Scotland, the Curriculum for Excellence.
There was no shortage of ideas emerging from this task. Teachers managed to fill the page with references to language, to mathematics and numeracy, to responsibility and to confidence and communication. There was no doubt that teachers would not only be comfortable using the Beebot in their classes but could also justify its use in terms of curriculum outcomes.

Here is one of the activities we used.

**ICT and the environment.**

**Beebot goes for a walk**.

You will probably have seen BEEBOT before. The on/off switch is on his base. Press **CLEAR** to erase previous programmes. Do this every time before entering a new programme.

Spend a few minutes playing with his direction buttons to help you appreciate how to make him move forward and turn corners. Then play.....

**BEEBOT goes for a walk in the park.**

**Activity**: Start BEEBOT at home and use the cards to take turns to programme BEEBOT to find particular locations. Each card starts from where BEEBOT finished the previous time.

**Thinking like teachers:** This is a home grown activity. It was easy to create. How does it support learning about ICT and about the environment?

Can you think of another sheet with different pictures and challenges? There is another BEEBOT challenge on the next table. Swop over and try this one. There are cards to direct you just as for this activity.

Below: the training is introduced. Right: Author with Stephanie Robb and a 'free' Beebot owner.


**5. Conclusion.**

The EU-ISE Comenius project brought together teacher educators from quite different social, economic and political perspectives. We shared a common interest in teacher education and in particular the role of ICT in science education. The training model used in Catalonia was of an extended course with reflection built in. Teachers were encouraged to explore both ideas for using ICT but also the pedagogical and curriculum potential and expectations of this work. I have considered this model and wanted to contrast it with the model I had developed in Scotland. In Scotland the courses I ran were shorter and had to build in pedagogical dimensions through a pre-course article or through one of the tasks making the pedagogical dialogue a central feature of the activity. They were designed to give teachers confidence by showing them interesting and novel practical tasks which they could use in their classroom next week. My approach was deliberately a short term immediate solution to bringing ICT into science classrooms. It is not clear if the Scottish approach would leave a long-term legacy in schools. What is clear is that real ICT activities would be tried and seen as successful and achievable by teachers who might have lacked confidence in ICT prior to the workshop.

Looking back at the Catalonian and Scottish CPD models I can see the clear benefits of each. Both result in classroom activities and increased teacher confidence. It is interesting to note that the Scottish Government has recently funded a new CPD initiative which uses a model very similar to the Catalonian model. Teachers attend a three day residential programme, rich in content and with a variety of CPD activities. They are then expected to return to schools and to explore one of the ideas in their classrooms. They are expected to prepare a report of their new classroom activities and then return a few months later to a one day follow-up event to meet their trainers and share their reflections.

This extended and reflective model has the benefit of placing teachers in the role of reflective researchers, looking at their own practice in a more analytical manner. The model is expensive in terms of time spent away from school and the residential costs or accommodation. It also can't provide regular CPD for the same teachers. The intensive course is unlikely to be offered to the same teachers in the next five years. Funds just won't allow this. The shorter CPD model I describe does allow for repeated attendance perhaps once every year or two. There is no accommodation cost and minimal cost to schools for releasing teachers.

For my own professional development as a teacher educator the EU-ISE project has offered me a number of professional outcomes:

- The chance to reflect on my own practice as a trainer and in particular to compare this practice with other models from partner nations across Europe
- To learn from watching and meeting other teacher educators and reading about their own journeys and successes in a pan European context.
- To develop and extend my interest in ICT in Science Education. Prior to this project I had little experience of running ICT courses for teachers.
- The establishment of a stronger network of contacts in ICT in Scotland, including commercial partners.
- To develop and use a new network if teacher educators across Europe, ready to share best practice and ready to take an interest in the work they do.

I am grateful to the Comenius project leaders for the opportunity to extend my own professional practice. I am also indebted to the support of the partners in the EU-ISE project, in particular the lead role provided by Peter Demkanin.

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

*Józefina Turło, Andrzej Karbowski, Krzysztof Służewski*

**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 20th 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 4th 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.

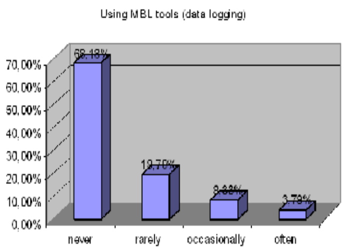
The outcomes of the project are intended to reach the following target groups: teachers of science in schools for ages 10-18 and trainee teachers of science as well as lecturers with responsibility for in-service and pre-service teacher training.

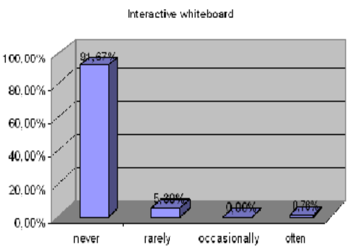
### 3.2. The project's first activity

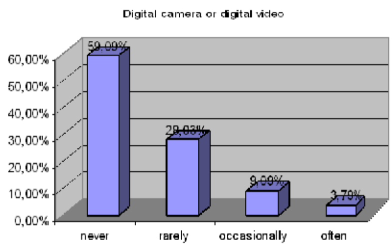
For the first activity we elaborated the international, comprehensive *Questionnaire* (http://www.fizyka.umk.pl/test/data.php) aimed at the investigation of the means in which ICT is actually used in science teaching on: *"Making use of ICT in science teaching"*. We collected 117 Polish answers (73% 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).

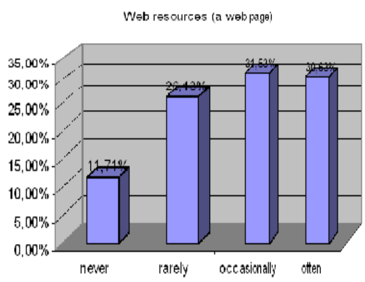
Furthermore, there are not enough digital cameras and MBL (data logging tools and sensors - only about 20% of schools possess these facilities) and especially digital microscopes and interactive whiteboards (they are in about 5% of investigated schools), which we can see in the figures below.

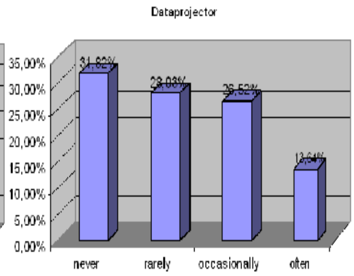


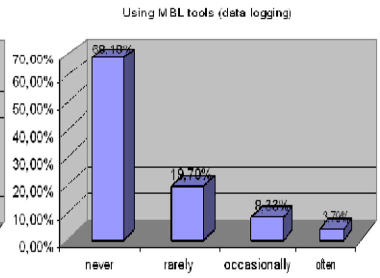




The next question was: *How often and what kind of tools do you use as a part of your science teaching?* As we expected (see figures below) it appeared that the teachers mostly like to use Word processing, PowerPoint, Internet and web resources, and CD-ROMs; occasionally they use Excel, applets, other 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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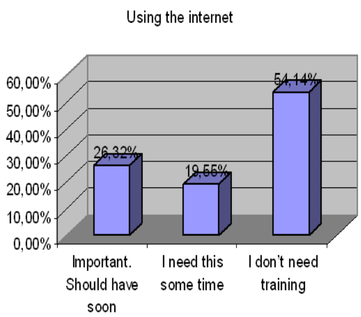


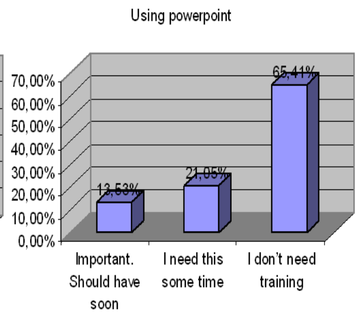


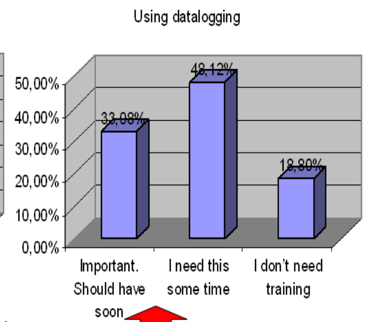


Based on the above questionnaire investigation and discussion with teachers, and if the methods and tools of ICT are of a good quality from a technical point of view, we can try to find some general and pedagogical features, which allow us to answer the question: *When, for what and how ICT should be 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 collaboration of students in teams | To promote active collaboration 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].

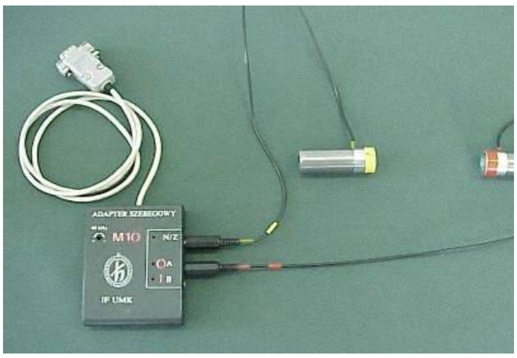

Fig 5. The ultrasound 40 kHz motion detector with transmitter and receiver.

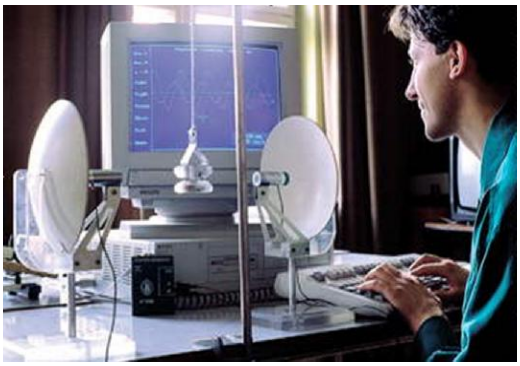

Fig. 6. Mr Andrzej Karbowski is studying the pendulum motion in the real time.

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

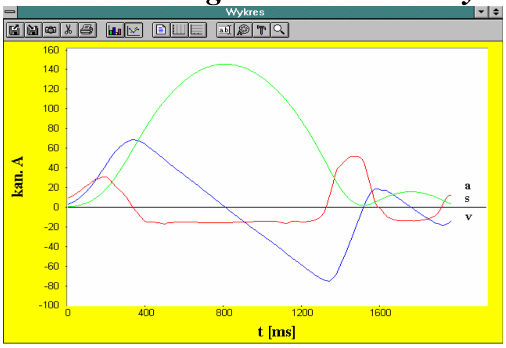


Fig. 7. The graphs of position, velocity and acceleration of school version of Galileo experiment (car moving on the inclined plane)

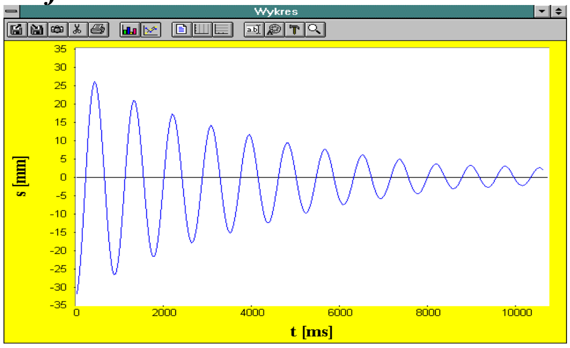


Fig. 8. The graph of position of damped harmonic motion (mass attached to the spring, placed inside the water).

- ***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.

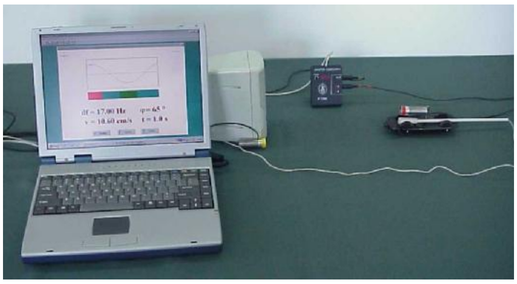

Fig. 9. A car with microphone and ultrasound receiver is moving with a speed $v_o$ towards the loudspeaker and ultrasound transmitter, which are at rest on the table.

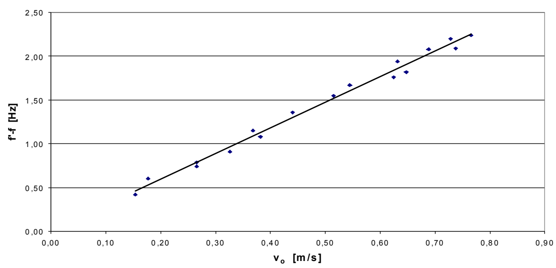


Fig. 10. The plot of relation between the frequency shift and the velocities of moving observer towards the stationary source.

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.

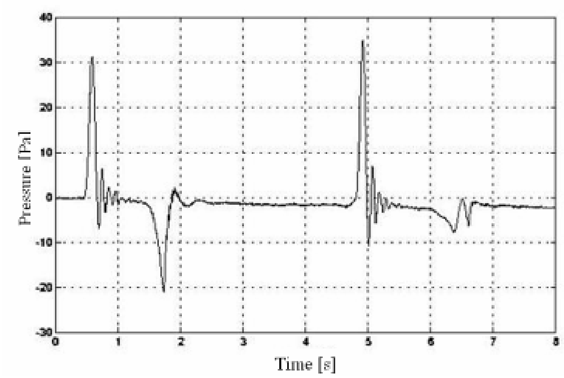


Fig. 12. Perturbation of pressure in the room caused by opening the window (two times).

- ***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.

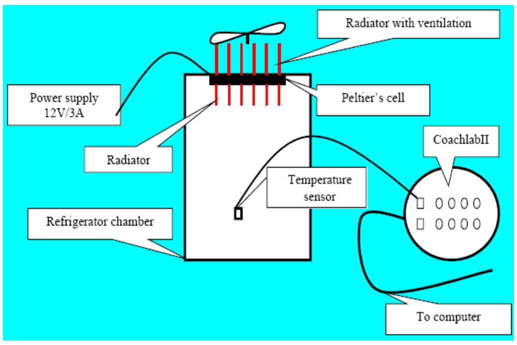


Fig. 13. The scheme of the Peltier's device.

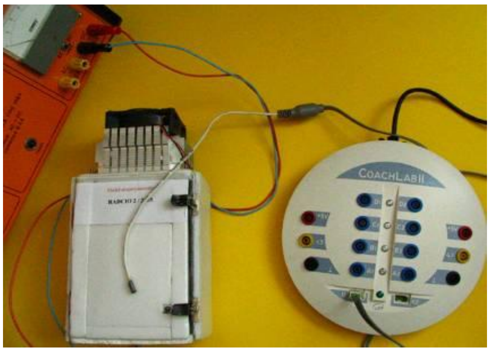

Fig. 14. The use of Peltier's cell for cooling.

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.

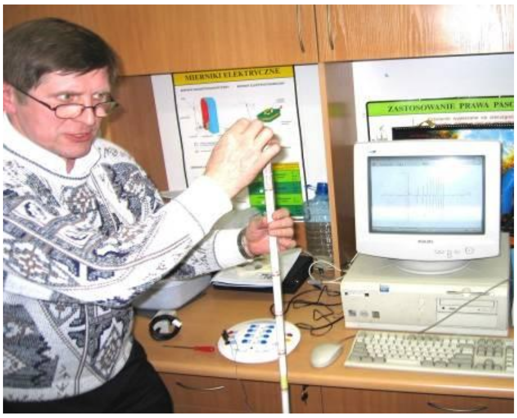

Fig. 15. Tadeusz Kubiak presents checking the dependence of magnetic induction on intensity of current flowing in the coil.

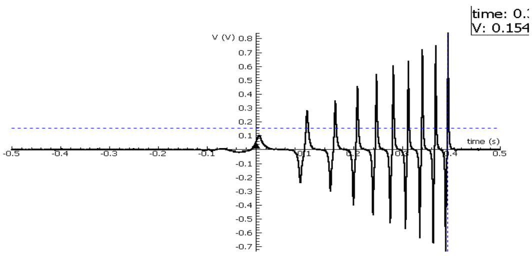

Fig. 16. On-line data and graphs illustrate change of induced potential in the plastic tube.

- ***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 $\mu$ (factor of magnetic permeability) to recognise the kind of material (diamagnetic, ferromagnetic or paramagnetic).

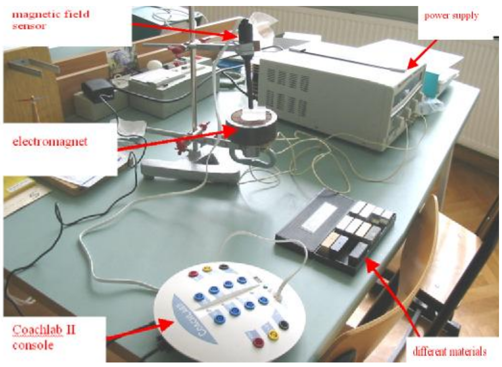


Fig. 17. The experimental set (designed by M. Kamiński) for measurement the permeability of different materials.

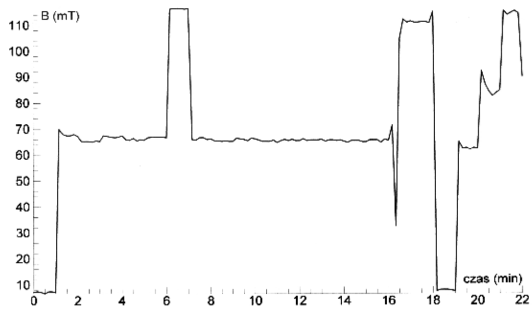


Fig. 18. The experimental results related to measurement of $\mu$ for diamagnetic and ferromagnetic – cast iron and steel (7 and 18 min).

