PATHWAY

Best Practices

of Inquiry-Based Science Education Methods and Activities

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Introduction

Introduction

Following the recommendations of the "Science Education Now: A renewed Pedagogy for the Future of Europe" report (Rocard, 2007) , the Pathway Supporting Action is bringing together experts in the field of science education research and teachers' communities, scientists and researchers involved in pioneering scientific research, policy makers and curriculum developers to promote the effective widespread use of inquiry and problem based science teaching techniques in primary and secondary schools in Europe and beyond. The aim of the project is to set the pathway toward a standard-based approach to teaching science by inquiry, to support the adoption of inquiry teaching by demonstrating ways to reduce the constrains presented by teachers and school organisation, to demonstrate and disseminate methods and exemplary cases of both effective introduction of inquiry to science classrooms and professional development programmes, and finally to deliver a set of guidelines for the educational community to further explore and exploit the unique benefits of the proposed approach in science teaching. In this way the project team aims to facilitate the development of communities of practitioners of inquiry that will enable teachers to learn from each other.

For the attainment of these goals, exemplary cases and specific practices need be identified, which will provide specific and tangible "success stories" which complement the teaching of purely abstract concepts. Within the scope of PATHWAY Coordination Activity, the identification of these "success stories", the so called PATHWAY Best Practices was explicitly addressed as a distinct issue.

The PATHWAY team has developed a series of basic principles that the Best Practices have to meet. The determination of the underlying principles that should govern the presented standardization approach is based on the concepts and the theoretical approaches deriving from recent educational research on the field. The proposed approach imparts a deep understanding of content, teaches prospective teachers many ways to motivate young minds, especially with the appropriate use of technology, and to guide them in active and extended scientific inquiry, and instils a knowledge of – and basic skills in using – effective teaching methods in the discipline. These principles are:

1. Best Practices should aim systematically to develop and sustain learners' curiosity about the world, enjoyment of scientific activity and understanding of how natural phenomena can be explained
2. Best Practices have to focus on all learners, both those who may later become scientists or technologists or take up occupations requiring some scientific knowledge and those who may not do so.
3. Best Practices must have multiple goals. They should aim to develop:
    - understanding of a set of big ideas in science which include ideas of science and ideas about science and its role in society
    - scientific capabilities concerned with gathering and using evidence
    - scientific attitudes.
4. The implementation of the Best Practice should be a clear progression towards the goals of science education, indicating the ideas that need to be achieved at various points, based on careful analysis of concepts and on current research and understanding of how learning takes place.
5. The themes of the Best Practices should result from study of topics of interest to students and relevance in their lives.
6. Best Practices should reflect a view of scientific knowledge and scientific inquiry that is explicit and in line with current scientific and educational thinking.
7. Best Practices should deepen understanding of scientific ideas as well as having other possible aims, such as fostering attitudes and capabilities.
8. Programmes of learning for students, and the initial training and professional development of teachers, should be consistent with the teaching and learning methods required to achieve the goals set out in Principle 3.
9. Assessment should be an integral part of the Best Practices. The formative assessment of students' learning and the summative assessment of their progress must apply to all goals.
10. Best Practices should promote cooperation among teachers and engagement of the community including the involvement of scientists.

Moreover, certain additional criteria were defined to support the implementation of the Best Practice in real settings:

1. must apply universally
2. can be developed through a variety of content, chosen to be relevant, interesting and motivating
3. can be applied to new content and enable learners to understand situations and events, as yet unknown, that may be encountered in their lives.
    - must have explanatory power in relation to a large number of objects, events and phenomena

Figure 1. Defining Best Practices in the framework of the PATHWAY approach.

that are encountered by students in their lives during and after their school years

- must provide a basis for understanding issues involved in making decisions that affect their own and others' health and wellbeing, the environment and their use of energy
- must provide enjoyment and satisfaction in being able to answer or find answers to the kinds of questions that people ask about themselves and the natural world
- must have cultural significance – for instance in affecting views of the human condition – reflecting achievements in the history of science, the inspiration from the study of nature and the impacts of human activity on the environment.

The Best Practices Template

The criteria set out provide a theoretical framework of reference of what consitutes a Best Practice according to the PATHWAY inquiry based approach. The Best Practices template also presents the required teacher competencies (according to Bogner, 2005) to help teachers get prepared for their implementation. These competencies refer to Subject Matter Knowledge (SMK), Pedagogical Knowledge (PK) and Pedagogical Content Knowledge (PCK) and are described in detail in Table 1.

The Best Practices provide concrete instruction design models for the different PATHWAY tools and applications, making the rationale, learning goals, learning activities, participants' roles, and processes to be followed in each case, explicit (Figure 2). To make the multiple functions of a Best Practice visible and the Best Practice itself easily usable by the various types of

Table 1: Teachers, students and experts contributions to the Desired Competences

Teachers and Students Contribution	Experts Contribution
Subject Matter Knowledge (SMK)	
Competencies related to **subject matter/content knowledge**	
• Scientific knowledge • School content knowledge • Knowledge of unifying theories in Science • The ability to operate with correct information	
Competencies related to the **nature of science** including inquiry knowledge and skills	
• Knowledge about the discipline • Knowledge of models • Connection of theory and practice • Knowledge of ethical approaches • Attitudes befitting a scientific ethos • History and Philosophy of Science	• Modeling • Inquiry knowledge and skills • Epistemology
Competencies in framing a discipline in a **multidisciplinary** scenario	
• Applications of Science in daily life • The discipline in a multidisciplinary scenario • Articulation with other disciplines • Link with everyday life sciences	• Link with science, technology and society in a personal context • Link with mathematics
Competencies in **knowledge of contemporary science**	
• Adaptation in new contexts • Knowledge of contemporary science	
Pedagogical Knowledge (PK)	
Competencies in mastering and implementing a **variety of instructional strategies**	
• Familiar with learning theories • Knowledge of relationships between teaching strategies and learning practices • Varied teaching practices (or methods) • Professional tools for classroom and curriculum managing • Continuous and formative assessment • Learning groups • Motivation, human relationship • Valorization of the constructivist and socio-constructivist paradigm • Monitoring learning processes and offering continuously cognitive and affective feedback • Creating a stimulative climate, • Encouraging free expression of the pupils • Respecting the pupils, their intellectual particularities, expectances, difficulties they encounter, their educational needs, their preconceptions (empathy) • Establishing a real communication link between the teacher and the pupil • Willingness to offer supplementary assistance, if necessary • Adopting a flexible and creative behavior in order to develop the creativity of the pupils • Being able to use technical equipments	• Competencies related to assessing conceptual change • Criteria based summative evaluation of students • Relating formative to summative evaluation

PK6: Competencies in sustaining autonomous **life-long learning**	
• Being flexible and able for cooperation • Being a team player • Autonomous work	• Life-long learning • Learning skills, e.g.critical analysis of science popularization; using various resources such as internet, library, etc.
PK7: Competencies related to **self-reflection** and meta-cognition	
• Adapting a reflexive behavior (metacognition) • Self-assessment • Adapting critical and self-attitude • tudying his/her own practice	
Pedagogical Content Knowledge (PCK)	
Competencies related to the area of **teaching/learning processes within the domain**	
• Knowledge of educational methodology and science education • Representations of the content suitable for teaching • Pedagogical methods and tools scaffolding learning • Imparting of contents • Implementation of knowledge • Offering examples and pictures which are adequate and accessible • Presenting alternative explanations	• Adapting the scientific language to students
Competencies in **using laboratories, experiments, projects**, modeling and outdoor activities to build understanding and skills of students	
• Assuring the links between theory and practice • Developing practical abilities • Laboratory skills • Imparting close-to-practice knowledge • Doing age adequate experiments • Going on field trips	• Didactics of problem – based or project-based learning
Competencies addressing students' **common sense knowledge and learning difficulties**	
• Being aware of students' common-sense knowledge • Being aware of students' learning difficulties	• Being Familiar with research about students' common sense knowledge and learning difficulties • Identifying epistemological obstacles
Competencies in the **use of ICTs**	
• Using ICT • Integrating the multimedia resources in the activities • Creating material resources, to use educational software	
Competencies in the **knowledge, planning and use of curricular materials**	
• Producing educational materials • Familiarizing with science curriculum • Planning lessons	• Knowledge and use of various curricular materials • Designing teaching-learning sequences to learn scientific concepts and/ or processes (laboratories) • Defining goals and learning opportunities for students

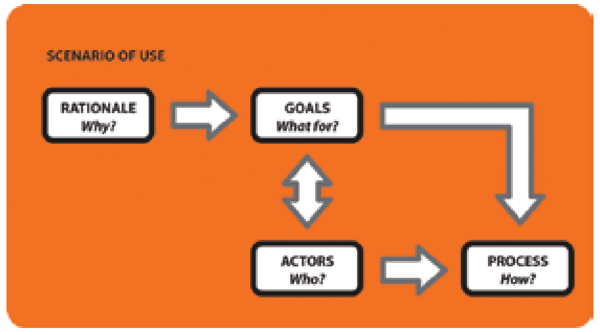


Figure 2. The main elements of the Best Practices

its potential users, the following structure of the information included has been devised and used consistently. In order to translate this process of describing the Best Practices into more practical terms, we have developed a specific template. In particular, to assist both for the developers of Best Practices and their target audience (teachers, teacher educators, museum pedagogues, etc), we constructed a set of guidelines to describe the process of implementation of a Best Practice. Therein, specific details of the Best Practice are presented, along with a description of their narratives and how they satisfy the above-mentioned principles. The structure of the template is as follows:

Title of the Best Practice.
Summary:
A short insight to the Best Practice describing the context and content.
Aims:
What is the aim of the Best Practice?
Description of the main activities:
The main activities included in this Best Practice.
End user:
The end user is the one who implements the Best Practices
Involved actors:
The involved actors, (e.g.students, teachers, *researchers, curriculum developers, the public).*
Location:
Where this Best Practice can be used. (e.g. school, at home, museum, internet, specific places).
Connection with the curriculum:
The links of the proposed Best Practice with certain areas of the school curriculum or other formal education curriculum.
Languages available:
In which languages the Best Practice and its material are available.
Where to find the application or Best Practice:
Indicate where the resource can be found.
Evaluation parameters:
How this Best Practice has been evaluated for its efficiency in promoting IBSE.
Duration:
The average duration of the Best Practice.
Additional information or resources:
Links to additional supporting materials.
Content:
A narrative description of the Best Practice.
Important principles to follow when doing Best Practices:
Explanation on how each Best Practice is in accordance with the required principles.
Required teachers' competencies:
Which (from a list of 13) competencies a teacher needs to know / have in order to use the material or application of the Best Practice. In combination with the 10 principles previously outlined, these details not only define the general characteristics a teaching Best Practice, but they break it down to specifics.

Building on the best of current practice

The implementation of the PATHWAY approach will highlight and promote Best Practices in teaching science by inquiry. Such a process will help to chart the course into the future. By building on the best of current practice, the Pathway approach aims to take us beyond the constraints of present structures of schooling toward a shared vision of excellence. The consortium will present a series of exemplary teaching practices, resources and applications that provide teachers (and their students) with experiences that enable them to achieve scientific literacy, criteria for assessing and analysing students' attainments in science and learning opportunities that school programmes afford. A long list of these resources is presented this book. The aim of the consortium is to offer to the teachers who will be involved in the training activities a variety of resources that is arranged so that it does not impose a fixed curriculum, but instead supports the development of a model that can be customized to reflect location, culture and ideology. The PATHWAY repository of Best Practices will be the window onto live scientific experiments and phenomena, ongoing research, and the personalities and stories of working scientists across Europe. This document descirbes a series of methodologies for initial teacher preparation and professional development (PD) programmes (Chapter 1) along with a series Best Practices for implementation in foirmal and informal learning settings. The PATHWAY Best Practices are organised in three main categories:

- School-Based Educational Activiies based on Inquiry-Based Science Education (Chapter 2)
- Educational activities connecting Formal and Informal Learning settings (Chapter 3)
- School - Research Center Collaborative Educational Activities (Chapter 4)

These materials are used for many years in numerous schools in Europe and they have proven their efficiency and efficacy as teaching resources that support inquiry. In the framework of the project the consortium proposes value-added services to increase the utility of these resources through coordination, systematic dissemination and effective teachers' community building. The PATHWAY training resources will be treated as case studies and will be disseminated in different environments (teachers' preparation and professional development institutions, schools) across Europe during the life cycle of the project. The process of observing and reflecting on teachers' actions, and on students' learning and thinking, can lead to changes in the knowledge, beliefs, attitudes, and ultimately the practice of teachers.

1.

Methodologies

for the initial teacher preparation

and professional development programmes

1.1 Evidence-based professional development

Summary:

Teachers are trained in experimental research, learning first-hand about research methodology and its outcomes. Thus, they build interest in Science for themselves, but they also become more effective "ambassadors" of Science for their students.
This strategy can be the basis of PD programmes lasting from a week to several years. This approach has been investigated in Germany and in the UK in the framework of PD programs and during the CERN High-School Teachers Programme. which lasts three weeks.

Aims:

These activities aim to:

- help science teachers develop expertise in the effective introduction of inquiry in their practice.
- develop teachers' "scholarship of teaching", which refers to the ability of teachers to present in public their teaching in such a way that others will learn from it (Hutchings & Shulman, 1999)
- build teachers' ability to reflect, to present evidence, and collaborate with their peers and is considered to be an important aspect of creating communities of practice (Lave & Wenger, 1991) .

Main activities:

In this program a set of inquiry activities has been developed beforehand and the teachers were required to implement the activities in their classes. Teachers became acquainted with the activities by experiencing them in three different modes: as learners participating in inquiry based learning, as teachers implementing inquiry based strategies in their classes and as researchers. In the third mode teachers collected data about their teaching and their students' learning, analyzed the data, and discussed the evidence collaboratively with their peers. Finally, the teachers prepared a portfolio documenting evidence of their practice. By the term 'evidence', we mean a collection of artefacts that show the teacher's work concerning their instruction and the students' learning, combined with written commentaries. In-between the meetings of the program the teachers interacted and were supported via an on-line platform. The results of the research conducted on this program showed that the strategy contributed to the professional development of the teachers. They changed their pedagogical knowledge and content knowledge regarding inquiry teaching; their anxiety concerning the implementation of the IBSE approach was reduced; and they became more reflective and more aware of their practice.
In this framework we are presenting three examples. The first case describes the FOPDA scheme that is implemented in Germany. The second presents a one-year Master programme that is implemented in the U.K. while the third case is describing the CERN High School Teachers Summer Programme.