- ***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.

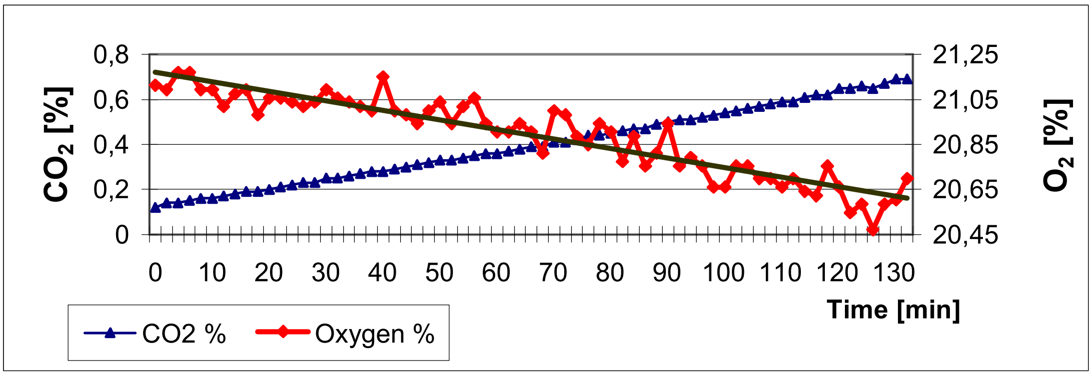


Fig.19. Concentration of oxygen and $CO_2$ for corn growing ca. 2h in dark.

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.

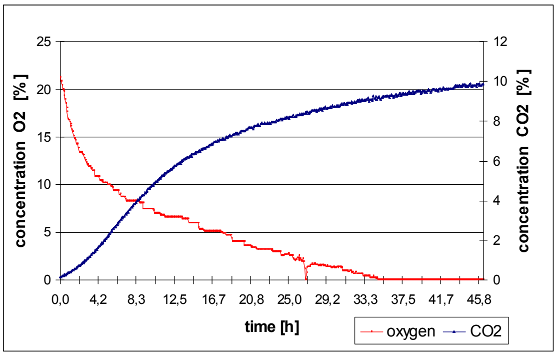


Fig. 21. Changes of oxygen and CO2 concentration during pea germination in darkness.

- ***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.

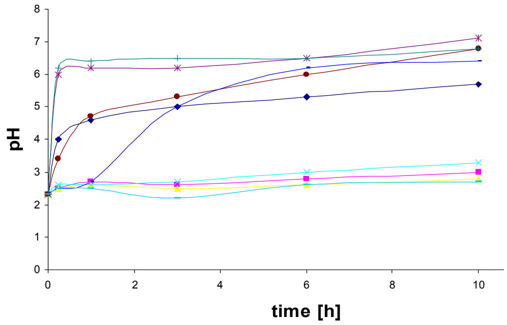


Fig. 22. Changes of pH of cola simulating stomach acid as a function of time after adding of different medicaments

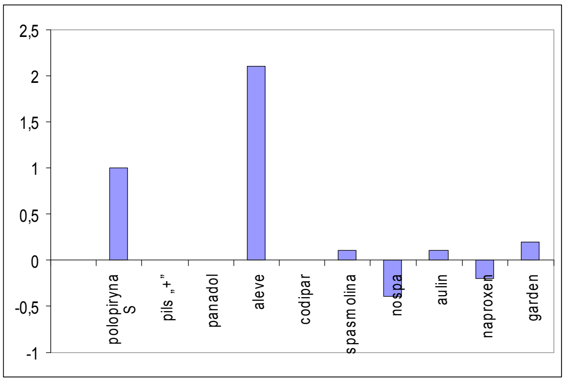


Fig. 23. Changes of pH of cola simulating stomach acid as a function of time after adding of different pills reducing pain.

- ***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.

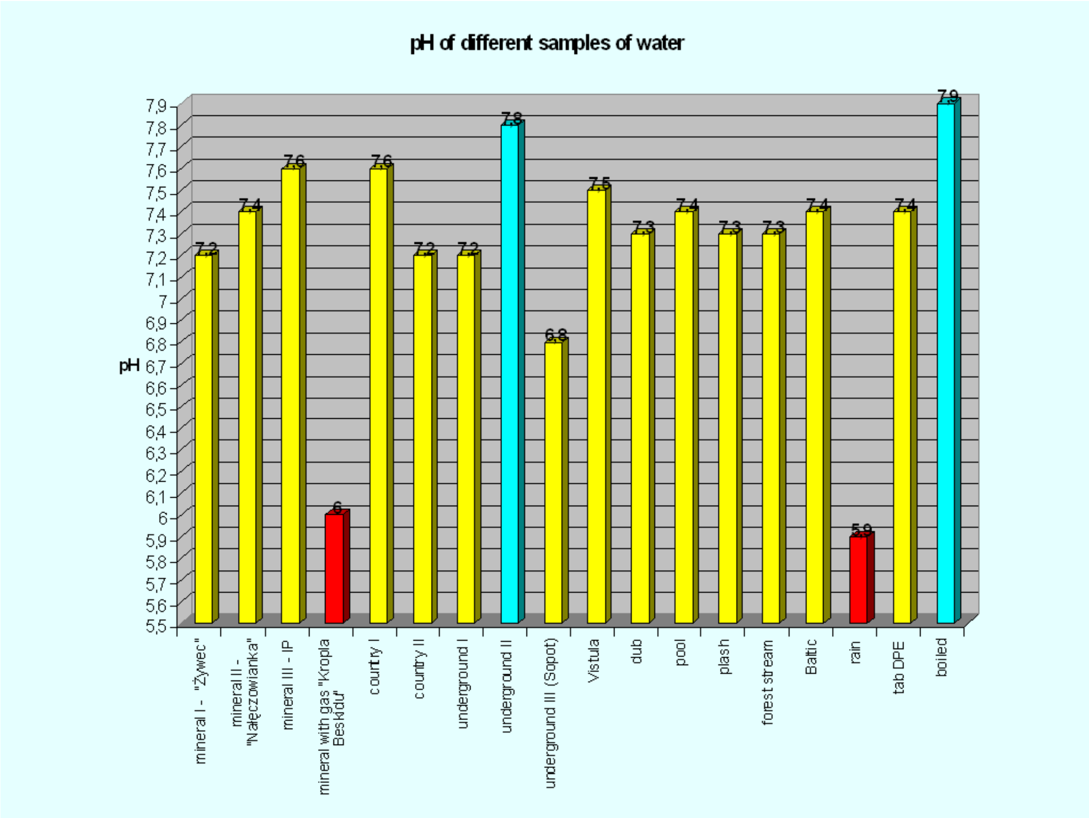


Fig.25. Diagram of data obtained from the measurement of pH of different samples of water.

**Acknowledgements**

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## Relating reflective practice to ICT teacher training in Catalonia - developing a new Teacher Training course

Josefa Guitart Mas, Mariona Doménech, Julián Oro

### Background

Since the year 2000 in Catalonia, the use of MBL, VBL, digital microscope as well as simulations have been promoted. The Department of Education has sent equipment (computers, sensors, digital microscope and simulation software) to secondary schools to initiate the use of this kind of ICT with students in upper secondary school,

Obviously teachers would need training to learn how to use this equipment so a teacher training programme was started. From 2003 to 2007 a module course of 30 hours was carried out in different cities in Catalonia. There were two kinds of courses. One of them was a seven week consecutive series of sessions during term time, and the other one was a daily session everyday for one week, in the summer holidays.

More than 1300 science teachers of the approximately 2800 in Catalonia (nearly 50%) took part in one of those courses, so a significant proportion of the science teachers. These teachers were supposed to help other science teachers at their own school.

Teachers that took part in these courses participated in a lot of laboratory work using the equipment, including: all the sensors, the microscope with digital camera and some simulation software. A new version of the software in 2004, allowed teachers to include activities that use the analysis of data of digital video (VBL).

The teacher training resources (guidelines) were designed for upper secondary students (16-18).

This teacher training process put the emphasis on the technical aspects of using this equipment. The guidelines used by teachers in these courses were standard that is they explained to students everything they needed to do and were generally designed to be used at the end of theoretical explanations. These guidelines were maybe more useful for the teachers' learning than for the students.

The results of these teacher training courses were that the teachers learned about the technical use of the equipment but maybe not so much about how students could improve learning using these kinds of ICT. The teacher training didn't emphasis the pedagogical possibilities of these kinds of ICT resources and some teachers believed that the use of these new tools would automatically promote better learning among students.

The emphasis on technical training resulted in forgetting about the potential of these ICT resources, which were to introduce methodology changes in the classroom or lab. These included promoting student predictions, graphical analysis, modelization processes, specifically when using some kind of applets or other simulations, or the possibility to introduce students to inquire about science with the resolution of questions in a contextualized situation.

These teacher training programs required a large economic effort but provided few changes in the classroom. Some teachers were able to use them, others not, and some other weren't very satisfied with the equipment.

There is available data from a survey made after the halfway point of the training program and more from a survey that was made during the "Effective use of ICT in Science Education" project. The analysis of this data shows that in spite of the large training process there has not been a generalized implementation, of the sensors or of the digital microscope. Moreover some data shows that there are secondary schools where the equipment has never been used, or has been used only in a sporadic way specifically when students in the last year of school (17-18) were making compulsory research work.

Why was the implementation level low when there were a large number of teachers who took these courses?

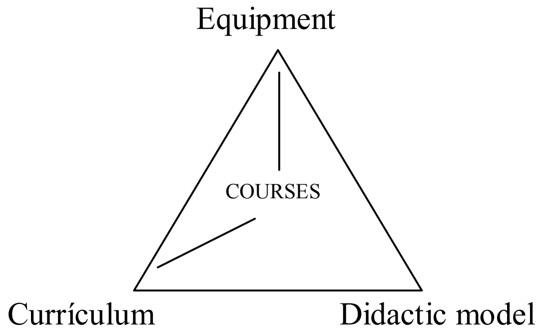
There are maybe different reasons that could explain these facts:

- The teacher training resources (guidelines) were designed for upper secondary students (16-18) and the equipment was sent to schools to be used for these students. The present organization of subjects in this level didn't help the laboratory work. The curriculum, especially for Physics and Chemistry, were very heavy in relation to the number of hours allocated to these subjects. Teachers generally said that there was not much time to use this equipment, and moreover there was not much time for students to learn how to use the equipment and to realize how it works.
- Each school got 3 full set of equipment. It means that students have to do group work in large groups (sometimes 5 students in a group). This fact makes it difficult for all the students to participate in collecting data and working with the computer. The interaction between students was difficult and the management of the activities complicated.
- Another probable reason is that teachers usually use a class methodology which separates a lot theoretical lessons from lab practices. There is not the habit among secondary teachers to incorporate some short experiments into their theoretical lessons and there is neither the habit of incorporating the use of ICT as simulations as a part of a whole lesson. The equipment included a projector, which was installed in the lab, but only a few schools have a computer and a projector in their classrooms.
- The teacher training model used didn't take too much into account about the suggestions from the research of science didactical and pedagogy about aspects for the best way to approach experimental work and the contribution of the use of ICT tools to the development of scientific competency. What kind of guidelines would promote competencies related to the nature of science and the scientist's work? Which are the best guidelines and activities to promote the students construction of scientific models and the application of them to other situations? How could the classroom management be when there is little equipment or when there are technical difficulties?
- The teacher training courses were full of practical activities for the number of hours available. Teachers perform a lot of experiments and there was not much time to think about how to perform the activities with their students.

These training courses provided teachers with a set of protocols and guidelines and with technical knowledge about the equipment. The courses were more successful for some teachers than for others. They allow teachers to be familiar with the equipment but often the use of equipment was unsuccessful for students because of the reasons explained above.

How can we achieve an effective learning? How can the problems associated to the technical difficulties and shortage of materials (computers, sensors, microscope, projectors,…) be solved? Neither of these aspects was approached in the teacher training programme and they are very important to achieve an effective use of ICT.

Probably the reason is that teacher training model used didn't emphasize the didactic model and it is an important aspect to take into account. The teacher training was principally based on the equipment, and the guidelines were related to the curriculum subjects, but only 16-18 level.




During the development of the project “Effective use of ICT in Science Education” there was a change in the teacher training model of the Department of Education. This fact and the in-depth study of good ICT practices carried out during the project led to a new ICT teacher training approach.

## A teacher training model based on reflective practice

### What is a reflexive practice teacher training model?

Reflexive practice is a teacher training methodology based on the experience of each teacher in their own classroom and the reflexion* (reflexion: the outcome of reflexive thought) on their own practice. It’s a teacher training methodology that starts with the teacher and not from theoretical knowledge. This methodology takes into account personal and professional experience, its focus being to update and improve teacher performance. This teacher training model increases the teacher’s knowledge of the subject and at the same time, the didactic and pedagogical aspects of the subject. Moreover, this teacher training methodology aims to make teachers personally responsible for their future professional development by transforming reflexions on teaching practice into habits, thus integrating these into day to day activities.

In this teacher training methodology, the starting point is, as we have said, teaching practice in the classroom. What we plan to do is to analyse teachers’ own teaching practice, to reflex about it and to collectively construct some proposals to improve specific points where learning among their students has not been effective. The teacher training activities based on reflexive practice have to be carried out in small groups of teachers with a mentor-training teacher.

This teacher training focuses on peer to peer learning. The teacher trainers place themselves in the same situation as the other participants of the group, but at the same time they have the role of experts and when necessary deliver the theoretical information (articles, books, presentations,..).

To implement this methodology it is necessary to create what we call the “learning community”. That means that it’s necessary to work in a systematic way in order to develop the atmosphere for mutual confidence between the members of this learning group, because these community teachers will have to share experiences, to observe each other, to self-observe.

The nucleus of the teacher training activity is what we call the reflexive cycle or ALACT model that each participant has to experience as a member of the group.
The communications between the members of the group, and between them and the teacher trainer, are of primary importance. Because of this, communication has to be straightforward and kept up continuously. This is partly done through the use of an online network (Moodle) specially created and designed for these group work teams.

**Some important aspects about reflexive practice.**

There are 5 basic principles that act as the foundations of teacher training based on reflexive practice.

1) The starting points are questions about the teachers' own daily practice whereby participants on the training course try activities out in their own classrooms.
2) The teacher training aims to promote systematic reflexion.
3) Learning is an interactive and social process.
4) To distinguish between 3 teaching and learning elements (Gestalt, Framework (ttt) and Theory (TTT)) and to work to improve these three elements.
5) The participants have their own identity, so this teacher training promotes self-understanding and encourages participants to exercise control over their own professional development.

In the development of this teacher training model there are different phases. The ESET phase has 4 stages with specific requirements for participants:

- Experience: To choose some examples from their practice that they would like to improve. Participants have to think of a specific situation and ask themselves how do they perceive their performance (behaviour, conduct, results,..)
- Structure: To try to relate this example to other ones from a similar area.
- Framework: To create a framework. To look for a general pattern arising from the examples, including all the experiences.
- Theory: What is the participants' opinion of the framework (ttt)? What do the experts say? (TTT).Where can the participants find the theoretical and practical information that can help them to learn more about this framework?

**Learning from practice: theoretical framework**

The theoretical concepts in learning from practice can be summarized as follows:
Gestalts: Immediate teaching behaviour
Reflection: the ALACT-model
Co-construction: Comparison
Theory and theory: (TTT), (ttt)
Each theoretical concept is related to an element of a proposed structuring of reflexive learning. These elements were designed as phases in teacher education but they are also relevant and applicable in professional development programmes.
In this part the four elements of structuring reflexive learning in teacher training programmes are described.
These elements could be part of a setup of a teacher training programme. They are interdependent and interrelated, and they must not be perceived in isolation, there are interrelationships between them.
Each element focuses on an aspect of learning from practice. In the first element, Experiences, the focus is on the idea that experiences are important in connection with

learning from practice. The second element, Reflection, contains the mechanisms of systematic reflection in learning from practice. In the third element, Interactive learning, the specific role of the participants is illustrated, and in the fourth element, Learning from the theory, the idea of the role of theory in learning from experience is being discussed.

**Element 1: Experiences**

This element focuses on the essence of learning from practice. There are three kinds of experience: past experiences, more recent experiences, and new experiences. Past experiences are experiences that teachers formerly had as pupils and which now determine the parts of their Gestalts. More recent experiences are those they have in teaching and new Gestalts are formed. Creating new experiences, the Gestalts can be enriched separate from school experiences. The most important questions are “what is happening here’, and what sense does it make to me?”