Narrative A - The FODPA training scheme:

Teachers attend a day-long theoretical IBSE workshop at HUB and increase their knowledge about key issues in inquiry-based chemistry teaching. In parallel, science education research has provided a consistent evaluation regarding instructional efficiency.
Teachers often report that students are unsure of how to tackle an investigation, even to do small methodic sub steps such as declaring variables or sketching a table of results. A possible reason for this might be that previous learning of problem solving-steps or problem-solving strategies does not transfer to a new problem task. In order to create teaching and learning environments, that allow transfer, conditions that facilitate transfer need be taken into classes.
Under these headlines the FOPDA-scheme presents detailed questions to support own investigation, e.g. what we know already, which variable has to be constant and unchanged in my experiment. The target groups are pre-service teachers (i.e., university students for chemistry education), and chemistry in-service teachers. The developed materials cover the curriculum of 9th and 10 the grade in the region Berlin / Brandenburg. In order to promote IBSE we developed lessons including this FOPDA-scheme which in the whole follow all of this principles but, of course, a single lesson does not cover every criterion. Therefore, we will only present some exemplary descriptions of the realisation of these criteria in our Best Practice example.

Methods of learning/training :
Pre-service teachers: evidence-based PCK development; in-service teachers: evidence-based professional development.

End user:
Pre-service and in-service teachers for chemistry education at two different stratification levels: the Gymnasium as a "university-preparatory secondary school" (highest level; up to the 12th grade); and the Sekundarschule, where students may receive the "intermediate secondary school-leaving certificate" (intermediate level, up to the 10th grade).
The developed materials cover obligatory according to the curriculum topics of 9th and 10th grade chemistry lessons.

Involved actors:
Science education researchers.

Location:
Outreach laboratory at the Humboldt-Universität zu Berlin and if preferred, we will also come directly into the schools.

Languages available:
German.

Evaluation parameters:
Paper-pencil tests:

- Pre-and Post test to measure the changes in the views on Scientific Inquiry and Nature of Science of teachers participating at the teacher training activities.
- The transfer tests "Interim", "Post" and "Follow-up" were designed to analyse the transfer of schema main steps and schema sub steps on non-chemistry topics.

Videos are taken in order to record and evaluate teaching and learning processes. This best practice has been certified by the internal evaluation of the Humboldt-Universität zu Berlin.

Duration:

- Student modules:
- pre-service teacher modules: term-long experimental courses
- in-service teachers: day-long

Optimum number of participants:
6 to 15 teachers.

Additional information or resources:
www.tiemann-education.de

1.1 Evidence-based professional development

Narrative B – Masters programme to develop understanding of IBSE:

Teachers undertake a one-year Masters programme, which completes their Masters education begun in initial teacher education and training. Many opt to study inquiry-based science education. Teachers study part-time, using a mixture of online discussion workshops with a small chat-room group, and face-to-face teaching sessions on Saturdays. They continue to work full time in school, undertaking (generally) research on aspects of their own practice, to follow their interests. They gain an understanding of educational research methodology and use such understanding to plan a small scale research project, in which they inquire into aspects of their practice. Those students undertaking inquiry about IBSE form the subject of this best practice. In many cases, teachers follow an action research model, where they realise and appreciate the limitations in their use of e.g. practical work in the classroom, and they realise that they need to make such work more inquiry-based. We undertake training with them to help them become appreciative of the research and professional literature, and they develop a focus for their study, including definition of appropriate research questions, which they then undertake in school. They have about one term to undertake data collection, and one term to write up the final thesis, with many going on to publish their findings in the peer-reviewed literature. They also present their work to their subject departments, spreading the impact of their training more widely, and involving a larger number of teachers.

Methods of learning/training:
Participants draw on evidence from the research literature to support development of their thesis, using in-school data collection, under guidance from University tutors working in a blended approach, via a VLE and face-to-face.

End user:
Teachers from 11-18 comprehensive schools.

Involved actors:
Teacher trainers and University researchers.

Location:
At schools and possibly in informal educational settings.

Languages available:
English.

Where to find the application:
University of Cambridge, mediated through the VLE.

Evaluation parameters:
Teachers complete formal evaluation questionnaires, and the Masters programme as a whole is regulated and evaluated by internal Faculty of Education procedures.

Duration:
This can be relatively open-ended, but it would generally last 12 months, working part-time.

Additional information or resources:
The site which outlines the Masters programme within which this falls is included here: www.educ.cam.ac.uk/courses/graduate/masters/strp.html

Optimum number of participants:
15

Narrative C – The CERN high school teachers' training programme:

In one such case, CERN invites a group of high-school teachers to Geneva, Switzerland, every year, to learn about particle physics – and how to integrate these subjects in the school curriculum. The programme aims to demonstrate a process for bridging the gap between science education and communication and the frontier research taking place at CERN. The process is supported by relevant materials and resources that promote creative problem solving, discovery, learning by doing, experiential learning, critical thinking and creativity. The three-week HST programme hosts dozens of teachers from around the world, offering a deeper insight into particle physics through a variety of lectures, visits and workshops. The programme's ambitious overall aim is to help these teachers inspire their students to follow careers in science. In the second week, they split up into working groups to evaluate CERN's existing educational tools or create new ones. The programme emphasises on a new way of learning about science that reflects how science itself is done, on inquiry as a way of achieving knowledge and understanding about the world. Based on the spirit of experimentation this approach is implemented through resource based learning and scaffolding. Scaffolding takes place by dedicated scaffolds and tools that assist teachers in all aspect of the inquiry and design processes. Scaffolds include tools for data collection, means to create intuitive and mathematical models of phenomena, visualisations of data and processes of inquiry and collaboration and templates for the creation of reports and designs. All tools and scaffolds that play a part in the shaping of the missions that are assigned to the groups of teachers, implying that they can meaningfully process them. The overall goal is to allow teachers to effective use the available digital resources of CERN in order to enhance their everyday (formal or informal) educational practice. The main benefit for teachers is the opportunity to gain exposure to some of the most exciting bleeding-edge science in a way that is appropriate to their individual level of understanding

Hutchings, P. & Shulman, L.S. (1999). The scholarship of teaching- New elaborations, new developments. Change, 31, 5, 10-15.
Lave, J. & Wenger, E. (1991). Situated Learning: Legitimate Peripheral Participation, Cambridge
Harrison, C., Hofstein, A., Eylon, B. S., Simon, S. (2008). Evidence-based Professional Development of Science Teachers in Two Countries. International Journal of Science Education 30, 5, 577-591.
University Press, Cambridge, MA.

End user:
Experienced and novice teachers.

Involved actors:
Secondary science teachers (both teacher trainees and in-service teachers); Researchers.

Location:
Variable,, depending on the specific case.

Connection with the curriculum:
The cross-curricular nature of this training means that it can be used across all three science subject areas (biology, chemistry and physics) from lower to upper secondary age groups.

Evaluation parameters:
Depending on the specific case.
Duration:
Variable, depending on the specific case.

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	x
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

1.2 Teachers as curriculum developers

Summary:

Within the framework of this training approach, innovative instructional activities are being developed by teams of teachers guided by facilitators during the programme. The teachers implement the proposed activities in their classes and assess the effect on students' learning. The rationale behind this approach is based upon the assumption that teachers find it natural to design their own instructional strategies, since this is what they do all the time. Moreover, this kind of activity is a natural arena for them to manifest their knowledge, giving them the respect that is so essential for professional development.

Aims:

- Develop innovative instrucional activities.
- Help teachers develop their role as facilitators of students' learning.
- Promoted teachers' knowledge of content, pedagogy, and the relevant science education literature.
- Stimulate teachers' creativity and lead to diversification of the instructional strategies they use in the classroom.
- Assist in the formation of a community of learners.
- To support the diffusion of IBSE in schools.

Main activities:

- Lab experiments on a wide range of subjects (e.g., engineering, architecture, painting, mechanics, calorimetry, acoustic, heat, falls and bounces).
- Interactive activities.
- Discussions, lectures, games

Narrative:

The "Teachers as curriculum developers" approach can be carried out in different contexts. A series of implementations of this approach has been demonstrated in the Museum context in the framework of the SMEC project (School-Museum European Cooperation). The main aim of the project was to encourage the use of the museum as educational resource for the teaching and learning of science in primary schools, and to contribute to the training of teachers for the development of competence and expertise in using museums. The course is open to museum educators and school teachers, head teachers, advisory teachers and teacher trainers. The intention to bring together in a unique training opportunity education experts of schools and museums aims to:

- create the conditions in which different, but complementary, competences reflect together on the use of museums as an educational resource that could facilitate the introduction of inquiry based approaches in the classroom
- exchange experience and expertise and enrich their mutual knowledge on each other's education work
- devise joint pilot projects using museums for science education.

The course is held by an international group of experts from Belgium, France, Germany, Hungary, Italy and Spain specialising in museum education, science education, teacher training, research and evaluation, new technologies. The structure of the course consists of lectures, round tables, museum visits, interactive workshops and practical activities. The course is running for 5 years. It is held in the National Museum of Science and Technology "Leonardo da Vinci" and in the Deutsches Museum in Munich, where the collections, staff and educational programmes are used as an integral part of the course activities.

Different scenarios have been proposed and tested in this vein:

Leonardo da Vinci: three easy pieces

The activities investigate subjects studied and experimented upon by Leonardo da Vinci

The course investigates the different aspects of Leonardo da Vinci works and studies: engineering, architecture, painting. The course takes place in two areas of the Museum: the Leonardo interactive lab and the Leonardo gallery with the historical models realised on the basis of the Leonardo drawings. The two areas permit to investigate in depth da Vinci's thoughts, his notes, his historical period, the influences of the contemporary artists and scientists, the heterogeneity of his studies. The investigation is made not on the basis of his manuscripts but through interactive activities. Leonardo becomes a valid example of the interconnection between historical and cultural aspects with physics. The influence of humanistic culture on the scientific one becomes an example of how to present science and technology in a multisciplinary perspective in school. Each day of the course is devoted to a specific theme. During the first day teachers investigate Leonardo's machines: the aerial screw, the pulley, the cochlea. They experience how the machines work and interpretate Leonardo drawings, and they try to put some of his projects in practice.

During the second day static is investigated, in particular the equilibrium of some architectures. Some examples of the questions posed to teachers are: why does the marble of Milan Dome not fall? Or, why are there arches in many buildings? And which function they have? How do they work? The third day is devoted to Leonardo's polyvalence in science like in art. The teachers act as workers in a renaissance studio and experience the apprentice. They learn painting techniques like fresco and discover the different techniques used in the Renaissance and they compare it with the Last supper experimental technique.

In the world of numbers

Teachers explore data collection and analysis with scientific and contemporary instruments (graphic calculators and sensors).

This course includes:

- Two training days for the teachers.
- An educational kit with tools to conduct experiments in school.
- An interactive activity (2 hours) for the students in museum lab.

The trainer proposes some activities to the teachers.The aim is exploring mechanic, calorimetry and acoustics in a experimental way. They investigate and elaborate data with instruments like graphic calculators and sensors.

The teachers build experimental sets where to apply mathematical models and forensic sciences. These disciplines support the resolution of criminal cases and over the past years, found a large diffusion in the media with crime fiction highly appreciated by students.

Scenes from popular movies or TV crime fiction and simulated situations are the starting point of the activities. Teachers and later students build problem solving situations and explore some scientific phenomena behind the investigation.

Questions that emerged where:

- How to trace the exact time of a murder? (exchange of heat between two bodies)
- How to know the speed of two vehicles before the collision? (mechanic)
- How to identify people trough the voice analysis? (analysis of sound waves)

Did you want the bicycle?

The course investigates the science and technology involved in the construction and use of the bicycle.

This course considers the bicycle both as a transport tool and a sports object.

The bike is also an interesting medium to explore scientific and technological themes.

In this course teachers investigate and consider how cyclists experiment with their equilibrium, barycenter and proportionality and understand forces, the transformation of force into movement and importance of rhythm.

The bicycle becomes a tool to raise the curiosity of students and also a way to explore the different subjects of the curriculum: physics, energy, biology.

Three easy pieces

The activities propose experiments about classical physics.

This course explores three themes of classical physics in a practical and funny way:

- Bounces: is it easy to bounce a ping-pong ball and to centre a glass with this ball? Starting from this experiment teachers discuss and investigate on which are the key elements in a bounce.
- Falls: "In the absence of air every body falls with a constant acceleration equal to g". What happens if there is air? Which are the characteristic of the fall?
- Heat boxes: Is it possible put the sun's heat in a box to use it when the sun is not there? The teachers investigate an important component of the solar radiation: the infrared radiation.

These are some of the questions used by the trainer to explore scientific topics. Teachers develop experiments to answer these questions and develop new questions.

The course is inspired by the work of the physicist Richard Feynman; Feynmann's approach to scientific knowledge is proposed to teachers and discuss as a way to raise the interest of students in physics.

Open labs

Open labs are short courses that present new activities for schools, investigate new topics and reflect on the methodology adopted.

Open labs are short courses that present new activities for schools, investigate new topics and reflect on the methodology adopted. Teachers experience the activities and discuss how to adapt the activities for their classes.

The discussion among the teachers is stimulated by the trainer and the aim is building a community working on the IBSE methodology facing the same problem and sharing the possible solutions. The topics investigated vary: chemistry, food, energy, safety in life and in science, physics, historical scientific subjects, contemporary scientific issues.

Energetic sense

The activities experiment different type of energy sources and energy properties.

This course provides three days of teacher training, a kit to propose experiments to the students at school and a visit of two hours for the students in the interactive energy lab in the Museum.

In the teachers training some aspects of energy are investigated: the history of energy production, energy transfer between different systems, the energy transformation, the energetic balance and the heat.

Different phenomena connected with different kinds of energies are observed and described through the use of activities and games. A particular focus is posed on the principle of energy conservation. For example in some cases the principle of energy conservation seems to be violated and the phenomena are so surprising that they appear quite like magic. The use of this apparently magic part of science as a means to raise the curiosity of students is discussed. The cause of the phenomena are investigated. The research and discovery of "hidden" energy lead to a better comprehension of what happens.

The activities deal with:

- The mechanical energy and the energetic state of a system
- The mechanical energy transformation in other energy forms
- The energetic balance
- The power consideration
- Materials that transform energy
- The efficiency of an energetic transformation
- The propagation of heat using a thermal camera

Science in practice

The activities of the training course focus on methodologies for science education applied to different topics

The aim of the course is to examine and experiment teaching and learning methodologies for science education helping teachers to strengthen their competences and role. For this, the course invests in the teachers as learners, as educators of the young and as reflective practitioners. Teachers contribute their own points of view to the discussion, bringing their personal experience to the development of the experiments.

At the same time, they are called to think about their students' point of view and learning needs. In this, the parents can also be regarded as important agents, they often influence food choices. Their role in learning is discussed too.

The learning and experimentation process within the course starts with a question posed by the museum experts which leads to initial hypothesis, identification of the parameters to experiment and a first evaluation of the already-acquired notions by the participants. The teachers work in groups on the basis of the question and the hypotheses, aiming to find out the answers on the basis of the data collected through experiments. Group work allows for negotiation of choices, discussion of results, understanding of errors and (indirect) evaluation of the learning methodologies.