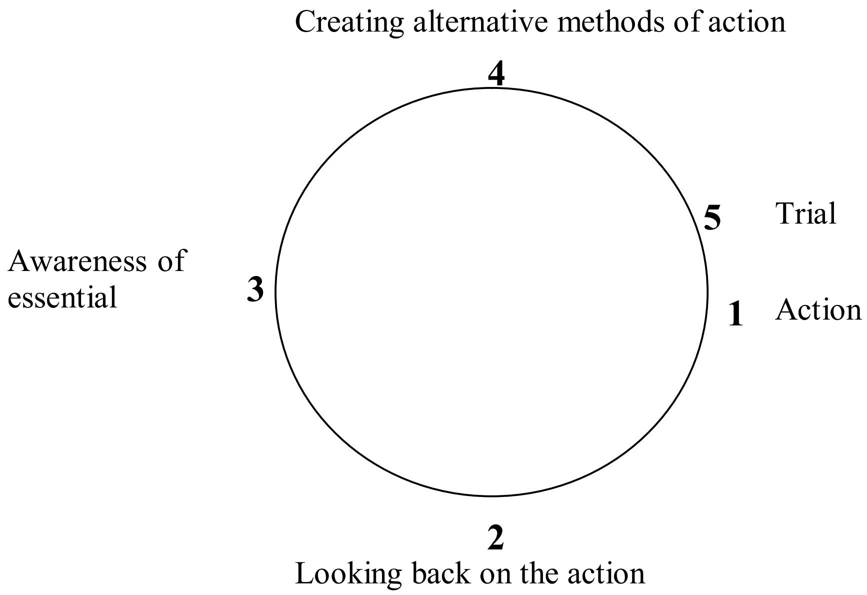
All these kinds of experiences are related to the immediate teaching behaviour. It means the small and large decisions that a teacher makes during a lesson period. These situations, in which teachers decide directly, are called immediate teaching situations. In working with recent experiences and explaining them, teachers will develop knwlege about the behaviour that their Gestalts will lead them into.

**Element 2: Reflection**

In this element, experiential learning is linked to reflective learning. This element consists of four components:

- Working with a logbook,
- Promoting structure in the learning from experiences: the ALACT model;
- Metareflection: it is important in the reflection process that once in a while-after a series of lessons- one reflects on one’s own development process.
- Promoting autonomy with the help of peer-learning.

The reflection model (Korthagen 1983)




**Element 3: Interaction**

In this element, learning from experiences is linked to the role of the group in learning (group dynamics and co-construction).
Within the learner group it is important to bring about an interaction called authentic interaction. For this, it must be ensured that individual reflection process is enriched by the mutually genuine interactions of all members of the learning community (participants and teacher trainers). The most important characteristic of such an interaction is that cognitive mental process are set in motion in the learner, of the kind that allow them to become conscious of themselves, of the outside world, and be open towards both.

**Element 4: Theory**

- The capital T Theory is the theory based on empirical research. It is a kind of theoretical knowledge that focuses more in thinking and knowing that on concrete teacher behaviour. It is often difficult to formulate a direct link between behavioural actions.
- The small t theory consists of the theoretical guidelines deeply rooted in teaching practice. This knowledge stems from practice and cannot always be scientifically proved. The main characteristic of small t theory is that it connects to needs of wanting instructions on how to act in practice: it focuses on acting in specific situations and is put together in conjuction with others situations. The objective is not to learn the theory by heart and then implement it, but to enhance the practice theories with contrast.

**The role of the teacher trainer.**

There are 4 main important and different roles: mentor, pedagogue, theoretician and role model. The trainer has four important responsibilities:

1) Mentoring the individual learning processes of the student teachers.

In this process, the most important fundamental attitude is the interest in each individual, with their specific learning-and life history
The trainer, as a mentor, acts as a supervisor for reflective activities, e.g. helping to structure experiences, provide security,
The role of the mentor is very important to the attitude towards teachers: open, empathic and accepting.

2) Classroom management in working with groups of students (pedagogue).

In working with a group, the trainer must be able to work flexibly with the different types of experiences. The trainer promotes many forms of interactive learning and they must establish a link between working with experiences and the training of skills. Te trainer has to enrichen and deepen experiences and also to train concrete skills.

3) Connecting practice and theory (theoretician).

The trainer should be able to explain the theory of Gestalts, connective experiences and the role of theory. The teacher trainer has to explain and use mechanisms of systematic reflections in discussions, during supervision and when helping teachers to learn from others.

4) Being a role model to the students.

Teacher trainer has to have the self-confidence to discuss his experience with learners, e.g. to be able to give examples of important events that have contributed to their development. The teacher trainer has to be able to reflect on one's own experiences and to learn from others.
So, the teacher trainer has:

- To be a mentor for participants
- To be flexible and use different styles of training (pedagogue)
- To be an expert in pedagogic theory (TTT) (theoretician) (e.g. the effective use of ICT)
- To be a role model for participants

**The Science Innovation Seminars: an example of teacher training courses to improve science learning.**

In the framework of reflexive practice teacher training, the Department of Education offered, for 2006-07 and 2007-08, science teacher training courses called "Science Innovation Seminars" for secondary school teachers. The main goal of these seminars, based on reflexive methodology, is to promote a professional process of improvement in science teachers. The seminars start from the participants' own teaching practice and promote shared work between peers by the creation and experimentation of innovative proposals in order to increase the motivation of, and the involvement of the students.
The Seminars want to promote reflexion by the participants around their experiences, to think about learning difficulties of the students, the possible causes of these, and to elaborate strategies to overcome these problems. The results of the research in science didactics are taken into account in this process.
Teacher trainers of these based on reflexive practice seminars had a trainers' course before performing them. The Science Innovation Seminars are the product of the teacher training methodology provided by the Department of Education of Catalonia and are an example of the implementation of this new teacher training methodology in the science education field.

## Looking for good ICT practice.

### Creating a teachers' network and analysing guidelines of ICT activities.

To look for the features of good ICT practice we worked with a group of secondary school science teachers using a method based on their own experience using ICT activities with their students.

The first stage of this work was for teachers to carry out activities following guidelines and analyse what was useful in the guidelines and which aspects could be improved. Teachers had to reflect on how the activities had been developed focusing on both positive aspects and difficulties encountered in using the guidelines.

The teacher team was formed by about 40 teachers, among of them there were Biology, Chemistry and Physic teachers of secondary school. The group of teachers carried out biology activities involving a digital microscope, and physics and chemistry activities using data loggers. There was a set of about twelve guidelines to practice with their students and to analyse later. Teacher could choose from the set of activities that were appropriate to their class. They analysed activities using a list of elements to be assessed and they had to answer questions after performing the activity. Those questions are written bellow:

About the guidelines for the activity:

- The context: Is it thought-provoking? Does stimulates discussion, predictions and hypothesis?
- Setting the experiment: Is it complicated? Is it efficient? Encourages participation?
- Carrying out the experiment: Does the time invested fit school schedule? What about the atmosphere during the experiment? Is it difficult? Does it stimulate pupils' autonomy?
- Analysis and conclusions: Do pupils do them? Do they go deeply into the topic? Do they compare variables? Are they related to the aims of the activity? Is the experience connected with its graphical representation?
- Generalization and application: Is the model behind the experiment evident? Is it easy to apply in different situations?

About the classroom dynamics:

- To what extent are pupils enthusiastic about the activity? (much, poor...)
- Does it stimulate peer discussion (among pupils)?
- Is group work efficient?
- To what extent are the groups working autonomously?

About the equipment, materials and space distribution in the classroom:

- Is it enough? Does it fit what is needed?
- Is the organisation of the classroom appropriate for the activity?

About the theoretical background:

- Is the topic under study relevant in the curriculum?
- Has the activity been done at the right moment in the course?
- Is it relevant? Is it the most appropriate? Is there a better activity?

About teachers' management:

- To what extent has the equipment been difficult to use?
- To what extent does the activity generate situations in which students have to explain those concepts and ideas that we expect to be learnt?
- To what extent the didactic guidelines solve the technical problems?

- To what extent the didactic guidelines solve methodological problems?
- How satisfied do you feel after doing this activity?

About pupils’ assessment: (grid for pupils)

- To what extent do they consider that this activity has helped them to improve in any aspect? Which?
- Theoretical contents
- Abilities and handling of lab tools, especially ICT
- Group work
- Interpreting results

To draw the conclusions of this work, we processed the information from activities which were tried out for at least 5 teachers, because we considered those results more representative. It is because of that, that the reported the analysis and conclusions are from the work carried out by 17 Chemistry and Physics teachers from 10 secondary schools and 7 Biology teachers from 6 secondary schools. Each teacher tried out one or more activity. Biology teachers tried out 3 activities using a digital microscope involving 84 students in total. The Biology, Chemistry and Physics activities are in the following table.

| **Selected tested activities** | **Subject/Age range/ICT** | **Number of teachers and schools** |
|---|---|---|
| To move in front of a position sensor. | Sciences / 12-16 / MBL | 10 teachers /<br>8 secondary schools |
| To drop an object and limit speed. | Physics / 16-18 / MBL | 7 teachers / 6 schools |
| To clean polluted water. | Chemistry / 16-18 / MBL | 5 teachers / 5 schools |
| Animal or plant cell?<br>(3 different models of activity and guidelines) | Biology/ 12-16/ digital microscope | 7 teachers / 6 schools |

Teachers followed activities as set out in the guidelines with their students. They also answered questionnaires to reflect on the usefulness of these guidelines and how the activities developed.
During this practice based period, teachers exchanged ideas and opinions and gave each other feedback about their experience.
Students has also analyse their performance with this grid.

| **TITTLE OF THE ACTIVITY:**<br>**LEVEL:** | | | | |
|---|---|---|---|---|
| ***For you, this activity...:*** | **not at all** | **poor** | **good** | **a lot** |
| – Has it been interesting, motivating? | | | | |
| – Has it been useful to improve your knowledge of the topic worked? | | | | |
| – Has it been useful to make clear some aspect that you hadn’t understood during the lesson? | | | | |
| – Does it stimulate your group work? | | | | |

| | | | | |
|---|---|---|---|---|
| | | | | |
| – Has it helped you to follow the guidelines without (or rarely) asking your teacher? | | | | |
| – Has it helped you to interpret the results (graphs, images....)? | | | | |
| **Did you have any problem with:** | | | | |
| – Understanding the aims of the activity? | | | | |
| – Setting up the experiment? | | | | |
| – Set up the computer system? | | | | |
| **Which section did you find more enjoyable?** | | | | |
| **Which section was the hardest to understand?** | | | | |
| **How much did you use your theoretical knowledge in order to solve the problem set in this activity?** | | | | |
| **How much do these lab tools (data loggers,….):** | | | | |
| – Make learning easier? | | | | |
| – Make things more difficult to learn? | | | | |
| **Write a short sentence with the conclusion of this activity** | | | | |
| **Add, if necessary, any suggestion and comments about the activity you've done:** | | | | |

The results of these grids also helped the teachers' team in drawing conclusions about good ICT, but these results are not included in this document, they may be the topic for a later report.

**Conclusions from the analysis of MBL and digital microscope guidelines.**

The general conclusions of this experimental phase, based on teacher and student opinions, are explained below.
(The format is conclusions followed by suggested solutions.)

- Activities within the guidelines are too long for the time proposed.
- Changes in the time tables of the activities could be introduced and if necessary long activities could be separated into two or more parts. For example the first session (before the experiment) could be classroom based and involve students thinking about the activity, brainstorming and hypothesizing about results.
- Students usually don't make predictions in spite of this aspect being present in the guidelines
- To include in the guidelines a form for students to make notes of their predictions. This way, teachers don't skip this part of the activity. This is

because there is more interest and better understanding if students make predictions before performing the experiment.

- The current instructions are difficult to understand especially for the younger students.
- To simplify them without making them too simple, so that the students still need to think as they work. The questions that students have to answer must be concise and not repetitive.
- Guidelines are generally very long because they include a lot of information. Students may be intimidated or confused between the instructions for the experiment and for the software.
- We plan to separate the software instructions and move them to the end of the manual as students may already be familiar with these instructions.
- There is also the possibility of putting the software instructions in the teacher's guide, in order for teachers to copy and place them by the computers.
- It is more effective when the laboratory materials for the experiments are easily set up and assembled because:
- Experiments can be done in class if the laboratory is not available
- Teachers spend less time getting materials, and it's cheaper
- Students can perform multiple experiments and collect more comparative data
- The easier the activity, the better the students can understand how the sensor and equipment works.

- The guidelines used, generally teach the students how to relate the context of the experiments to other situations. The experiments are based on principles that students can apply in other areas of learning.

Reading and interpreting graphs:

- Problems with students because they are not used to reading and interpreting charts. We plan to:
- Create specific activities to teach students to read and interpret actual graphs (real time graphs)
- Begin with simpler experiments and graphs
- Students need to be familiar with all kinds of graphs, not forgetting point graphs as well. These graphs can help them to understand how to optimize the mathematical function.
- Create a file of graphical images in order to share them among teachers and use with students.
- The activities need to correspond with topics students are learning in the classroom. The order of the activities in the didactic sequence is very important. Sometimes it's almost impossible to do the most suitable at the best moment.
- Teachers need suggestions on how to adapt instructions of the activities to their classroom syllabus and schedule. We will add these suggestions to the teachers guide.
- The students are very motivated during activities, but their interest decrease at the end of the activity. They aren't motivated to understand quantitative aspects, interpret graphs adequately, or to write a report of their conclusions.
- To find strategies that increase the interest and enthusiasm of students in these aspects. Some students are not naturally interested in science, so it's very difficult to motivate them with scientific learning. Perhaps, if there is a follow-

up assignment based on these qualitative aspects, graph interpretation or on their conclusive reports and graphs, they may feel the need to finish the work.
- There is not full agreement among the teachers about the best way to conduct the activity. Some teachers prefer that the students work in groups with limited help from the teacher. Others think it's best to intervene when the class is having a common problem and to conduct the students though the experiment.

Feedback from secondary biology teachers after trying out guidelines of activities using the digital microscope.
- The activities are well designed but they are too long for the time proposed for them.
- The management of the classroom depends on multiple factors. These factors include the number of computers and students, available material, the layout of the laboratory, ...
- Generally, students work with enthusiasm and a certain degree of autonomy.
- It is important that the activities begin with problem situations which students should resolve during the activity. The activities that have been used for students of 12-13 years old have turned out to be too difficult for them and they are more suitable for students of 14-15 years old.
- The students 12-13 years old do not have experience in the management of the digital microscope and need a session to familiarize themselves with it. In this way, they would get more from of the activities proposed for our project.
- It's very important that students carry out activities at the appropriate moment in the didactic sequence, especially in the activities for students 16-18 years old.
- The activities awake interest in the students and promote group work.

Feedback from students after taking part in the digital microscope activities. The students:
- Positively value the utilization of ICT and the experimental work
- Like these kind of activities but they need much more time to perform them.
- Do not have technical difficulties with the software relating to the microscope, although they encountered some problems preparing slides for the microscope.
- Aged 16-18 rated the activity positively and consider it helpful to relate the exercises in the lab with the concepts and theory. This combination of practical and theory helped them to understand the subject. These students identified well with the objectives of the activity.
- Aged 12-16, on the other hand, have difficulties in relating the exercises in the lab with the theoretical aspects. Many of these students consider the execution of the activity irrelevant in learning about the subject. These students have difficulties in understanding the objectives of the activity.

After the results of the 1st phase of experimentation and having reached conclusions, we know about which features of the guidelines were more important. The cooperative work between teachers of teams, and the individual and collective reflexive process provide interesting conclusions of the most important features of an ICT activity.

Moreover, an important aspect was noticed. How to plan the activity (adapting the activity to the specific didactic objectives and the level and previous knowledge of students) and how to manage the students during the activity was very important to improve learning. It's because of that, in the 2nd phase of experimentation the attention was focused on these aspects. (This will be deal with in more detail in section 3.4)

**Proposal of didactic guidelines when creating ICT classroom resources**

A the end of the 1st experimental phase, when guidelines of the activities where already analysed by the teacher team, a didactic guideline that could be taken into account to elaborate good ICT proposal of activities was designed with the aim of summarizing the results and conclusions.

-Advice for teachers to create the pupils' protocol for ICT laboratory activities and the didactic guidelines for the teacher-

The protocols for the suggested practical activities for pupils aged 12-16 and aged 16-18 should include the following listed sections. These guidelines can be adapted in a flexible way according to the level of students and the specific aims of the activity. A guideline for an activity should take into account:

1) Context of the activity

In order to set the proposed experience, the starting point should be a problem or daily fact relevant to the pupils. The aim is to provide references to pupils so that they can set out a question or a problem.

2) The question to ask or the problem to solve

The aim of this question is to make clear the aim of the activity. The number of aims of a practical activity should be kept low.

3) What will we do to solve the problem and how will it be done?

This section focuses on the perception of the problem and on how to decide the operative way to solve it (which variables take part, how to measure them, etc.) as well as the method to follow. It may have the following steps:

a) What do we know about the problem?

In this step we try to put in action the pupils' previous knowledge. It's the moment to raise questions: What do we know about......?

b) Which hypothesis?

This is the moment to set the hypothesis. If it is suitable for the activity, from the different opinions of pupils, we'll try to determine the variables of the process and to identify the independent and dependent variables. All of these will be raised from questions asked to the pupils in order to guide the discussion.

c) How do we do it?

From the opinions of pupils and their discussion, we'll try to elicit what to do during the activity. At his point it will be necessary to introduce those aims that have not arisen from the previous discussion which are, however, relevant for the activity.

4) Doing the experiment

We now ask the students to do the experiment. We can help them by giving some information and putting the following questions:

a) material and equipment
b) setting the experiment
c) predictions (when they are working with MBL, VBL or simulations, they should make predictions about the graph). Predicting is a good tool for students to show the aim of the activity. It's, therefore, very useful to include predictions in guidelines for practical activities. Time invested in them will help students to identify the aims of the activity.
d) Setting up the system according to the parameters needed when working with MBL/VBL activities (it will be necessary to give separate instructions about

selecting the appropriate sensor and/or video and their setting up of the data logging system (it's considered useless if included in the pupils guidelines).

e) Carrying out the experiment.

5) Analysing, processing and interpreting the data

Here we must find:

- a qualitative analysis of the data obtained (or of the expected results) to be done before the quantitative analysis
- data processing
- checking the previous hypothesis or predictions and, then, comparing them with actual results
- interpreting the results

6) Conclusions

The conclusion should answer the initial problem

7) Generalization and application to different situations

During this step we'll try to make clear the scientific model related with the proposed activity. It should also include proposals to be applied in a different context.

8) Communicating skills

It's very important to ask students to produce a report on the activity. This could be done by hand or on a computer. When working with MBL,VBL, it is suitable to export the graphs to the document.

*Didactic guidelines for teachers:*

It should explain how to guide students through the activity, emphasizing those aspects that help to build the knowledge and to transform the pupils' intuitive models into current scientific models.

It should also contain all the required technical guidelines. Any learning difficulty in the proposed activity should also be explained.

We understand that in order to take a step forward in the comprehension and construction of knowledge, the learning difficulties should be part of the didactic objectives of the activity.

**Analysis of classroom management: the use of video analysis as a key tool.**

We realised, after the first phase of the project, that one of the most important aspects to take into account when performing ICT activities with students is classroom management.

The same team of teachers that used guidelines in the lab kept on working to look for a good way to manage these ICT activities.

This work was also made by the teachers reflecting on their own practice when performing these activities.

Video analysis is one of the best ways to collect evidence of what happens in the classroom and to analyse many different aspects involved in the class management. This includes the performance of the teacher in the classroom. This technique is considered very useful when using reflexive teacher training methodology. It allows teachers to analyse themselves and have peer to peer feedback about their performance in the classroom and to look for evidence of the teaching and learning process.

Teachers had to reflect on their own practice. The other teacher participants in the group could also see recorded videos of their colleagues. This process is close to the aim of the

method used when learning from experience. They could learn peer to peer and from their answers to the video analysis questionnaires, conclusions were made.
When we say classroom management, we mean and understand different things: time management, the lay out of the classroom or lab, and the distribution of equipment in the case of experimental or computer work. Obviously, we include the teachers' behaviour in the different phases of the lesson and also the students' participation in individual or group work.
To carry out the video analysis it is very helpful to use an observation grid or questionnaire with questions about the organization of the environment, how does the teacher present the activity, the planning of the activity before carrying it out, the interactions between the students and between the students and the teacher, the organization of the activity in one or more lessons, the analysis of the results and the conclusions, to cap and to summarize the activity, and the feedback from the students.
.The next table shows the number of teachers engaged in this part of experimentation, the number of different activities performed and videos recorded. There were 15 films of teachers performing activities with their students.

Before recording videos some suggestions and recommendations for filming an ICT activity were given. These suggestions are:
Before starting:

- Setup of classroom or lab:
- Distribution of material
- Grouping of students
- Details of:
- Equipments (lab material, ICT material,...
- Assemble equipments (how the equipment is assembled, who assembles the equipment)
- how student do ICT set up (computer and data logging set up, sensors, microscope set up,...)

At the start:

- Presentation of the activity (how the teacher presents the activity, what the students are doing,…)
- Students making their predictions

During the session:

- Group working, teacher-students interactions
- Feedback from students
- Student-student interactions

At the end:

- Results and conclusions (what the students do; what the teacher does,..
- The end of the activity (some homework, ….).
- If the activity has to be continued film the next session (in the classroom, the computer classroom, lab,..)

**Conclusions about de classroom management using ICT**

The conclusions of the analysis of classroom management were raised after the video analysis. We focus the analysis into six selected video records (three MBL activities, one digital microscope activity, one VBL activity and one activity using simulation software).

In these videos were clear the different stages in the development of the activity. All the teachers of team analysed those videos through a questionnaire which included questions about: the lay out of classroom or lab, how the aims of the activity are presented, the context of the activity, how the activity has been planned, students' interactions and teachers' intervention, analysis of the results and conclusions, feedback from the classroom.

This questionnaire was also used in the teacher training course when participants analyse their own videos.

The conclusions of the analysis of classroom management using ICT activities can be summarized and grouped as follows:

- The lay out of classroom or lab (the organization of the environment)
- Students have to be placed in a way that everybody can see the computer monitor and the teacher.
- A lay out that promotes a good development of the activity is that student are sat in groups around the computer. This way the teacher can go near them if necessary.
- A lay out without with groups (without rows) can be difficult for teachers to explain to the whole classroom or lab, but this kind of lay out has advantages for group working.
- Students must be placed in a way that they can discuss the predictions, the results and the conclusions between them.
- How the aims of the activity are presented
- It is important that the students own the aims of the activity, so the teacher has to present them in a suitable way. It is useful to present the activity as a problem that students have to solve, or making some questions that allows students to understand the aim.
- The presentation of the aims has to be clear and concise and with the participation of students.
- It Isn't a good practice to read the aims to the students.  A long list of aims at the beginning of an activity makes no sense for the students.
- The context

Activities have to be presented in context and it's useful that teachers ask something about context in the beginning and during the activity.

- The relation between other activities and the integration of this activity in the learning cycle
- It is useful for teachers to make questions and comments to relate the activity with other ones in the same learning cycle or didactic sequence. This helps students to relate their present learning with previous experiences and to construct their own knowledge.
- Sometimes teachers perform ICT activities as an isolated activity with not clear connections with the other activities. It is much better to integrate them into a didactic sequence so that students realise this.
- Predictions and hypotheses
- It is highly recommended that teachers organize timing during activity and don't forget to spend the necessary time for students to make their predictions and hypotheses and for discussion amongst students in their group.
- It is also important to contrast those predictions and hypotheses with the results of the experiment to find an explanation.

- Teachers have to promote that the students contrast their results with their hypothesis and argue their conclusions. It is important that students share their results and ideas.
- Teachers have to be able to use the predictions and explanations of students in order to know the misconceptions of the students and to help the students to overcome their learning difficulties.
- Autonomous work
- It is appropriate that the teachers help the students to work in an autonomous way. This is an important competence that students have to develop.
- Teachers should promote deductive learning where teacher guides the student towards the answers. They have to promote a dialogue between student and teacher, that conduct the students to overcome their difficulties, solve problems and construct learning. Teachers could ask students what are they doing? Why are they doing it this way?
- Sometimes it can be necessary for some explanation to the whole classroom.
- Teachers' intervention
- It is appropriate that the interventions of teacher be making questions that student can answer by themselves in order to overcome difficulties, as what is called deductive teaching (Socratic dialogue).
- When teachers ask the questions they have to remember to wait some time before answering, this way the student will try to answer the question.
- The role of the teacher has to be interactive, asking questions to make students think of the answer, more than a teacher giving a lot of instructions, telling results before performing experiment,..

- About the guidelines
- Obviously guidelines are also important and it is convenient that teachers known them before performing the activity, and if necessary to adapt them to the specific didactic objective of the activity in the learning cycle.
- Guidelines for students have to be short and concise. Students don't have a long time to read them because there isn't much long time to perform the activity.
- It is recommended that students, especially those students aged 16-18 have the guidelines some days before performing the activity. This way they could own the aims.
- A good possibility, especially for students aged 16-18, is that the guidelines are on an interactive website.
- Technical instructions are sometimes necessary, especially if it is the first time that student use that kind of ICT (sensor, digital microscope,..). It is better to include them at the end of the guidelines or in some instruction documents displayed near the computers or equipment.

## The design of an ICT teacher training module

### The foundations of the course

The design of the teacher training course in order to improve the effective use of ICT takes into account the following aspects:

1) The conclusions of the analysis of guidelines of activities and the conclusions of video analysis of the classroom management. It means the conclusions of the work about how to plan ICT activities and the classroom management in order to look for the best ICT practice carried out during the project. The didactic model for the effective use of ICT comes from the conclusions drawn from the work in the project.
2) The teacher training model, based on reflexive practice, implemented by the Department of Education, to improve the teaching and learning in different curricular areas, and especially in the new teacher training methodology used in the Seminars of Innovation in Science. So there was the idea of the reflexive practice in the design of the course.
3) The aims of the "Effective use of ICT in Science Education" project that after feedback between partners of the project, points at the design of a teacher training pilot module of about 20 hours (included sessions with participants and autonomous participants' work).

### Characteristics of the course

The teacher training course created for the project: **"Effective use of ICT in Science education EUISE"**

- A course for science teachers (Biology, Chemistry and Physics) at secondary school.
- All the participants will have used ICT resources (data logging, digital microscope, VBL or computer simulation) because they need some basic knowledge about technical issues.
- The aim of the course is to help the participants in the improvement of the planning and management of ICT activities. There is only a small part of the course for technical aspects.
- The course takes the teachers own experience in using ICT with their pupils and looks to arrive at a consensus of what features make good management of ICT activities. The participants will see and analyse films of teachers in action, they will plan ICT activities in groups or individually, they will do activities with their students and will film their own classroom ICT session.
- Methods used during sessions are a variety of analysis and comparative methods (individual reflections, discussions, presentations, group work, feedback,.. ).
- The course consists of 4 sessions (10 h contact time) and 10 hours non-contact time. Session 1, 2 and 3 can be run consecutively but there must be a break of 6 weeks between sessions 3 and 4.
- The non-contact work consists of :
- To plan an activity that can be done with their students. It may be the same activity participants have already planned working in groups during the course or they have already seen in the videos.

- Film all or part of the chosen activity taking into account aspects of good management of ICT activities and model videos.
- Keep in touch with the teacher trainer and the participants of the group by using Moodle and to keep using it after the course.

**The aims of the course**

Each session has a specific aim and each activity included in the session has also a specific objective. Below we explain aims and objectives of each session and each activity.
*Session 1:* To start with the teachers own experiences in order to reach a consensus about the features of a successful ICT activity.
Specific objectives of the activities in this course session:

- To start building a positive learning environment (the community of learners).
- To reflect on teacher's own experience in the use of ICT .
- To categorize the different aspect that must be taken into account when doing ICT activities.
- To reach a conclusion about features of successful ICT activities.

*Session 2*: To experiment with ICT resources (data logging, video based laboratory, digital microscope or computer simulations) to plan an activity based on these resources.
Specific objectives of the activities in this course session:

- To familiarize themselves with the different technical aspects of the use of ICT.
- To reflect on their own experience to reach conclusions about what means to plan an ICT activity well.
- To plan an activity based on the ICT resource that they had previously experimented with in the first part of this session.

*Session 3:* To emphasize the importance of a good planning and management in using ICT by comparing the plan of the participants along with films.
Specific objectives of the activities in this course session:

- To share the work done with all the participants.
- Show some model examples of ways to manage ICT activities.
- To compare their planned activities with the management observed in the films.

*Session 4:* To exchange feedback about participant's films and to arrive at some concrete proposals to use in the future for the continuing development of good practices along with using Moodle as a way of exchanging and improving the use of ICT.
Specific objectives of the activities in this course session:

- To share results and realizations that they have had since the course started.
- To share observations of the films in order to increase knowledge.
- Express how the course has helped you and your considerations for future development.
- 

**The activities of the course**

There is a set of activities in the four sessions of the course; a set of documents to help teacher trainers during the course; and homework between the sessions. Each activity has a worksheet for the participant and a document for the teacher trainer, if necessary. The documents to help the trainer were created by using the conclusions of the 1st and 2nd experimental phase of the project. The titles of the worksheets and documents are listed bellow:

**Session 1:**
**Worksheet P2: "My experience in the use of ICT is…"**
Individual and group worksheet.
**Document F2: "Aspects that can turn up when valuating the success of an ICT activity"** Document to help the trainer in this activity. Based on "Elements to be assessed in an ICT activity" used in the script analysis (1st phase of the project).
**Worksheets P3: "What makes an ICT activity successful?**
Individual and group worksheet
**Document F3: "Relevant aspects of the use of ICT activities".** Based on the Biology report and the Chemistry and Physics report with the conclusions of the script analysis (1st phase of the project).

**Session 2:**
**Documents P4/F4** Some instruction sheets or activities proposal.
**Worksheet P5. "What does mean to plan an ICT activity?"** Worksheet for the individual work and the work group. It contains too a space to fill in during the feedback.
**Document F5: "What has to be took into account when planning an ICT activity".**
Summary of the aspects to consider in the planning of an ICT activity.
**Worksheet P6: "Our proposal for the management of the planned ICT activity is...."**
Group worksheet. It contains questions about the planning and management of the activity based on the instruction sheet used at the beginning of this session. It contains spaces to fill in where each group writes the answers.

**Session 3:**
**Document F7: "Example of planned activity"**
This is an example of a planned activity among the activities options on Documents P4 (session 2)
**Video selection.** (20 min aprox for each kind of ICT). It's recommended that they contain the same activities that participants have done in session 2.
**Worksheets P8 (P8-1-; P8-2-; P8-3, P8-4):** Set of questions to help participants to observe and analyse films. A worksheet for each video.
**Documents F8(F8-1-;F8-2-;F8-3-;F8-4-;F8-5):** Worksheets P8 with the answer of the questions.
**Worksheet P9 (1): "What did I see in the video that I didn't take into account in my plan?"**
Worksheet for individual work.
**Worksheet P9 (2) "What would I change after seeing the video and comparing it with my plan?**
Worksheet for group working.
**Worksheet P10(1): "What have you achieved? What do you want to improve on?**
Worksheet for individual work.

**Session 4:**

**Worksheet P10(2) "The most interesting aspects of the activities that participants of this group have done"**
Worksheet for group working.
**Worksheet P11(1) "Film analysis grid".** This grid is used by teachers experimenting in this project to analyse videos recorded by other experimenting teachers.
**Worksheet P11(2) "What can I take from the film that hill help me in the classroom?**
Worksheet for individual work.
**Document F11 "Points to remember for good ICT management".** Conclusions report of the analysis of videos of the teachers experimenting in the project.
**Worksheet P12 "Course evaluation: part of I have learned and what's next"**
Worksheet for individual and group work.

**Homework between sessions 2 and 3:**

To finish the task in the second session that wasn't completed during the session.
The corresponding participants for teach task has to upload the proposal (using what the group has write in worksheet P6 "Our proposal for management of the planned activity is….and to prepare presentation for the next session.

**Homework between sessions 3 and 4:**

To plan an activity that can be done with their students. It may be the same activity they have already planned or that they have already seen in the videos.
To film all or part of the chosen activity taking into account the advice on document F8 and also the model videos. Send or upload the film to the teacher trainer.
To keep in touch with teacher trainers and the participants of the group by using Moodle.

**Work after the course:**

To continue the experience exchange through Moodle.
To continue working together and to keep learning with greater depth in the use of ICT activities.

**General plan of the course**

| SESSION 1<br>Timing 2 h<br>To start with teacher own experiences in order to reach a consensus about the features of a successful ICT activity. | | | |
|---|---|---|---|
| Activity | GOALS | METHODS | MATERIAL |
| 30 min | To start building a positive learning environment (the community of learners). | Each participant introduce themselves (name, speciality, school,…) and briefly summarize their expectations of this teacher training course. The trainer introduce himself and explain the goals and structure of the teacher training course and try to accommodate them with the expectations of the participants.<br>Depending on the number of participants, it might be useful a previous group work to take easier the feedback about the expectations from participants. | **"Teacher training course. Effective use of ICT in Science educations. Goals and features.**<br>Optional: Presentation cards of the participants wher could write their name, speciality and school. They can use them in the other sessions. |
| 30 min | To reflect on teacher's own experience in the use of ICT . | A) Individual work: To get an understanding of the experiences of participants' use of ICT by asking about their positive and negative experiences and explaining the motives and reasons. The participants have to think and write an ICT activity that goes well in classroom and then think and write 2nd activity that they don't feel completely satisfied with. Write the reasons for the good activity, and the reasons for 2nd activity going not well.<br>B) Small group work: The participants explain to each other what they have written, compare reasons and write about common experiences. | **Worksheet P2: "My experience in the use of ICT is…"**<br>Individual and group worksheet.. |
| 20 | To categorize the different aspect that must be taken into account when doing ICT activities. | Feedback from the previous activity. The trainer receives feedback from groups asking participants to give reasons for activities how well did or didn't work. This is to look at what aspects should be taken into account when doing an ICT activity and will look to categorize and classify different items depending on the type of aspect. The document F2 can help the trainer in this part of the activity. | **Document F2: "Aspects that can turn up when valuating the success of an ICT activity"** Document to help the trainer in this activity. Based on **"Elements to be assessed in an ICT activity"** used in the script analysis (1st phase of the project). |

| | | | |
|---|---|---|---|
| min | | | |
| 40 min | To reach a conclusion about features of successful ICT activities. | A) Individual work: Ask the participants to answer the question "What makes an ICT activity successful?<br>B) Small group work: Participants explain to each other and compare what they have written. They look for common aspects and write them in order of importance.<br>C) Feedback. The trainer promotes an abstraction and synthetic process to get conclusions of the features of the good ICT activities. The document F3 can help the trainer in this part of the activity. | **Worksheets P3: "What makes an ICT activity successful?**<br>Individual and group worksheet<br>**Document F3: "Relevant aspects of the use of ICT activities".** Based on the Biology report and the Chemistry and Physics report with the conclusions of the script analysis (1st phase of the project). |

| SESSION 2<br>Timing 3 h<br>To experiment with ICT resources (data logging, video based laboratory, digital microscope or computer simulations) to plan an activity based on these resources. | | | |
|---|---|---|---|
| Activit y | GOALS | METHODS | MATERIAL |
| 80 min | To familiarize themselves with the different technical aspects of the use of ICT. | The participants are to choose an ICT resource (sensors, digital microscope, video digital or computer simulations) and work in a group using the same equipment and following the same protocol. They can choose between 8 instruction sheets (4 ICT types and 2 instruction sheets or activities proposal for each ICT) Group work to follow the protocol and learn about the technical aspects. | **Documents P4/F4** Some instruction sheets or activities proposal. |
| 50 min | To reflect on their own experience to reach conclusions about what means to plan an ICT activity well. | A) Individual work: Ask the participants to aswer the question "What does mean to plan an ICT activity (worksheet P5).<br>B) Work group: work in small groups to look for the common aspects in individual reflections.<br>C) Feedback session with the group to reach conclusions about what should be taken into account when planning and ICT activity. Document F5 may be used for helping the teacher trainer in this feedback session. | **Worksheet P5. "What does mean to plan an ICT activity?"** Worksheet for the individual work and the work group. It contains too an space to fill in during the feedback.<br>**Document F5: "What has to be took into account when planning an ICT activity".** Summary of the aspects to consider in the planning of an ICT activity. |

| | | | |
|---|---|---|---|
| 50 min | To plan an activity based on the ICT resource that they had previously experimented with in the first part of this session | A) Work group. The students of activity 4 work together in the previous groups and plan a learning activity with an appropriate goal and level. They have to explain the way they manage the activity, what kind of worksheet they will give to the students,… They must take into account the conclusions of the feedback and fill out worksheet P6.<br>A possible way of management: One person has to fill out worksheet P6 with the proposal. Another person has to write up proposal and upload to moodle. Remainder of the group wil present the proposal in the next session. | **Worksheet P6: "Our proposal for the management of the planned ICT activity is...."**<br>Group worksheet. It contains questions about the planning and management of the activity based on the instruction sheet used at the beginning of this session. It contains spaces to fill in where each group writes the answers. |
| HOMEWORK | Finish the task of the second session that you didn't complete during the session.<br>The corresponding participants for teach task has to upload the proposal (using what the group has write in worksheet P6 "Our proposal for management of the planned activity is….and to prepare presentation for the next session. | | **Support documents :**<br>**Basic instructions on how to use Moodle.** (way of how to register in a course, upload documents, forum participation,…) |