The final results of the different groups are shared among all the participants. At the end, museum experts facilitate a general discussion about the methodology adopted as well as about the topic itself. They encourage teachers to focus also on how to adapt the activities to the work in class.

Sharing of experiences among the participants is an important part of the course. The teachers discuss among colleagues and with the museum experts sharing experience, solutions of possible problems and ideas for projects that integrate the topic of the course in the class activities.

These scenarios will be analysed in detail in the following chapters.

1.2 Teachers as curriculum developers

Methods of learning/training:
Inquiry, experimentation, collaborative learning, scientific method, discussion.

End user:
In-service teachers of primary and secondary school.

Involved actors:
Teachers.

Location:
National Museum of Science and Technology Leonardo da Vinci.

Languages available:
Italian.

Where to find the applications:
www.museoscienza.org/scuole/corsiFormazione.asp

Evaluation parameters:
Discussion with teachers. This best practice has been certified by the internal evaluation of the Museo Nazionale della Scienza e della Tecnologia "Leonardo da Vinci".

Duration:
Variable (from 2 hours to open-ended).
Optimum number of participants:
15-20

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

1.3 Developing instructional leaders in IBSE

Summary:

Integrating IBSE practices with training received from school-based mentors as part of an Initial Teacher Training course.

Aims:

To develop a common understanding of IBSE practices within a group of mentors as part of their teacher education program and to work with the trainee teachers to integrate this understanding into their teaching.

Main activities:

Development of an understanding of IBSE with experienced science teachers who are mentors through faculty-based sessions. Where possible, the support of their work with trainee teachers on the faculty of education teacher training and then the sharing of their experience of this work and their own understanding of IBSE in secondary schools. Two cases of this approach are presented, one as part of the PGCE (Post Graduate Certificate Education) course of the Faculty of education of the University of Cambridge and a second one as part of the Professional Development programme of the Greek Ministry of Education.

Narrative B-Instructional leaders training in Greece

During training courses, ICT is integrated with Pedagogy building blocks. These are based on modelling and simulation and include prediction, observation, explanation, analysis, implementation, verification. The course is implemented in two Phases.

Phase A

a) The principles and fundamental curriculum issues for teachers were developed for the disciplines of Natural Sciences, Mathematics, Primary School Education, Literature.

b) b. Trainers were selected for different territories of Greece depending of the specific needs of each territory. The selection of the initial trainers was based on an examination process where they had to develop a didactic scenario and to explain certain approaches they would follow for issues related for example in a problem based situation.

c) A Management Information System (MIS) and a Forum were developed for communication and exchange of ideas.

d) A critical mass of trainees was selected based on their previous successful implementation of the program "Teachers training for the basic skills for ICT-P1" and their willingness to be involved in the training process, as well as on their experience and qualification in ICT. The project was implemented in Attica, Ioannina, Patras and Thessaloniki.

e) Support centres were established in different territories for the support of the training process.

Phase B

a) A Scientific Board was established under the umbrella of the Greek Ministry of Education for the implementation of the project; also, Scientific Groups for every discipline, with a Scientific Coordinator assigned for every discipline.

b) Trainers were selected for this phase phase of the project.

c) Training material was developed for the different disciplines (360 hours for every training period with 160 hours devoted to a General Part and 200 hours to the Didactics of the specific discipline). The training material / modules were based on the principles of Science Education and PCK and were developed by the Scientific Committee, as well as by experienced teachers.

d) Standard operational procedures were established for the development of training guidelines, for the dissemination activities, the implementation of the project and, finally, for the subsequent employment of trainees as trainers/multipliers of the project at specific training centres connected to schools.

e) The trainings were carried out over a 2-year period (November 2007-2009) at the University Training Centres, each of which had the responsibility to implement the training program according to the guidelines provided by the Ministry's Executive Board and the Scientific Board. During that period.

End user:
In-service teachers.

Involved actors:
Teachers, teacher educators.

Location:
Teachers training centers.

Connection with the curriculum:
All the activities cover the current curriculum for Grade 10,11,12 students. Slight modifications could apply to the applications to be appropriate for Grade 9 students

Languages available:
Greek.
Where to find the application or case: www.spsycharis.gr at the part dedicated to PATHWAY.

Evaluation parameters:
This methodology is officially sanctioned by the Greek Ministry of Education.

Duration:
50 hours

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	x
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

1.4 Developing IBSE scenarios using the COSMOS ASK learning design authoring toolkit

Summary:

Science teachers are provided with a Learning Design authoring Toolkit, namely COSMOS ASK-LDT, with predefined learning design templates suitable for designing IBSE Scenarios. The IBSE Scenarios developed with the use of COSMOS ASK-LDT are compatible with IMS Learning Design Specification and this enables science teachers to share their IBSE Scenarios through web-based repositories such as the COSMOS Learning Design Repository (www.cosmosportal.eu).

Aims:

The main aim of this best practice is to support and guide science teachers in the process of designing IBSE Scenarios by using pre defined learning design templates that follow the inquiry-based teaching model.

Main activities:

The main activities of this best practice could be summarised as follows:

- Science teachers are presented with a methodology for expressing and designing the main elements of IBSE Scenarios;
- Science teachers are presented with the main functionalities of COSMOS ASK-LDT for developing IBSE Scenarios;
- Science teachers design and develop their own IBSE Scenarios following the presented methodology and using the COSMOS ASK-LDT;
- Science teachers provide their feedback regarding the process of developing IBSE Scenarios following the presented methodology and using the COSMOS ASK-LDT.

Narrative:

The best practice targets science teachers of any educational level and support them in the process of designing and developing IBSE Scenarios that can be shared and reused via web-based repositories such as the COSMOS Learning Design Repository (www.cosmosportal.eu).
First, the participants are presented with a methodology for expressing and designing the main elements of IBSE Scenarios. This methodology provides the means to:
(a) describe the main elements of an IBSE scenario in narrative format.
(b) design the learning activities' flow of the IBSE Scenario.
(c) describe the learning activities of the IBSE Scenario by using a common vocabulary.
The next step includes the demonstration of the COSMOS-ASK-LDT main functionalities. COSMOS ASK-LDT is a stand-alone graphical authoring tool, which enables its users to graphically design IBSE Scenarios based on the interconnection of learning activities. COSMOS ASK-LDT can export IBSE Scenarios conformant with the IMS Learning Design specification and publish them to existing web based repositories. Additionally, COSMOS ASK-LDT enables its users to characterise the learning activities used for developing IBSE Scenarios, based on a common vocabulary of terms derived from the "DialogPlus Taxonomy of Learning Activities". Afterwards, participants are use COSMOS ASK-LDT, so as to design and develop their own IBSE Scenarios by following the methodology presented in the first step. Finally, there is an evaluation activity, concerning the use of the methodology and the COSMOS ASK-LDT for designing and developing IBSE Scenarios.

Methods of learning/training:

- Combination of knowledge transmission, that is, presentation about the methodology for expressing and designing the main elements of an IBSE Scenario, and a demonstration of COSMOS ASK-LDT;
- Trainee-centred activities in which there is active participation, including activities where trainees use COSMOS ASK-LDT for developing their IBSE Scenarios and the provide their feedback about the process.

End user:
Science teachers of any educational level.

Involved actors:
Technology-enhanced learning experts and science teachers.

Location:
Takes place in a classroom laboratory equipped with a video projector and workstations for the participants.

Languages available:
The proposed methodology and the tool interfaces are available in English language.

Where to find the application:
The COSMOS ASK-LDT can be downloaded from the COSMOS Learning Design Repository (www.cosmosportal.eu).