SESSION 3
Timing 3 h
To emphazise the importance of a good planning and management in using ICT by comparing the plan of the participants allong with films.

| Activity | GOALS | METHODS | MATERIAL |
|---|---|---|---|
| 40 min | To share the work done with all the participants. | Representatives of each group present their proposal for the planned activity that has already been upload to the Moodle.<br>They can do it using Power Point or an OHP. (each group has 5 min approximately). | **Document F7: "Example of planned activity"**<br>This is an example of a planned activity among the activities options on Documents P4 (session 2) |
| | Show some model examples of ways to manage ICT activities. | A) To watch videos with example of teachers in action..<br>B) Each participant completes form P8 that corresponds to their chosen ICT activity. There is a worksheet for each video.<br>C) Feedback from the participants about the most important | **Video selection.** (20 min aprox for each kind of ICT). It's recommended that they contain the same activities that participants have done in session 2. |

| | | | |
|---|---|---|---|
| 100 min | | aspects. Document F8 may help the teacher trainer. | **Worksheets P8 (P8-1-; P8-2-; P8-3, P8-4):** Set of questions to help participants to observe and analyse films. A worksheet for each video.<br>**Documents F8(F8-1-;F8-2-;F8-3-;F8-4-;F8-**5): Worksheets P8 with the answer of the questions. |
| 40 min | To compare their planned activities with the management observed in the films. | A) Each participant complete worksheet P9 (1).<br>B) Group work: feedback of the answers of worksheet P9 (1) and suggest changes to replan the activity using the worksheet P9 (2).<br>B) One or two groups to explain to the whole group their proposed changes in the new planned activity.<br><br>In some cases the initial planned activity may be the same that some of the activities shown in the films, in other cases not, The teacher trainer choose the activities with the most interesting suggestions of change to be presented to the whole group. | **Worksheet P9 (1): "What did I see in the video that I didn't take into account in my plan?"**<br>Worksheet for individual work.<br>**Worksheet P9 (2) "What would I change after seeing the video and comparing it with my plan?**<br>Worksheet for group working. |
| HOME WORK | Plan an activity that can be done with their students. It may be the same activity you have already planned or that you have already seen in the videos.<br>Fill all or part of the chosen activity taking into account the advice on document F8 and also the model videos. Send or upload the film to the teacher trainer. Keep in touch with the teacher trainer and the participants of the group by using Moodle.. | | **Support documents:**<br>**"What and how to film an ICT activity. Orientations and ,…….l** |

| SESSIÓN 4 (6 weeks later)<br>Timing 2 h<br>To exchange feedback about participant's films and to arrive at some concrete proposals to use in the the future for the continuing development of good practices along with using moodle as a way of exchanging and improving the use of ICT. | | | |
|---|---|---|---|
| Activity | GOALS | METHODS | MATERIAL |
| 30 min | To share results and realizations that they have had since the course started. | A) Work group: The participants fill out worksheet P10(1) to show two aspects they have taken into account when planning ICT activity for their students and that they haven't taken into account at the start of the course. To explain the difficulties they experienced and what they want to improve on.<br>B) Work group. The participants briefly explain the activities they have done and they have written about in worksheet P10(1). They have to look for common aspects and write them in worksheet P10 (2).<br>C) Feedback as a group and write up th feedback in worksheet P10 (2). | **Worksheet P10(1): "What have you achieved? What do you want to improve on?**<br>Worksheet for individual work.<br><br>**Worksheet P10(2) "The most interesting aspects of the activities that participants of this group have done"**<br>Worksheet for group working. |
| 60 min | To share observations of the films in order to increase knowledge. | A) The participants previously read worksheet P11 (1). They see a selection of films from participants and complete film analysis grid with the observations of what they have seen in the videos. (There will be some time (3-4 min) to answer sheets after each video).<br>B) Individual work: they answer worksheet P11(2) to express what they have see in films that they can apply to their own practice.<br>C) Feedback to discuss the contents of worksheet P11(2) and to promote the learning process with the experiences of other participants. Document F11 may be used for helping the teacher trainer in this feedback session. | **Worksheet P11(1) "Film analysis grid".** This grid is used by teachers experimenting in this project to analyse videos recorded by other experimenting teachers.<br>**Worksheet P11(2) "What can I take from the film that hill help me in the classroom?**<br>Worksheet for individual work.<br>**Document F11 "Points to remember for good ICT management".** Conclusions report of the analysis of videos of the teachers experimenting in the project. |

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|---|---|---|---|
| 30 min | Express how the course has helped you and your considerations for future development. | A) Individual work. Answer worksheet P12 with questions about what they have taken away from the course, what problems remain and their proposal for ongoing learning in the use of ICT.<br>B) Group work. Feedback to discuss worksheet P12 in a small group.<br>C) Feedback group. The representative of each group explains the future interests for the participants of this group. | **Worksheet P12 "Course evaluation: part of I have learned and what's next"**<br>Worksheet for individual and group work. |
| HOME WORK | Continue experience exchange through the Moodle..<br>Continue working together and keep learning with greater depth in the use of ICT activities. | | |

**The evaluation of the course and conclusions**

*Feedback from the trainers*

After performing the pilot teacher training course, feedback from the trainers allow some conclusions to be made.

There were no problems with the activities of the course and the general development. The trainers felt satisfied with the course but the time planned for some activities was too short, and it is because of that, that some activities were not completely finished. Sometimes these sessions overrun a few minutes.

There is the possibility to enlarge the time schedule for each session. Sessions of three or three and a half hour would allow them to finish and to reflect on the activities that in the pilot course were not completely finished.

Participants had to do a lot of homework. For this kind of work some extra hours could be added.

*Feedback from teacher participants*

After the pilot course we have put together what participants wrote in the worksheet P12 used in the last session of the course. Participants were satisfied with the course and would like to keep on working together.

**Worksheet P12**

**"Course evaluation: part of I have learned and what's next"**

*a) Individual work*

| **In what specific way has the course helped me?** |
|---|
| **The teachers wrote suggestions and comments about the didactic model and about the technical aspects of the use of the ICT equipment.**<br>**….about ITC, the course has helped me:**<br>**- To take into account what is necessary to plan the activity well and to incorporate them at the most appropriate moment of the learning cycle**<br>**- To design and create ICT activities**<br>**- To take into account previous aspects of the performance of the activity: to plan, to formulate objectives,.. and aspects after the performance of the activity: the assessment, post-activities,..**<br>**- To be able to find more possibilities about how to use the ICT equipment, and be less afraid about the use of sensors of the MBL equipment.**<br>**- To incorporate in a real and effective way ICT activities in the science lessons** |
| **What parts of this course are relevant and can be used in my classroom?** |

| |
|---|
| **The suggestions and comments of the teachers are about their own practice and to share experiences with other teachers when group working in this course.**<br>**… teachers wrote what they have achieved with this course…**<br>**- A better technical ability to use sensors of MBL**<br>**- New kinds of laboratory activities**<br>**- The possibility of using activities with simulations in their lessons**<br>**- To video record an own activity with their students**<br>**- The usefulness and enrichment when group working**<br>**- Didactic strategies to plan and to manage ICT activities in classroom** |
| **What are already your principal difficulties in using ICT?** |
| **- Teachers think that the most important difficulty is the technical resources, they are not enough and not very good quality. Also to find an appropriate layout of the lab, to choose the most suitable activities, and the time management.**<br>**- They also think that an important difficulty is to "change their teachers' minds" and to promote the necessity of the use of ICT**<br>**- To use really effective ICT activities, so that students have to think and construct learning** |
| **How and what aspect would you like to keep working on to improve your use of ICT?** |
| **- Some of the teachers think that they need to learn more didactic aspects, while some others say that they need more technical courses**<br>**- They would like to keep on group working, in a similar environment as during the course, with the aims of developing and improving knowledge to develop new ideas in their teacher practice.** |

*b) Group work and feedback.*

| **What would you like to keep working on to continue to improve and develop your skills with ITC?** |
|---|
| **- They would need more sessions to experiment more activities. There was not enough time to design activities neither to draw conclusions (especially).**<br>**- To perform another course of these characteristics to depth and to enlarge knowledge in this kind of use of ICT (better a longer course)**<br>**- To keep the ideas and experiences exchange between teachers and group working**<br>**- To find and to establish an evaluation system to objectively compare the effect of the use of ICT, would be interesting**<br>**- To create ICT activities on the context of environmental chemistry related to biology and science of the Hearth. This way, activities would be more inter-subject.**<br>**- To keep on working with the group because it has been a very interesting and enriching activity. The group work has been enjoyable.** |

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## Microcomputer Based Laboratories in Czech Science Education

*Pavel Pešat*

The Microcomputer Based Laboratory (MBL) is a deep-seated term for a system that integrates hardware and software tools for measurement, control, data processing and modelling in science education. These tools are universal and can be used in different science subjects such as biology, chemistry, physics, or mathematics, with many different curricula. Although the computing power of modern personal computers exceeds the potential of microcomputers from the 1970s by many orders of magnitude, the word *microcomputer* is still used in the traditional sense of a computer that fits into one working place with one experimental set-up.

First attempts to build up a measuring system based on a microcomputer with an 8080 processor (like Sinclair ZX Spectrum or Commodore 64) appeared in Czechoslovakia in the 1970s[9]. Computer-controlled (an 8-bit one like IQ 151 or PMD) experimental assemblies were introduced into science (especially physics) training laboratories at nearly all faculties preparing future physics teachers in the late 1980s[10]. Conferences[11] were organised to share experience of computers in science education. Companies making laboratory equipment produced computer-controlled devices like the IQ 151 controlled air track[12] for primary and secondary schools. Hence, the situation was ready for more powerful computers based on the IBM PC XT/AT standard and much more sophisticated electronic appliances that came on the market at the end of 1980s.

In the mid-1990s there were several MBL systems ready for use (or under large-scale development) in science teaching at primary and secondary schools and teacher training faculties. However, not all of them were equally successful in the educational market nor consequently found their way into schools.

### Intelligent School Experimental System ISES

The school experimental system ISES was developed by Lustig and members of his team at the Faculty of Mathematics and Physics, Charles University, Prague, and nowadays it is the most wide-spread MBL system in Czech schools. There were more than 500 sets sold to schools in last 15 years, especially to secondary schools and universities. Usually there is one ISES set per classroom, but there are physics laboratories fully equipped with MBL ISES, e.g. Nad Štolou grammar school in Prague with 12 sets, M. Lerch grammar school in Brno with 10 sets and Kyjov grammar school with 7 sets of ISES Professional. Annual meetings of ISES users are organised to support the use of the MBL ISES in science education.

The ISES system itself consists of:

- the commercially available interface board with A/D and D/A converters for ISA or PCI slot mounted into the PC motherboard,
- an ISES control panel connected to the interface board by a special cable,
- a set of sensors connected to the control panel,
- necessary wiring cables,
- supporting software that controls the hardware and provides basic tools for data-processing and control,
- teaching materials.

There are two main types of ISES sets called Basic ISES and ISES Professional that differ in accuracy and data transfer speed. The ISES has four input channels, and one to two controlled

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9 ISES website

10 Petřík, Lustig, Šťastný

11 Conference „Elektronizace v přípravě budoucích učitelů fyziky“

12 Špulák: Air track experiments

output channels. Just this output channel can be used as a programmable voltage supply to feed the AC circuits, what is an advantage. The hardware is controlled by ISES software that is still available in the version ISESWIN (Basic ISES, for DOS or non NT Windows) or version ISESWIN32i (ISES Professional, NT-based Windows). Up to 2006 there was no USB version available, the serial COM connected version came to the end in 2000. A big effort was made to develop a so-called remote controlled ISES laboratory that helps teacher to perform a live and real physical experiment placed in the distant laboratory site and controlled from his school via the Internet[13]. Technical specifications of the system, individual sensors and proposals for teaching experiments are available at the ISES website[14].

**Coach**

Another MBL system used here in Czech schools called Coach was developed by the team of Ellermeijer at CMA Amsterdam[15], which is an enterprise arm for the Science and Technology Education Resources developed by the AMSTEL Institute of the Faculty FNWI (Faculty of Science, Mathematics and Informatics) of the University of Amsterdam. The total amount of Coach MBLs sold to Czech schools is about 150 altogether. There are several sets at most physics education departments at teacher training faculties, at secondary schools there are several science labs equipped with 3 or 4 Coach sets (F. X. Šaldy grammar school in Liberec, the Secondary School for applied cybernetics at Hradec Králové) or just by one set used by the teacher to demonstrate experiments.

There are many brands of CMA interfaces supported by Coach software, e.g. the 4-channel ULAB that works as a datalogger as well and supports both on-line and off-line measurement, CoachLab2+ for on-line measurement and simple control as well as interfaces by Texas Instruments (e.g. CBL), Vernier and Lego. CMA interfaces can handle many sensors; some of them are of the unique CMA origin, other manufacturers make some of them for CMA.

The big advantage of the Coach 5 software is the integration of authoring tools giving teachers the possibility to develop their own teaching projects for demonstration purposes as well as for individual research projects by students. This project approach was elaborated in detail for learning mechanics[16]. However, Coach 5 is just a 16-bit application for Windows, what sets limits to its properties. Coach 6 as an extended, enhanced 32-bit application was expected by autumn 2006. The MBL Coach is a very complex system which makes it difficult for some teachers. Technical specifications of the Coach MBL, interfaces, sensors and proposals for teaching experiments are available at the CMA website[17].

**ComLab**

The main objective of the ComLab[18] project coordinated by Kocijancic from University of Ljubljana, Slovenia was to integrate different ICT tools in science and technology teaching. Two aspects were emphasised: "Real laboratory" exercises, based on a computer data acquisition and control system, and "Virtual laboratory" activities, based on computer simulations of various science phenomena. For real laboratory purposes, the system combines its own data acquisition and control system ComLab2 with Vernier[19] sensors or user-made sensors. The eProLab programme supports real-time experiments utilising the data acquisition systems developed within the ComLab project. The ComLab MBL system is introduced through a partnership with the Department of Physics of the University of Ostrava. New teaching materials were developed, some other adopted and Koníček tested the whole

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13 Remote controlled laboratories ISES in English: http://www.ises.info/default_a.htm
14 ISES website in Czech: http://kdt-12.karlov.mff.cuni.cz/index1.html
15 CMA homepage in English: http://www.cma.science.uva.nl/english/
16 Pešat 2001
17 CMA homepage in English: http://www.cma.science.uva.nl/english/
18 ComLab homepage in English: http://www.e-prolab.com/comlab/index.html
19 ComLab homepage in English: http://www.vernier.com/

system[20] in real school life at grammar schools in the Ostrava region. At the moment the MBL ComLab, which is relatively cheap compared to ISES or Coach, equips just several schools.

**Intelligent measuring units for sound cards**

Petřík at Faculty of Education in Plzeň developed an intelligent measuring system based on PC sound cards[21]. The idea was to ground the MBL system on A/D and D/A circuits that are used in PC sound cards. Fully operational software converting the sound card into an oscilloscope was combined with simple electronic unit with ammeter shunts and voltage dividers. However, to use this system in science teaching required implementation of other sensors that had to be adjusted to the system by the teacher. The scale of ready hands-on experiments was relatively small and was not extended sufficiently to correspond to the whole science curriculum. Although the system was designed as a universal voltage oscilloscope that can be used while teaching many topics in physics, it did not spread significantly to schools.

**Robolab**

There were several educational projects carried out by Czech primary and secondary schools to introduce the LEGO products, especially Robolab[22], into the science education. These projects were granted within the SIPVZ policy (state information policy in education). However, it was found that the LEGO systems do not fit sufficiently well to the Czech physics curricula, and are better suited to an appropriate position in IT education, and further attempts in school physics are probably less likely.

**Leybold, Pasco, Phywe, Phillip Harris, Vernier …**

MBL systems developed by Leybold, Pasco, Phywe, Phillip Harris, and Vernier etc. are available on the Czech market for schools too. Relatively high prices prevent them from use in Czech primary and secondary schools. Several such pieces of MBL were bought by research teams at departments of physics education at Czech universities, especially such appliances that are unique and unavailable within systems like ISES or Coach, e.g. 3 dimensional sensor by Pasco.

**Educational resources of experiments for MBL**

MBL systems of all the main producers are accompanied by user manuals with detailed descriptions of experiments for setting-up corresponding to their own product. A different approach was realised by the team of Lustigová that developed the educational portal TELMAE[23]. Descriptions of many MBL experiments can be found there including information about set-up, settings, measurement conditions etc.
A broader overview about ICT implementation into the science education can be found in the study file by Koníček[24], too.

**Experience with MBL systems in Czech schools**

MBL systems in physics teaching are widely used in Czech secondary schools since 1995. At the primary school level the MBL systems are still considered by teachers to be too advanced. Future teachers are prepared how to use MBL systems and MBL-based experiments in lessons. The majority of grammar schools have at least one MBL system available for teaching physics. As a result, students coming from schools to universities refer to the positive and motivating impact of MBL - supported teaching of physics. Opposite to that, we

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20 Koníček 2005
21 Petřík 2000
22 RoboLab webpage in Czech: http://www.eduxe.cz/legomenu/robolab/lmfs_rcx.htm
23 Telmae in English: http://telmae.karlov.mff.cuni.cz/welcome.nsf/welcomeEN?OpenPage
24 Koníček 2003

still do not have any thorough educational project investigating the quantitative improvement of student skills or knowledge in physics. The improvement caused by MBL systems is sometimes covered by other effects like less experimental skills or worse preparedness of teachers to use MBL systems and ICT generally in teaching physics. However, testing the ICT skills and MBL experiments within the school leaving examinations can be expected in the near future (e.g. similar to the Netherlands) and Czech teachers and students have to be in step with others.

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[9] *Školská fyzika. Praktický časopis pro výuku fyziky,* cit 2006-06-11, url<http://www.pef.zcu.cz/pef/kof/cz/sf/mincisla.htm>

## One small, but significant step in science education in Slovakia

*Peter Demkanin*


### Abstract

The *next few pages bring information about the methodology and results of the work on the EUISE project in Slovakia. The current state of science education is mentioned within the introduction and the use of ICT in science education and a brief history of MBL and ICT tolls in science education is presented. In the following sections the main goals of the EUISE project in Slovakia are presented, interwoven with the partial results. Examples of effective timetables of teacher training are presented. The idea of experiments planned directly by the pupils is one of main advantages of using MBL tools so one example of such experiments is presented in detail. At the end a list of results relevant to Slovakia is presented.*


### Introduction

Physics education in Slovakia is still based on the state, which introduced reforms between the years 1970-1980. The secondary school curriculum for 11-15 years and for ages 15-18 (gymnáziá) contains lots of issues relevant to the period of industrial revolution in Slovakia (around 1950), but far less relevant nowadays. Also it can still be seen that the foundation of physics education is as a projection of the science system to education. The untenability of this state and the need for reform had been formulated some years ago in the National Programme (Rosa, Turek, Zelina, 2002). The National Programme has not been supported by investment in the school system and the Programme was not implemented. Even if some groups are permanently working on preparation of such reforms, and some relevant decisions have been accepted, we still see that we are somewhere near the beginning. Groups around several projects have studied the school systems from abroad. In Slovakia, the systems from England, Finland, some parts of Germany and also the system of the International Baccalaureate, are the most popular. We can take lot of inspiration from abroad, but we see that mechanical copying of any system is not possible. We must be inspired by others, prepare our own basis for education. In recent months the government of Slovakia introduced profound curricular transformation of primary and secondary education and many of the ideas presented in this book have been articulated to relevant decision makers.

### History of utilization of ICT tools in physics education in Slovakia

The history of the usage of such tools in schools in Slovakia goes back to the years around 1986, when the computers "Didaktik" had been produced and supplied to schools. Even if these computers had been produced by a Slovak company also producing 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 had been stopped and these computers in schools have not been used any more. During the years 1988-1992 the 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 estimate 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 with ten IBM compatible computers with some modelling software (e.g. for geometrical optics) and also with one set of MBL tools from a German producer, Leybold Didactic. In-service teacher training supplemented the delivery, but this stream diminished quickly and now I am 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 - developed a system IP-Coach, which is still developing and produced by CMA at the University of Amsterdam.

The basic idea of the use of the system Coach from the beginning is “open learning” as featured in the 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 had been based on the vision of pupils learning by investigating as 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 environments and offering applications in varied educational situations.

Figures 1 – 4 illustrate the innovation of the MBL hardware. Even if the innovation of the interfaces is still ongoing, 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 themselves – the computers produced some years ago are quite quickly replaced by newer ones, what is quite costly.

Fig. 1. CMA IP-Coach panel, 1994

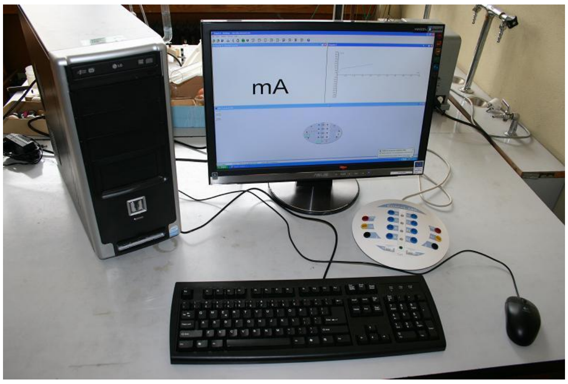



Fig. 2. CMA CoachLabII+, 2004

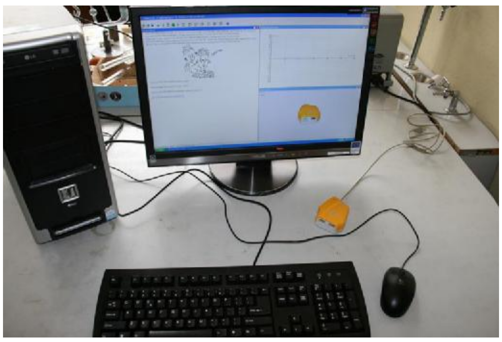


Fig. 3. CMA EuroLab, 2007


Fig. 4. Vernier LabQuest, 2007

Although the system CMA Coach is incorporated in the curricula 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. I am not aware of any research in Slovakia examining the obstacles that hindered teachers from more frequent usage of ICT tools in education, but from today's viewpoint the main factors seem to be:

- education has never been a real social priority in the years after 1989, after the smooth, but radical changes in 1989 and 2002 we needed to absolutely change the political system, financial system, currency, judiciary and so on, and we were satisfied by the relatively stable and high level of the education system.
- the national plan for informatics in schools had been realized by the project Infovek. It sometimes tried to focus utilization of computers delivered to schools for as many subjects as possible, but the numbers of classrooms equipped with computers allowed almost only the total use of them in the special subject called Informatics (Computer Science).

Systematic courses to use MBL tools in physics education in Slovakia had been established in 2004 by the project Infovek (www.infovek.sk), within which a small subproject was devoted to introducing MBL tools in science education at secondary schools. Here are some parameters of this project:

- 15 schools from all over the Slovakia selected,
- 2 teachers invited to 5 days training from each participated school,
- one of the 2 teachers was a physics teacher, the second was a teacher of another science discipline (usually chemistry, on some occasions biology),
- the participating schools were equipped with one set containing one data logger (CoachLabII), the software Coach5, and sensors (pressure, temperature, pH, sound),
- distance learning (a combination of synchronous and asynchronous) and support was provided for one year after the 5 days training; at the end of this distance learning the schools reported utilization of the equipment in their classes.

  Following 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 and Vernier (these tools are compatible to a high level). From the point of view of secondary schools, we are still somewhere at the beginning. One set of MBL tools is in about 10% of higher secondary schools and in only a few primary and lower secondary schools. Only two schools are equipped with many sets of tools for full pupils' experiments. What on the other hand is quite good, is that a lot of teachers are informed about the potential of MBL tools; about one quarter of physics teachers have experienced working with Coach - during teacher training - and each new physics teacher is able to use it. The Ministry of Education plans a call for projects related to equipment for science education by the end of this year.

**The role of project EUISE in the wider introduction of MBL tools in Slovakia**

Governments in all EU countries, including Slovakia, have high expectations for the use of Information and Communication Technology (ICT). The expectations for ICT in school science education are in Slovakia at a quite low level, the ICT is more focused upon the school subject Informatics (Computer Science), language laboratories, and general presentation technology. Here is the first role of the project EUISE in Slovakia – to compare the situation in the utilization of ICT tools in Slovakia with other countries, such as Finland, Scotland, Spain (Catalonia), Poland and also others.

Briefly speaking, the ICT tools for science education contain hardware, software and teachware. The general aim in Slovakia was to equip schools with computers (in computer rooms), connect most of them to internet and supply some software, mainly encyclopaedias and applets. This way is the easiest way, taking into account the financial and personal resources. In Slovakia we have all schools connected to the internet and equipped with computer suites, but we see extremely low level of utilization of such rooms in Physics education. Here are other roles of this project

- look at the obstacles, which impede the effective utilization of ICT tools in Physics education
- compare the hardware (including peripherals), software and teachware used in Physics education in Slovakia and in other countries.

The computers at schools in Slovakia are mostly (apart from the subject Informatics) used for retrieving information from the internet (even if high quality information for education in the Slovak language is rare) and for writing and presenting projects. We clearly see the utilization of ICT tools in physics school laboratories in better-developed schools (countries) so in this project we focused on utilization of MBL (data logging) tools in science in computer supported school laboratories. Within this project we

- compared MBL tools used, format of activities done with these tools, teacher training related to MBL tools.

Affordable ICT hardware and software, together with national initiatives to promote the use of ICT in education, has placed an expectation on teachers which has not always been matched by their own training or expertise. As a result many teachers feel unable to make the best use of new technologies. Shared experience of the emerging best practice is rare. In short, the computers and equipment often have arrived without an accompanying shared pedagogy to support their use by teachers. The producer of the hardware and software for the school science consults with the user – the teacher, but this seems to be more commercially driven than through objective impartial research. It is common to find schools in which one or two enthusiasts are happy to integrate ICT into their teaching whilst others lack the skills and confidence to move ahead with it. In Slovakia the ICT revolution is still accompanied by support for the training of teachers. However this training is largely targeted at basic skills rather than at pedagogy and subject specific issues. Here lies the next role of EUISE project in Slovakia

- to prepare a series of activities with teachers of science disciplines, train them in effective utilization of ICT tools, inform them about the situation in other countries and present new possibilities, train them to avoid and remove obstacles.

**Methodology of work on project EUISE in Slovakia and partial results**

Within the EUISE project in Slovakia we have decided to focus our attention on computer-aided science school experiments, in science ICT supported laboratories as well as ICT supported experiments in the field (outside laboratory). Beside this we examined other uses of ICT tools as presentation technology (smart board, data projector, large computer screen) and special subject specific software such as applets.

**Network of teachers**

As we tried to be as much informed as possible about the situation in various schools (state/private, small/big, major cities/small cities) we have created a network of physics teachers for this project. At the beginning we had 50 teachers; at the final stages of this project we have almost 100 teachers. We communicated with these teachers mainly by emails and we met at the teacher training sessions mentioned below. Most of the teachers filled out our international questionnaire mentioned below. Almost all the teachers were beginners in utilization of MBL tools at the beginning of this project. At the final stage of this project all the teachers are accustomed to work with MBL tools, about half of them have one set of these tools (usually used for demonstration experiments) and some of them are writing project proposals for local grant awards.

**Searching for the best practices at secondary schools**

Communicating with teachers via emails, at the meetings within teacher training and visiting some schools we tried to find some examples of use of ICT tools in physics education. Soon we found, that good examples are in Slovakia very rare (during years 2005-2006). Here are some of them:

- motivating students to prepare presentations oriented to specific problems using information from the internet – quite often such activities are joined with language training, because students often use information from web pages written in English;
- presenting results of their own work by students using presentation software and a projector;
- utilization of computer and projector by teacher at the lecture stage, using animations, applets, video sequences (last one only rare)
- motivating students to write part of their homework (lab reports, project reports) using word processing and spreadsheets
- publishing assignment for homework and some other information on a school web page (rarely)

As we saw we can not find sufficient examples good enough for dissemination into Slovak schools, we have decided to look for inspiration in the regions where schools are much better equipped and where is much more experience. Here is the stage, where in Slovakia we were more the beneficiary rather than as a producer of best examples. Quite lot of information we got also from the literature.

**Analyse of teacher competences relevant to use of ICT**

This part of the project arose as crucial for preparation of effective teacher training. Even if this was originally planned for the first stage of the project, in Slovakia we continued in this activity till the final stages of the project. We see that here are more levels of competences relevant to this project.

- One level constitutes competences connected to day-to-day usage of the tools in classes; this level seems to be common for all countries. For this level we have some sources to study and learn from.
- Other level constitutes competences related to starting to build the computer-based laboratory and related to introducing the MBL tools to the school programme. In this sort of competences we in Slovakia seem to have a special position. These competences are impacted to a high level by the social status of teachers (extremely

low in Slovakia), the ratio of costs of MBL tools and salary of teachers (MBL tools seems to be very expensive in relation to this and many teachers are afraid of damage to the MBL tools by themselves or by students).

- Next level of competences is related to management of the school, we have found two extremes here. At one extreme a good physics teacher means the teacher, who does not want anything (uses textbook, chalk and board). In this sort of school active teacher (teacher trained by our training sessions) has not an easy situation, can use so called home experiments with low cost materials, but hardly can persuade colleagues for such investment, even if they are from additional financial sources (local grants). The other extreme are schools making demands on teachers to be “modern”, such schools are also not always prosperous, often teachers leave such schools, active teachers go to better paid jobs, less active teachers to schools with lower demands. But the competences related to this level involve key human competences and general teacher competences (communication with school management, communication with pupils and parents) and we did not examine these deeply.

**Teacher’s training**

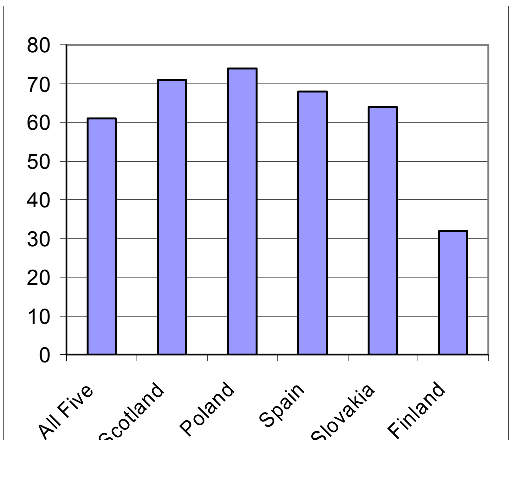
The main goal of the project as the type of project where developmental activity rather than pure research was to create some sessions of teacher training to effectively use ICT tools in science education. On the other hand we used the se sessions also as a ground for focused applied research in the fields of theory of science education and lifelong learning. The method we used was a focused, international questionnaire, focused planned discussion group discussion with teachers, and observation of teachers' work in a laboratory. The international results of questionnaire are in another chapter in this book, but some special results relevant for Slovakia with some explanation are below. Next in this chapter we also bring in the examples of timetable of training sessions and results of the research on the teachers in Slovakia.

**Additional questionnaire results relevant for Slovakia**

Here we continue with presenting the results of the international questionnaire. We stress the results important for Slovakia. As explained in the chapter devoted to the international results of the questionnaire, the maximal positive answer is marked by 100%, the maximal negative answer by 0%.

For Slovakia, a new member of European Union, with low investment to education, we found it very pleasant, that our teachers are comparable to teachers from much better equipped schools with more developed school systems. Such result we have found in question 7. This result we still should take carefully, the choice between weak and good depended also on the self-confidence of teachers.