Evaluation parameters:
Science teachers are able to evaluate the process of designing and developing IBSE Scenarios by using appropriately designed evaluation questionnaires. Furthermore, the usage and adoption of the developed IBSE Scenarios by the participated science teachers during their day-to-day teaching activities is another evaluation parameter.

Duration:
The total duration is fifteen (15) didactical hours. The first six (6) consist of a presentation about the methodology for expressing and designing the main elements of IBSE Scenarios. The next three (3) consist of a demonstration of the COSMOS ASK-LDT main functionalities. The last six (6) consist of a hands-on session where participants design and develop their own IBSE Scenarios and they provide their feedback regarding this process.

Optimum number of participants:
20-25 participants.

Additional information or resources:
Additional information about the methodology for expressing and designing the main elements of IBSE Scenarios, as well as about the COSMOS ASK-LDT is available at the COSMOS Learning Design Repository (www.cosmosportal.eu).

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

1.5 INQUIBIDT – Inquiry-based Biodiversity Teaching in Teacher Education

PATHWAY

Summary:

One problem of teaching about biodiversity is the vast number of facts that are necessary to have available in the field. InQuiBiDT includes mobile technology such as smart phones and tablet computers to support self-directed, location-based learning and knowledge construction at the actual location. InQuiBiDT participants explore the flora and fauna just at their doorstep. The main activities consist of gathering data about one specific location and communicating the results to other participants as open source material. To achieve this, students use ICT and mobile devices as information resource, aid to their location-based inquiry, as their general communication tool as well as a tool for dissemination of their results in the later stages. The results are open source and published in a wiki format to further spread the idea of learning about biodiversity by inquiry. The target groups are pre-service teachers as well as secondary school students

Aims:

The central idea of the Best Practices is to create a modern approach of exploring the traditional biological subject of taxonomy using the IBSE approach. The biodiversity of plants and animals can be explored with support of digital media. The advantage of these taxonomy classes are the opportunity to use location-based units of instruction and inquiry on site by using the mobile computers to store and analyze data. Through the availability of information on file and off the internet, supporting information on the actual habitat and biozenosis can enhance the inquiry experience. The mobile devices also help the learners to interact and create information directly on site and thus facilitate communication and presentation skills. Through the availability of supporting information on demand, the InQuiBiDT approach also caters for differences in learner's abilities, since the participants decide about their need for information during the inquiry process.

Within the InQuiBiDT course pre-service teachers experience inquiry-based science education approaches (IBSE) that they can use in other courses as well as for their further professional development as teacher. The work on a specific habitat includes structured, guided and open inquiry elements that can also be used for school students by pre- or in-service teachers that participate in this course. The information in the wiki format that accompanies the course shows the scope of information that can be accessible for public use. The InQuiBiDT approach can be structured as a single project, a census of one or more habitats, or a larger commons project, using social media and geocaching elements to create more access points for public use.

Main activities:

- Inquiry on site: One specific habitat is examined. Abiotic factors such as humidity of soil, temperature etc are collected. Biotic factors such as indicator species and species diversity are identified.
- Inquiry off site: The students create a systematic overview of the kingdom of plants and animals using social and collaborative methods (e.g. jigsaw-method, collaborative concept mapping or wiki content creation)
- Inquiry on site: Data collection and processing, as well as presentation using mobile devices such as cell phones, tablet computers and GPS devices.
- Inquiry off site: communication using open source tools for the creation of information that is available of various mobile devices to use on site.

1.5 INQUIBIDT – Inquiry-based Biodiversity Teaching in Teacher Education

Narrative:

The InQuiBiDT course starts with an introduction to the system of plants and the biodiversity of local flora and fauna. This is done in a classroom setting to bring the students up to speed. The students then break up into smaller groups that inquire into one specific area of taxonomy (e.g. a few families of plants to learn more about) to become 'experts' in that field. These experts on certain families of species assemble into new groups consisting of one expert from each expert group so that the majority of families are covered.

These mixed expert groups start their inquiry on site of a specific habitat using GOOGLE Maps and GPS to locate the site. There they record the local biodiversity and abiotic factors. The data gathered can be analyzed on site or off site, using the facilities of the university. The task of building a hypothesis and analyze the data is an open inquiry approach that grants a maximum of independence to the students.

After analysis, their results are edited for presentation on a wiki website that can only be accessed by other habitat groups by scanning a geocached QR code with a smart phone or tablet computer. This information is created for a general audience that visits the habitat and finds and scans the stashed QR code. The data and results on the website should educate about the habitat and its consistence of species as well as give further interesting information on biodiversity and ecology.

The other habitat groups now visit the other habitats and use the QR code to access the respective wiki website. Since they have the experience of their own InQuiBiDT habitat, they can add to or even correct the information that is already published by the other groups. Especially with animal species, more visits can lead to more sightings. So, every group can contribute to their fellow group's information.

By using habitat that differ in their ecology and consistence if species, the students visit unfamiliar habitats where they can use their skills from their own habitat to learn about the others. This way, the students experience diverse learning opportunities about biodiversity, covering a wide range of habitats that would only be presented briefly in other taxonomy courses.

End user:
Pre-service teacher students (age 18 to 23 years), in-service teachers, secondary school students grade 5-9 (11-15 years)

Involved actors:
Researchers, teacher educators, in-service teachers

Location:
School or university, schoolyard, field and outdoor, internet

Connection with the curriculum:
Biodiversity as part of the environmental education and the education for sustainable development can be found in secondary school curricula as well as in the curriculum for pre-service teacher education and in-service teacher training.

Languages available:
German.

Where to find the application or case:
Web-based information, location-based learning using geocaches and mobile devices

Evaluation parameters:
InQuiBiDT evolved since 2004 and different aspects of it have been in the focus. Compared to traditional biodiversity teaching, the InQuiBiDT approach showed higher achievement and emotional involvement compared to traditional teaching concepts (Schaal & Randler, 2004, Schaal, 2009, Schaal & Matt, 2011).

Duration:
A pre-service teacher InQuiBiDT course is designed for 3 ECTS which means for about 90 hours in total (attendance and self-directed learning).
An in-service teacher workshop is conceptualized for about 8 hours.

Additional information or resources:
http://wikis.zum.de/inquibidt

Teachers' competencies

1	subject matter/content knowledge	x
2	nature of science	x
3	Multidisciplinary	x
4	knowledge of contemporary science	
5	variety of (especially student-centred) instructional strategies	x
6	lifelong learning	
7	self-reflection	
8	teaching/ learning processes within the domain	x
9	using laboratories, experiments, projects	x
10	common sense knowledge and learning difficulties	
11	use of ICTs	x
12	knowledge, planning and use of curricular materials	
13	Information and Communication Technologies with Technological Pedagogical Content Knowledge	x

1.6 Teacher professional development in informal learning settings

Summary:

Teachers work directly with museum educators who specialize in using inquiry approaches within the context of museum learning. Through hands-on, practical workshops, theater performances, teachers practice inquiry techniques that can be applied both within the classroom and informal learning settings.

Aims:

This activity aims to support teachers in:

- developing teaching approaches which promote IBSE
- developing opportunities for learning science outside of the classroom.

Main activities:

Out-of-school training for in-service and pre-service teachers.

Narrative:

This methodology is based on the consolidated literature and experience in museums in the fiels and has been developed and applied by the Horniman Museum and Gardens in London and the National Museum of Science and Technology Leonardo da Vinci in Milan. Both of these museums deliver successful learning programmes to tens of thousands of students each year.

Teachers visit the museum to take part in professional development programmes that foster an open dialogue between museum education staff and school teachers. This is in order to share best practice in IBSE teaching techniques. Teachers are introduced to the benefits of using museum collections and workshops to support their teaching both within the science classroom and within informal learning environments such as museums, zoos, botanical gardens, science centres and aquariums.