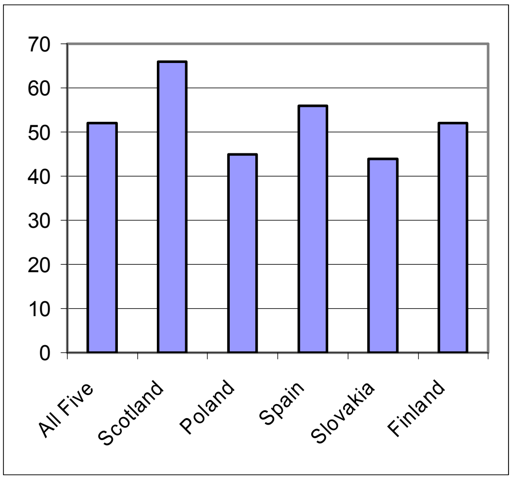
*Can you please make a self-evaluation of your ICT competence?*



☐ ’helpless’ (I cannot use ICT at all)
☐ weak (I can use word processing, Internet browser and e-mail minimally tolerably)
☐ good (I can use word processing, presentation graphics, MBL/Data logging, e-mail and an Internet browser satisfactorily)
☐ excellent (I can use the previous tools well, make web-pages, can use learning management systems and also know the pedagogical principles of using ICT)

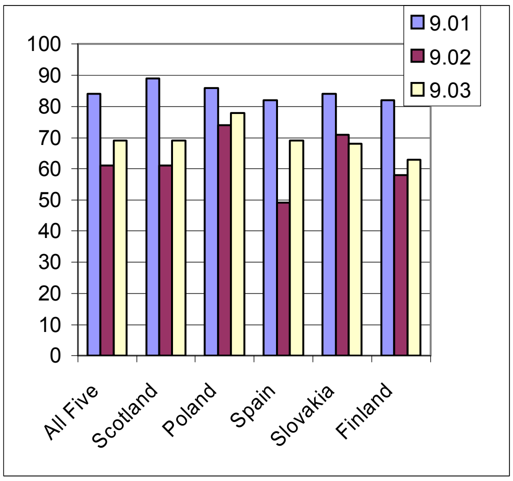
For us is interesting the answer of our teachers to question 8 – our teachers estimated that only about 70 % of students use computers at home (including computer games). From our discussions with students and teachers our estimate is higher. Two explanations are possible – in small cities only less students use computers, or the teachers have slightly biased opinion. On the other hand, the result is the same as for Poland with comparable education history.

*How many of your students use regularly ICT at home (e.g. word processing, computer games, internet, chat, music) – your estimate*
☐ Less than 50%
☐ 50% - 70%
☐ 70% - 90%
☐ More than 90%




Even if we are aware of the small number of computers in schools, teachers in Slovakia see utilisation of ICT tools positively, on the same level as in other countries. In question 9.2 we reversed the answers, so high score means positive attitude to ICT.

9.1 ICT can have a positive effect on learning in science.
9.2 The positive effect of ICT on learning in science is overestimated.
9.3 More ICT resources in schools will result in better learning.

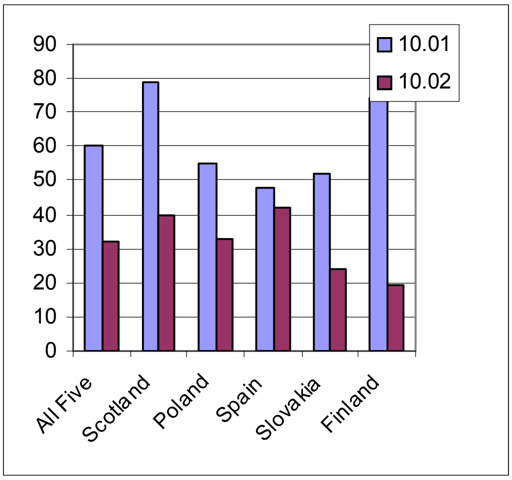



In the questions related to equipment available we can clearly see, that physics (science) teachers in Slovakia on average have a computer available for teaching only sometimes. They have more than one computer per 4 students almost never; the score is not zero because some teachers at some schools use sometimes computer rooms mainly used for the subject informatics.

*In a classroom you have available or access to*

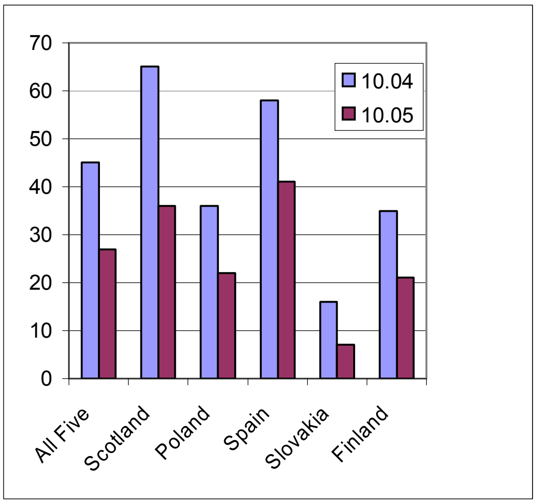
One or some computers (less than one per 4 students)

Almost enough computers (more than one per 4 students)




The question continues with focus to MBL tools, here we clearly see the vast difference between Slovakia on one side and Scotland and Spain on other side. Together with this information it will be interesting to consider the case of teachers trained in the utilization of MBL tools. This topic is more commented upon in another article in this book.

4. Some MBL (data logging) tools and sensors
5. Enough MBL (data logging) tools and sensors



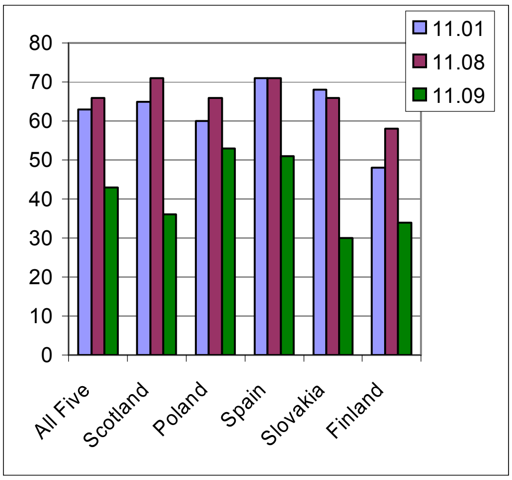

Next we clearly see that science teachers in all countries use word processing and internet searches. From the point of view of Slovak teachers it is interesting in question 9, we were surprised by quite high score (even if smallest in comparison with others), because a good database for education in Slovak language is still only a plan, not reality (year 2006). In discussion with teachers we found, that teachers had in mind in this question mainly the Wikipedia.

*How often do you use ICT as a part of your **science teaching** (either led by yourself or guiding your students to use ICT)? **Do not** include administration in your responses. Select one from each row on this basis: 1 never; 2 rarely (perhaps once or twice a year); 3 occasionally (perhaps once each month); 4 often (almost every week)*

1. Word processing

8. Search on the Internet (Google or another general search engine)

9. Search on a specialised database (source of information) available through the Internet (e.g. newspaper,)

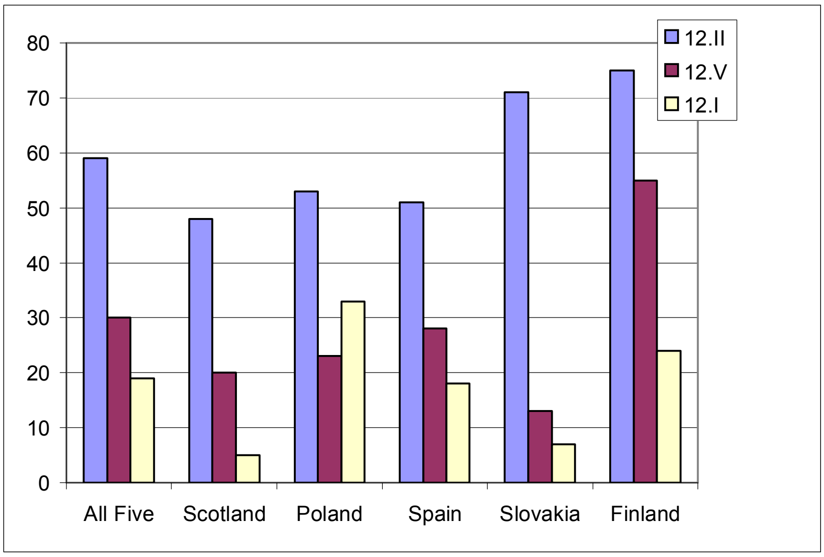



The last question was taken as the inspiration for our series of teacher training; we clearly see that physics teachers in Slovakia wish training in using data logging (MBL tools). This is in correlation with extremely low level of such equipment in schools presented in answers to question 10. On the other hand, training is quite often offered by various projects in Slovakia related to general ICT skills (internet, presentation software) that teachers do not prefer now (year 2006).

*Your training and development needs. Please indicate your priority for ICT training.*

*1. = Important. Should have soon. 2. = I need this some time. 3. = I don't need training.*

I. Using the internet
II. Using data logging
V. Using PowerPoint




One of the main results of the questionnaire was a challenge for us to focus the teacher's training to the effective MBL use.

**Teacher's training timetables**

We have done a reasonable number of sessions of teacher training in various circumstances and various goals. The main idea was to find an effective structure for more widespread training as a part of planned national action. Here we bring examples of activities with timetables from 2 years to 10 minutes. This whole scale of timetables can be relevant and effective in various circumstances. As the most effective we found the training abbreviated as Smrekovica and short time activities with teachers. Here are some details:

Smrekovica, 5.-8. sept. 2006

| | |
|---|---|
| Number of teachers: | 51 |
| Subject: | Physics |
| Region: | whole Slovakia |
| Duration: | 4 days, whole days, situated in forest chalets |
| Lecturers: | Slovakia (Comenius University) and Czech Republic (Charles University) |
| Types of activities: | main type: number of teachers in one activity 10-14, duration of each activity 80 min, teacher working in groups of 2-4,<br>evening activities: all teachers and lecturers in one room, presentations of pre-registered teachers, each 15 min<br>number of activities related to use of ICT – half of whole number of activities |

Findings:
Teachers view – teachers satisfied, got good ideas usable in day-to- day teaching, complemented with training and written material.
Lecturers view – the training session was self-reliant, was good for planning of timetable (rotation of groups of teachers), but such long (5 days) training allowed to plan also some successiveness, what was not applied.
Lecturers view – the evening sessions where teachers pre-registered presented her/his activities (practices) had very varied quality - we recommended planning sort of selection and pre review before the presentation. Some of the presentations were excellent.

Results: Such relatively expensive teacher training (need to plan travel, accommodation and full subsistence) has been found as one of the best type of training, because the teachers have been involved in the activities fully and for the whole day. Also the informal communication among the teachers has been found as fruitful. On the other hand the teachers whose schools are not equipped with the MBL tools relatively early (within about 3-5 months) cannot use the major part of the skills they have been trained for. Even if they have been active for some time in looking for some resources for new equipment, they soon became passive in this field.

Šoltésove dni, 6. – 7. Dec. 2006

| | |
|---|---|
| Number of teachers: | 92 |
| Subject: | Physics |
| Region: | Bratislava |
| Duration: | 2 days, 7 hours per day, situated at Comenius University, Bratislava |
| Lecturers: | Slovakia (Comenius University) and Czech Republic (Charles University, Prague) |
| Types of activities: | main type: number of teachers in one activity 10-14, duration of each activity 80 min, teacher working in groups of 2-4, |

| | |
|---|---|
| | number of activities related to use of ICT – half of whole number |

Findings:
Teachers view - teachers satisfied, got good ideas usable in day- to- day teaching, complemented with training and written material
Lecturers view – series of activities were to a high level, series of self-reliant activities and some conjunction seems to be missing. The informal meetings of teachers and lecturers were missing. The teachers were consumers to a high level of the programme (even if active within activities), the possibility to present teachers' "best examples" was missing. We did not find an effective strategy to put such possibility within the timetable, because of the location of the session – teachers went home in the afternoon as soon as possible and some teachers also had her/his classes in the morning at their schools (such teachers attended only some activities).

GAE, 2006/2008

| | |
|---|---|
| Number of teachers: | 16 |
| Subject: | all science + mathematics + informatics teachers from one school |
| Region: | Bratislava |
| Duration: | 2 years, series of activities at the school, at Comenius University and at Slovak University of Technology, Bratislava |
| Lecturers: | Comenius University and Slovak University of Technology |
| Brief timetable: | – Aug. 2006 – first info about system Coach, training of basic sensors use, info about other possibilities, 6 hours<br>– one set of Coach delivered to school Aug. 2006<br>– Jan.2007-dec. 2007 series of 7 activities at universities, modelling of school experiments by teachers with lecturers<br>– Dec 2007 full laboratory equipped, 6 computers, 6 interfaces CoachLabII+, some sensors<br>– Dec. 2007 – Feb 2008 series of training sessions chemistry, earth science (part of subject geography, biology, physics), each session 90 min, all science teachers involved in each session)<br>– March - April 2008 series of presentations, of own school experiment by each of science teachers. |

Findings:
The physics, chemistry and biology teachers became able to use the activities prepared by the lecturers also within their own teaching plans, sometimes a technician was needed to solve simple problems with computer software. The teachers become able to ask lecturers qualified questions, but were not able (or not willing) to prepare their own experiments. The experiments presented on the last activity were suitable for use only after major revisions.

Short time activities – teachers only

| | |
|---|---|
| Number of teachers: | 95 |
| Subject: | Physics, Chemistry |
| Region: | whole of Slovakia, mainly Bratislava |

| | |
|---|---|
| Duration: | 2 years, activities at Comenius University and at secondary schools |
| Lecturers: | Comenius University |
| Types of activities:<br>: | Short time activities (30 - 90 min). All activities were oriented to use of ICT in science education. Main focus was put to use of MBL tools. The main goal of such activities was to make teachers informed. |

Here are some of the timetables:
Timetable 1:

| time | | activity |
|---|---|---|
| 0.00 | | brief info about MBL system (sensor, interface, software, computer |
| 0,10 – 0,20 | | temperature measurement in Author mode – frontal measurement, lecturer on computer connected to large screen (projector), teachers in groups of 2-3 on computers, |
| | 0,10 | connection of sensor to interface |
| | 0,15 | measurement of temperature of hot water in plastic coffee cup |
| | 0,17 | graph introducing, graphic representation of removing and inserting of temperature sensor from and to the cup of hot water |
| 0,20 – 0,40 | | speed of sound measurement, introducing planning experiments (planned by students as an integral part of the activity), |
| | 0,20 | speed of sound – selecting problem |
| | 0,25 | brainstorming – methods |
| | 0,30 | two microphones – method by lecturer (if possible based on method suggested by one of participants) |
| | 0,33 | need for triggering |
| | 0,35 | data collection – in graph representation, reading from graphs, calculation of speed of sound. |

Timetable 2:

| time | | activity |
|---|---|---|
| 0.00 | | brief info about MBL system (sensor, interface, software, computer) |
| 0,10 – 0,20 | | temperature measurement in Author mode – frontal measurement, lecturer on computer connected to large screen (projector), teachers in groups of 2-3 on computers, |
| | 0,10 | connection of sensor to interface |
| | 0,15 | measurement of temperature of hot water in plastic coffee cup |
| | 0,17 | graph introducing, graphic representation of removing and inserting of temperature sensor from and to the cup of hot water |
| 0,20 – 0,45 | | isothermal process verifying + pedagogy related |
| | 0,20 | isothermal process introduction, syringe, room temperature, pressure sensor |
| | 0,25 | pressure sensor connection, method of measurement discussion, volume manually entered |
| | 0,27 | data collection, commenting the isothermal process and sources of systematic error (heating the air in the syringe) |
| | 0,37 | making a graph, sorting the data in the table |
| | 0,45 | making a linear graph |
| 0,50 – 0,70 | | speed of sound measurement, introducing planning experiments |

| | | |
|---|---|---|
| | | (planned by students as integral part of the activity), the same as in previous timetable |
| 0,70 – 0,90 | | open discussion about MBL laboratory equipping and about possible financial (grant) sources |

Very useful, we see and we have done, also simple one activity presentations with comments, e.g. observation of magnetic field value and direction in a room (magnetic field sensor); measurement of tension of a string in a simple geometrical shape (half litre plastic bottle suspended on V shape string) by force sensor; speed of sound measurement; observation of emf produced by magnet falling through a coil (electromagnetic induction)

Findings:
For teachers, who do not have the equipment the third sort of activities seems to be most inspiring, they can see the possibilities, can compare her/his teaching methods with MBL methods, most of them answered that they will actively look for possibilities of getting such equipment. On the other hand some teachers after the third sort of activities felt themselves unable to use such equipment, a much lower proportion of teachers proclaiming such problem than among teachers participating on the first and second type of activity.

Short time activities – teacher with students and students without teacher

| | |
|---|---|
| Number of teachers: | 25, number of students 700 (age of students 13 -18) |
| Subject: | Physics, Biology |
| Region: | Bratislava |
| Duration: | 2 years, activities at Comenius University and at secondary |
| Lecturers: | Comenius University |
| Types of activities: | Short time activities (45 - 90 min). All activities were oriented to use of ICT in science education. Main focus was put to use of MBL tools. The main goal of such activities was to make teachers informed and see real (almost real) class with own students with use of ICT. We offered one-two sessions for one class, topics were arranged with teachers. Sometimes we made a session with students without presence of their teacher. |
| Topic examples: | Speed of sound measurement, measurement of permeability of air (magnetic field sensor), isothermal process, isovolumetric process, Ohm's law and V-I characteristic of a bulb, monitoring ECG, monitoring heart rate, observing CO2 and O2 in a process of respiration (plants and humans), measurement related to calorimetric equation (melting of ice, thermal capacity of solids and liquids), oscillators (basic parameters, kinematics of harmonic motion, weight suspended on a string or on a spring), sound exploration (vowel sound graph, interference, beats), alternating currents (power, circuits with resistor, coil and capacitor), electromagnetic induction (mutual, transformer, electric energy distribution model with transformers, internal induction on a coil) |

Fig. 5. CMA IP-Coach panel, 1994

Fig. 6. CMA CoachLabII+, 2004

Fig. 7. CMA EuroLab, 2007

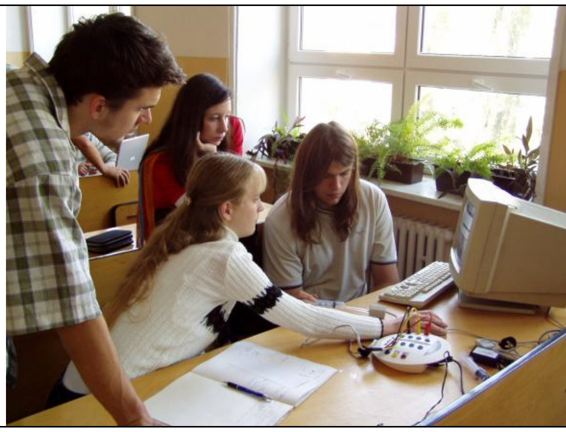


Fig. 8. Vernier LabQuest, 2007

**One example of short time activity – teacher with students**

a) The basic ideas

i) equipment

In the past years we see in all developed countries investment of modern equipment in schools. The costs of hardware have fallen; equipment has become more reliable (University of York Science Education Group, 2005; Demkanin, 2006; Lavonen, J., Juuti, K., Aksela, M., & Meisalo, V., 2006). After 15 years of cooperation by our University (Comenius University) with CMA Amsterdam we decided to equip our laboratory with interfaces CMA CoachLabII, software Coach6EN (at the beginning Coach5EN) and with sensors CMA and Vernier. The secondary schools in Slovakia are not equipped with MBL tools yet; one of our goals was to inspire secondary schools.

ii) students

Our research was focused on secondary school students, age 15-18. We know that our students use computers and other ICT tools easily. We can see that students bring to the computer based laboratory basic ICT skills that they have learned elsewhere (University of York Science Education Group, 2005; IBO, 2001). So we have decided not to teach students to work with software and hardware in any introduction courses, we only mentioned some parameters of the hardware such as a sampling frequency and use of triggering.

iii) methodology

For the methodology of a student's laboratory work we have adopted criteria from International Baccalaureate Physics Guide (IBO, 2001), where the laboratory work is focused on student's planning, data collecting and processing, evaluation, manipulative skills and personal skills.
At this stage we have decided to examine only measurement with MBL, not other possibilities of the software used as programming, video measurement, and modeling.

iv) teachers

For work with teachers (in-service and also pre-service) we have decided to connect all three previous basic ideas together with the training of preparation of teacher's instructions.

b) One activity as an example:

i) basic parameters of the activity

| | |
|---|---|
| Time allocation: | 90 min planning + data collecting OR 45min planning + 90 min data collecting and processing |
| Number of pupils in a group: | 9-15 |
| Age of pupils: | 15-18 |
| Previous knowledge: | kinematics of uniform motion, |
| Previous skills: | a basic skill with MBL tool is advantage,<br>experience with self-planning experiments |

Competences to be deepened: *personal competences* (ability to effectively work in small teams, ability to consider needs of other groups working in the same classroom, ability to manage the time allocated), *competences in handling equipment* (working with equipment safely, basic orientation in laboratory – knowledge of parameters of basic equipment in school laboratory), *competences relevant for design and performing experiments* (ability to formulate hypothesis and subsequently propose proper method and apparatus, ability to make a trial measurement for testing the apparatus and method, ability to collect data and save the collected data for future processing).

ii) teacher note

The main idea of this activity is to allow pupils to design their own experiment and subsequently perform this experiment and evaluate it. The topic is taken as very simple, to measure the speed of sound in air, and to do so in the laboratory/classroom, not outside. Pupils are kept active in more phases of this activity and all pupils' proposals are taken into account and discussed in pairs of classmates and some of them also in the whole group.

STUDENT'S INSTRUCTION, No. EXAMLE

Task: **Measure the speed of sound in air in your classroom.**
Try to be as much precise and accurate, as possible.

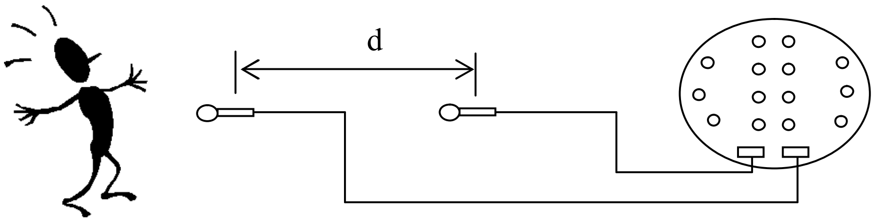
Hint: consider maximal sampling frequency of MBL tools in our physics laboratory

You will work in pairs and you can use any equipment from school laboratory.
Time allocation for design and performance of your measurement is 80 min.
Keep all notes for writing your lab report, your report hand in next week.

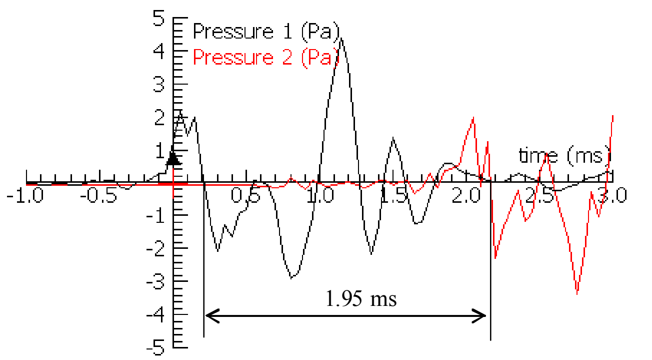
iii) Brief description of methods prepared by students

The experiments proposed by majority of the students can be grouped to 5 major methods briefly described below. At the final part of this article is mentioned the number of students prepared/planned each of these methods.

Method 1: This method is based on the idea of signal propagation through air. A signal produced (e.g. hand clamp) is registered by first microphone and with some time delay by the second microphone.




The time shift $t$ can be taken from time graph of both signals, $d$ can be measured directly, so $v = d/t$ can be calculated.




Microphone separation 70 cm

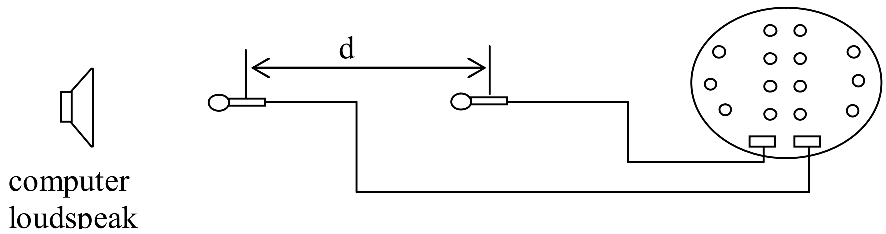
Trigger set by first microphone to 1Pa, pre-trigger time 1 ms,

Measuring frequency 20 per milisecond

The time shift should be read carefully. I usually recommend reading it for about 5 different separations, twice for each. If student, taking $d$ as independent variable and $t$ as dependent variable, draws $t$ versus $d$ graph, the slope of the graph is $1/v$.

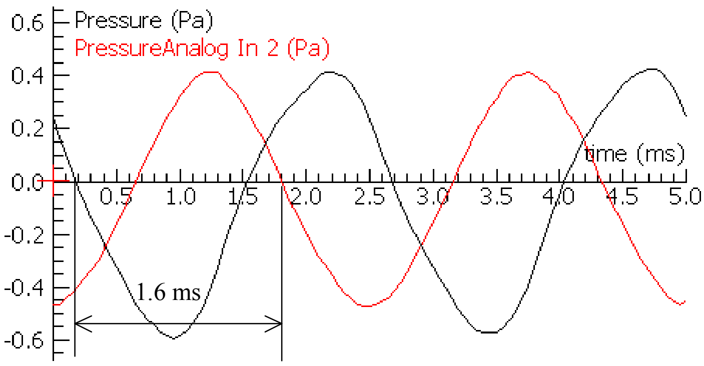
Uncertainty can be estimated as follows: $\Delta t = \pm\ 0.05$ ms, $\Delta d = \pm\ 0.5$ cm what gives relative uncertainty about 3 %.

Method 2: This method is based on the use of periodic signal, usually harmonic signal. If harmonic signal is produced by a source and two microphones are connected to an MBL interface, the signals from two microphones are shifted in the same way as in the previous experiment, but starting the measurement by the trigger level is not necessary. A tuning fork is usually used as a source of the harmonic sound, but why not use the sound output of the computer? There is some software on the internet for producing a harmonic signal with a variable frequency, one very simple freeware made by one of my secondary students is on: http://www.ddp.fmph.uniba.sk/~demkanin/ROZNE/Frequency.exe



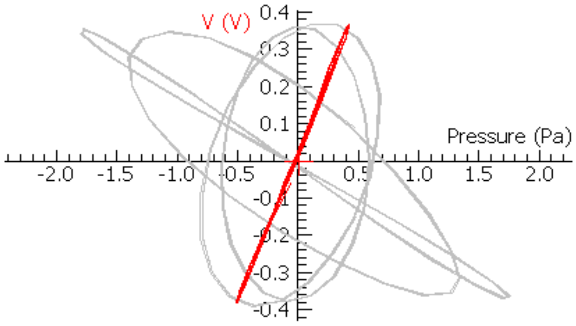

distance between microphones 50 cm

frequency of the sound 400 Hz.




The data processing is the same as in method 1, but the uncertainty I assume to be lower for the time interval. So the relative uncertainty of the measured time I assume to be about 2 %.

Method 3: The previous method can be changed. One signal goes from the loudspeaker, while the other signal is directly from the output of the sound card of the computer (the signal from sound output of the computer is bifurcated). Here the problem is that we do not know the phase difference between the two signals. By moving the microphone to or from the loudspeaker we can change this phase difference so we can find two successive distances, where the signals are in phase. The difference of such distances is the wavelength of the wave. From this wavelength and known frequency we can calculate the speed of sound (in air). When students are finding the position of the microphone where the signals are in phase, they can put time on the horizontal and the voltage and pressure on two vertical axes, or one signal (pressure) on horizontal and second signal (voltage) on vertical. In the second diagram we will get Lissajous figures.




On the x-axis is signal from microphone while on the y- axis is signal from the sound output from the computer. The blue line is for such position of microphone, when the two signals are in phase.

At the measurement time was set to 5 ms, sound frequency 1 000 Hz, sampling frequency 20 000 Hz

In this measurement sound frequency $f$ could be a controlled (independent) variable, wavelength $\lambda$ dependent variable. Speed of sound $v$ can be found as the slope of graph $1/\lambda$ versus $f$. The relative uncertainty of $v$ I assume to be about 2 %.

Method 4: Quite common is a method similar to method 1, where the source of the sound signal is put together with a trigger signal. The source of the sound are two electrically conducting rods, they are hit against each other. At the moment of hitting the sound signal is produced and also a simple electrical circuit is closed which can be used as triggering signal for starting the time measurement. Students usually design Method 4 if they have only one microphone.

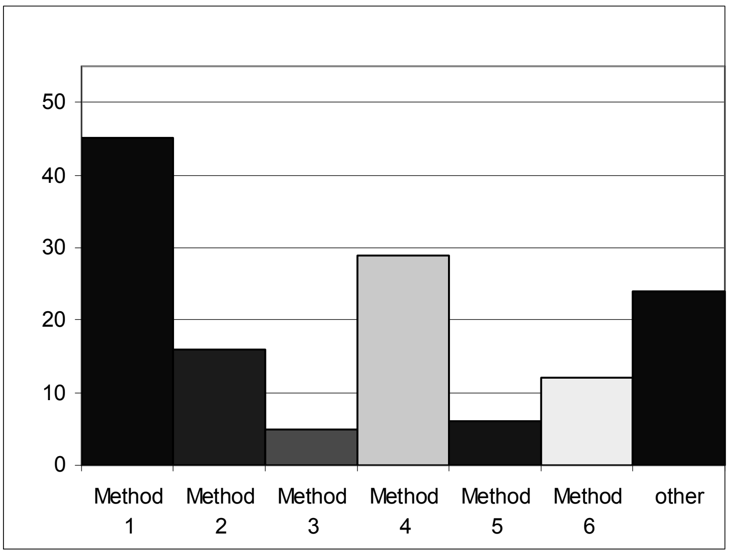
Method 5: Method is based on reflection of the sound on a wall. Signal (e.g. hand clamp) is registered by a microphone and the same microphone registers the signal reflected from the nearest wall. Speed of sound can be calculated by the same way as in method 1. The precision of this method is usually lower than in other methods mentioned.

Method 6: The more conservative way for measuring speed of sound (in Slovakia) is the standing wave in pipe method. In a pipe – usually open at one end we control the length and keep constant the frequency, or control frequency (of sound from computer loudspeaker) and keep constant the length. Such measurement I consider to be more abstract as direct measurements mentioned in this article. Even if students often find it in textbooks, they only seldom design it as a reaction to the instruction sheet presented above in this article.

This particular measurement can be designed also without the MBL tool, directly by the microphone input of computer and software for sound analysis. Not one of our students proposed such methods.

iv) Comparison of the methods by numbers of students proposed such methods

In our research we have used this example instruction with students in groups of 5 to 15, planning the experiment, each independently, and performing selected plans in groups of 2 to 3. We have recorded in years 2005 - 2007 all together 137 students. The age of students was from 15 to 18.




Number of students vs. method of measurement designed. Very similar methods have been grouped to 6 main methods, “other” means not proper student’s design.

## Conclusions

Finding 1: **teaching students to use software for MBL**

The discrepancy with the situation from 20 years ago (reported e.g. by Beurs, Ellermeier 1993) is that 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 Coach5, Coach6 on the level of measurement, data processing and presentation proved that the students are only needed to be informed about the parameters of the system. Software is so user-friendly that we can start to use it on an intuitive level. This finding does not apply for software for modeling and video measurement, here some instructions are necessary if want students to use them independently and effectively. From this viewpoint this is good, if these pieces of software are joined in one software environment, such as Coach6. This finding does not apply for teachers; teachers need some instructions and training.

Finding 2: **language, translation of software**

We have found no problem with using software in English language with students of secondary schools in Slovakia, BUT the majority of the teachers are not able to use it, the teachers needs software to be translated to Slovak language.

Finding 3: **equipping and teacher training**

The supply of equipment (interface and sensors) is necessary to complement the teacher training. We found just as effective 3-4 days face-to-face training and at least 1 year distant learning with a 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 information for the teacher about possibilities and inspiration for teachers to activate them in effort to gain the equipment (e.g. for writing good school projects as a reaction to projects calls). Some schools (teachers) seem to be unable to procure goods (any type needed for education) that they both desire and can afford.

Finding 4: **ICT tools in science disciplines and subject Informatics**

School subject called Informatics (Computer Science) can help usage of ICT tools in physics (and other science disciplines), but this is more an exception than a rule. In Slovakia we have such a subject but it has its own goals and content – it can help in developing general student competence related to using ICT tools, not competences for special software and data logging hardware. The cooperation between these two subjects can be in the field of programming (robotics and higher level of measuring), but this is not a prescribed content of science subjects. On the other hand usage of MBL tools in science disciplines can help Informatics in fulfilling its goal to develop basic knowledge and understanding of information processing (acquisition, processing and communication). MBL tools offer concrete (not abstract) examples for fulfilling this goal.

Finding 5: **ICT tools and mandatory documents (curriculum design)**

The incorporation of ICT tools (data loggers) offers much more activity-oriented education and this shift can be strengthened by curriculum design.

In Slovakia for physics education we have 2 types of mandatory documents: Standard (Tomanová, Demkanin, 2001) and Syllabus (MŠ SR, 1997). For students, who are planning to take final exams from physics here is one more mandatory document, Requirements for final exams (ŠPÚ, 2004). In standard there is no mention of ICT, In the Syllabus is only a general sentence …use ICT in problem solving and modelling of physics phenomena…. The most specific are Requirements for final exams; candidates should be able to use ICT in modelling of physics phenomena, in processing measured data and be able to work on internet. All these sentences are insufficiently specific, so teachers and students are not really motivated by these documents to use ICT in physics education.

On the other hand, for example in the programme document for the International Baccalaureate physics syllabus (IBO, 2007) is clearly stated that each of the following must be used at least once during a course with each student: data logging in an experiment, software for graph plotting, a spreadsheet for data processing, a database, computer modelling/simulation.

Finding 6: **ICT and active learning**

The truth that ICT tools have potential to activate students is fully proved by many researchers - these tools can provide students with quick response to their actions – at the same level in direct measurement, as in modelling. The "what if "questions are often easily investigated during a stage of building hypothesis. On the other hand, this potential 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. The process of physics education in secondary schools is usually centred around a set of textbooks, or on teacher instructions. There are good examples of effective use of ICT in both approaches. One example of an approach in which the activities with ICT tools are incorporated directly to the textbook is Spectrum Physics (Cooke, Martin, 2004). The second approach is successfully used in many schools by teachers using textbook Giancoli, 2005 as source of information and leading students to use ICT tools by oral instructions and demonstrations.

Finding 7: **MBL experiments and written exams**

ICT tools (MBL tools) are effectively used in measurements and experiments, in laboratory and fieldwork. But some students and also some teachers are focussed upon high level exams; they try to prepare themselves for exams and quite often do not follow all the goals of physics education. We have tried (and not only us) to incorporate some aspects related to MBL tools to written exams questions. Some examples are:

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 experimental designs.

Finding 8: **Strategy of laboratory work**

Focusing students' laboratory work on planning, data collecting, data processing, evaluation, manipulative skills and personal skills has been proved as an 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. Quite a reasonable number of teachers considered this time as not effectively spent. With such teachers we should patiently discuss the goals of physics (science) education.

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