The training:

1. Uses a teacher-as-learner model to introduce teachers to inquiry approaches to learning using museum collections and resources.
2. Demonstrates how to build on natural curiosity to explain things in the world around us
3. Promotes inquiry learning through demonstrating engaging practices in hand-on, exploratory, open-ended discovery learning.
4. Role-models student-directed learning approaches where there may be multiple different outcomes and answers.
5. Encourages the discussion and evaluation of multiple hypotheses and lines of inquiry.
6. Challenges teachers to reflect on their own practice. The training session includes collaborative group tasks in which participants are given opportunities to develop and share ideas for how the museum learning approaches could be used to promote inquiry-based learning in their own classroom practice.

End user:
Pre-service and in-service teachers of students aged 5-18.

Involved actors:
Museum education officers, informal learning officers.

Location:
Horniman Museum and Gardens, London.
National Museum of Science and Technology Leonardo da Vinci, Milan

Languages available:
English, Italian.

Where to find the application or case:
www.horniman.ac.uk
http://www.museoscienza.org/english/

Duration:
Teacher training workshops last from 2 to 10 hours.
The length depends on the experience of teacher taking part to the workshops, on the science topic to exploit and on the variety of the activities presented.
They usually take place after school.

Additional information or resources:
Training will be advertised on the museum website at www.horniman.ac.uk and through the London STEMnet networking channels.

Teachers' competencies

1	Competencies related to subject matter/content knowledge	
2	Competencies related to the nature of science including inquiry knowledge and skills	
3	Competencies in framing a discipline in a multidisciplinary scenario	
4	Competencies in knowledge of contemporary science	
5	Competencies in mastering and implementing a variety of instructional strategies	
6	Competencies in sustaining autonomous life-long learning	
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	
10	Competencies addressing students' common sense knowledge and learning difficulties	
11	Competencies in the use of ICTs	
12	Competencies in the knowledge, planning and use of curricular materials	x

1.7 Subject knowledge enhancement through inquiry

Summary:

This methodology supports pre-service and inexperienced teachers to develop their subject knowledge and pedagogical approaches for teaching science. They engage in IBSE activities in a 'teacher as learner' model of professional development to reflect on, develop and refine their practice.

Aims:

This is designed to model good classroom practice, as well as develop their own understanding of IBSE.

Main activities:

Participants take part in workshops designed around group work and discussion and based on IBSE stimulus material and equipment. The teachers are provided with wide ranging materials including texts, images, video, games and practical equipment. Workshops utilise best practices in IBSE to support the development of the teacher's subjects knowledge through inquiry activities.

Narrative:

The Subject Knowledge Enhancement (SKE) course is designed for teachers to take part in at some point in their careers after they have qualified. It has also been used to support pre-service teachers and museum education officers who are teaching science subjects outside of their knowledge specialisms.
It aims to support and develop participant subject knowledge in subjects outside if the participants' expertise as well as to help participants keep up to date with the latest advances in scientific research.
Participants take part in after school workshops that comprise group work and discussion around stimulus materials and equipment. They work through content covered in the subject area by taking part in classroom activities based on the inquiry model of teaching and learning. Participants are asked to consider both how their own understanding of the subject knowledge develops, as well as review the activities to assess how they might use them in their own practice.
Together with prompts and suggestions from the tutor the participants are asked to find ways, in groups and individually, to construct and articulate their own understanding of the topic, as well as develop strategies and approaches for classroom teaching of these materials to students. They are provided with an opportunity to discuss and share their views and experiences to help move the group towards a common understanding. Where the course is offered over several workshops, appropriate outcomes are shared within the group by the use of a course wiki and then more widely as they work back in the departments in their own schools.

End user:
Teachers of students aged 11-18, museum and science centre education officers.

Involved actors:
Teacher trainers, CPD leaders.

Location:
Out of school training venues, science centres, museums.

Languages available:
English.

Where to find the application:
Materials are webhosted in a secure wiki. Contact the University of Cambridge Faculty of Education for details.

Evaluation parameters:
Teachers complete formal questionnaires and the course itself is evaluated within the network of Science Learning Centres.

Duration:
Courses vary from one-off focused workshops to extended programmes of several hours over several weeks.

Optimum number of participants:
20-25.

Additional information or resources:
Details of the SKE program are available here: www0.tda.gov.uk/teacher/returning-to-teaching/ske-for-returners.aspx and details of the Science Learning Centre East of England here: www.sciencelearningcentres.org.uk/centres/east-of-england

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	
3	Competencies in framing a discipline in a multidisciplinary scenario	
4	Competencies in knowledge of contemporary science	
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	x
11	Competencies in the use of ICTs	
12	Competencies in the knowledge, planning and use of curricular materials	x

1.8 Inquiry-based teachers' training in the science laboratory / training centers

During the science teachers' training on METABOOK

Summary:

During the "METABOOK- Creation and Experimental Application of Multimedia Electronic Book in High School Physics" Minerva Project (90175-CP-1-2001-1-GR-MINERVA-M) and after the creation of National ebook material for Physics, Chemistry and Biology, which use the inquiry-based methodology, the Pedagogical Institute followed the official training procedure of the Greek Ministry of Education to train the Greek science teachers into the new material. In this procedure the teachers are trained in the science laboratory / training centres (ΕΚΦΕ) by the members of the Pedagogical Institute, the science school counselors and the training centre responsible.

Aims:

To train the science teachers into the supporting digital and laboratory material.

Main activities:

Using precise parts of the new material (e.g. METABOOK) the science teachers make precise applications under the guidance of the school counselor and / or the course responsible of the Pedagogical Institute.

Narrative:

The Pedagogical Institute is part of the Greek Ministry of Education and uses the national training procedure for the continuous education / training of Greek science teachers. For this purpose, there is at least one science laboratory / training centre (EKFE) in every prefecture of Greece. They are well equipped with the necessary science instruments and computers. The typical procedure is the following: during the implementation of a training program, the member of the Pedagogical Institute collaborates with the science school counselor of every Greek prefecture (who supervises an EKFE) and the EKFE responsible to undertake a necessary number of training activities. Over the last ten years, we have used this procedure for the training of the involved science teachers in the Minerva project METABOOK, and the digital material on Physics, Chemistry and Biology created to support the ordinary books of secondary education. Besides the above main procedure, the science school counselor of a region may call some groups of teachers for additional training at the EKFE. The evaluation of every training day is made by asking the trainees to fill in a certain questionnaire. During this period the Pedagogical Institute has focus on the implementation of IBSE. All the created official didactic packets in Science (Physics, Chemistry and Biology) and the supporting digital material have been created to facilitate the IBSE. For this purpose the number of training centres has been substantially increased. But it is not clear that all this effort has reached the students. According to the annual reports of the school counselors no more than 5% of Greek science teachers use IBSE in the classroom! Important Remark: While the training procedure may be considered excellent, it has not yet been measured, whether this training improved the classroom teaching. The non existence of any teachers' evaluation procedure in the Greek educational system does not permit the PI members and the school counselors to enter the classroom and objectively measure the effect of any training program!

Methods of learning / training:
This belongs to the teachers' continuous training procedure of the Greek Ministry of Education.

End user:
Science teacher of secondary education.

Involved actors:
Members of Pedagogical Institute (which are creators or supervisors of the new digital material), the school counselor and the EKFE responsible of the region where the training activity takes place.

Location:
It takes place in the science laboratory/ training centres (EKFE) of each region of Greece.

Languages available:
Greek.

Where to find the application:
The METABOOK at 1ekfe-anatol.att.sch.gr/metabook/metabook_gr/initial.htm, the Physics material at www.pi-schools.gr/software/gymnasio/fysiki_b_c, the Chemistry material at www.pi-schools.gr/software/gymnasio/ximeia_b_c and the Biology material at www.pi-schools.gr/software/gymnasio/viologia.

Evaluation parameters:
This is the official training procedure of the Greek science teachers.

Duration:
It starts with one day for each group of teachers, but the school counselor may call on additional training for some teachers.

Optimum number of participants:
No more than 20 teachers for each training day.

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	
7	Competencies related to self-reflection and meta-cognition	
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	

1.9 Networking practitioner research in learning communities

Summary:

Networking practitioner research is an approach to school improvement and teacher continuing professional development. It emphasises action research being done by schools and networking among schools. It positions teachers as researchers and teachers as collaborators. In science education, networking practitioner research has been identified as important in building the skills and knowledge of science teachers across the three science subjects. In the UK many science teachers are expected to teach science subjects which are not their area of specific expertise. This best practice was captured by the South London Networked Learning Community as part of a UK government funded Networked Learning Communities (NLC) programme conducted between 2002 and 2006.

Aims:

To provide a model of teacher-led action research that takes place through collaboration and networking with colleagues across multiple schools according to the following purposes:

1. Purposes of practitioner research:

- Teachers' professional development – collaborative practitioner research that involves individual teachers in critically examining their own practices
- School improvement – schools engaging in research in order to enhance teaching and learning
- Knowledge creation – schools carrying out research in order to contribute to validated public knowledge about good practice

2. Purposes of school networking:

- Mutual support and sharing of ideas
- Engagement in joint research – e.g. several schools testing solutions to shared problems; several schools testing innovations in different contexts; several schools involved in randomised controlled trial

3. Sharing of good practice / innovation transfer-dissemination of research findings into good practice has been resistant to solution – best practice has to be demonstrated, not just explained, and must be practised through trial and error, through the creative adaptation of the innovation to be transferred

Main activities:

Teacher-led action research on their own practice in science teaching. Networking between science teachers in different school sites.

Narrative:

Networked practitioner research assumes that teachers are researchers of their own practice-self-inquiring practitioners continually and continuously engaged in reflexive and critical evaluation of their own theories and practices – within networks of schools, research and teacher education institutions. In the South London Networked Learning Community, teachers from across different institutions teamed up to explore shared classroom interests and problems in science teaching and learning. These areas for teacher-led action research included: "independent learning by reflection in science", "students' self-perceptions in science", "organisational structures for thinking in science", and "higher-order thinking skills in science". Participating teachers in the South London NLC articulated the benefit of the approach as: "action research as enquiry", "evidence-based reflective practice", "engendering a culture of enquiry in the schools", "constructive criticality", and "creating a culture of innovation, creativity, and risk-taking".

Based on the case study of best practice in networked practitioner research at the South London NLC, as well as partner networks in the national programme, the project findings offer a model of Research, Enquiry and Professional Learning which is based on a four-stage, cyclic model of:

1. posing questions
2. taking action
3. collecting evidence
4. reflecting and re-posing questions

In order to enable cycles of professional inquiry, the educational institutions and their wider networks in the project had to have:

- a commitment to systematic questioning of one's own teaching
- the commitment and skills to study one's own teaching
- the concern to question and test theory in practice

A more detailed breakdown of how to promote inquiry amongst trainee teachers working within school-based networks is as follows:

1. Developing and sustaining supportive and invigorating relationships – information sharing and psychological support; openness and mutual trust; respect for diversity of contributions drawing on teachers' existing knowledge and experiences.
2. Determining clear purposes and strong commitment to the work – developing common core values and beliefs; establishing shared understandings of purpose, relevance, ownership and accountability.
3. Ensuring voluntary participation – variety of activities and structures for members to work flexibly and in a range of ways, with different levels of commitment, to suit professional and personal needs.
4. Engaging and maintaining commitment of school leadership.
5. Building effective and flexible communication strategies – systems to support members;

1.9 Networking practitioner research in learning communities

recognise importance of discussing practices and shared issues; provide means of disseminating work in ways which are useful in different contexts.

6. Learning from alternative perspectives within and beyond schools – drawing on knowledge and experiences of range of members, including students; involving other institutions, such as universities, to provide training on research methods, theory and longer-term critical challenges to the network's development.
7. Maintaining resources in terms of time and energy – ensuring sufficient resources to get the network started and sustained; recognising time required for teachers to build relationships, take risks and find creative solutions to shared problems.

Methods of learning/training:
Blended in-school training.

End user:
Teachers.

Involved actors:
Researchers and national body for school improvement (NCSL).

Location:
In school continuing professional development (CPD) programmes.

Languages available:
English.

Where to find the application:
McLaughlin, C, Black-Hawkins, K, McIntyre, D & Townsend, A (2008) Networking Practitioner Research (Abingdon: Routledge).

Evaluation parameters:
The methodology was part of the UK government funded Networked Learning Communities (NLC) programme conducted between 2002 and 2006. More than 134 school networks took part, involving approximately 35,000 staff and over 675,000 pupils. Best practices were studied and evaluated in detail by a team from the University of Cambridge school of education. For the evaluation, six NLC networks were studied, each one consisting of a cluster of schools which acted together to identify and carry out research on an area of school improvement. The research team carried out interviews with participating teachers, collected documentation and observed network sessions and lessons intended to demonstrate the effects of practitioner research. A questionnaire was completed by 651 teachers participating in the networking practitioner research programme.

Duration:
Open-ended. The South London NLC programme continued for 3 years with funding.

Optimum number of participants:
In year one of the programme, 12 teachers participated across 6 schools; in year two this scaled up to 24 teachers in 6 schools; and in the third year of the programme 48 teachers participated across the cluster of 6 schools.

Additional information or resources:
A substantial databank of resources from the entire NLC programme is available at: www.nationalcollege.org.uk/index/about-us/national-college-initiatives/previous-initiatives/networked-learning.htm

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	
3	Competencies in framing a discipline in a multidisciplinary scenario	X
4	Competencies in knowledge of contemporary science	
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	
10	Competencies addressing students' common sense knowledge and learning difficulties	
11	Competencies in the use of ICTs	
12	Competencies in the knowledge, planning and use of curricular materials	x

2.

School-based educational activities

based on inquiry-based science education

2.1 The hearing of sound

Pupils investigating vibrations as the source of sound.

Summary:

The "Hearing of Sound" consists of four interdisciplinary learning stations in biology and physics, where students of age 14-15 can learn about sound waves and human hearing by inquiry. Students learn through the help of the provided material and experiments on their own. The teacher steps back and holds the role of a guide. He helps to overcome problems, but he is not the centre of the class room attention and does not provide answers to common questions students have. His role is to encourage students to find the answers themselves, by contacting their team, the given texts and the experiments..

Aims:

(a) To foster **interdisciplinary scientific thinking** in order to connect disciplines which have been seen hitherto as separated. With the example of hearing, the disciplines biology and physics are connected by acoustics and the anatomy of the human ear. It is important for students to realize, that although scientific subjects are often taught separated, that these subjects have common overlapping boundaries, linking them in reality. It is important to provide students with the ability of view a problem they encounter in real life from more than one angle. The "Hearing of Sound" is one occasion where this ability is trained, due to its interdisciplinary view on a topic.

(b) To apply the **pedagogy of Inquiry Based Science Education** (IBSE) in concrete learning activities.

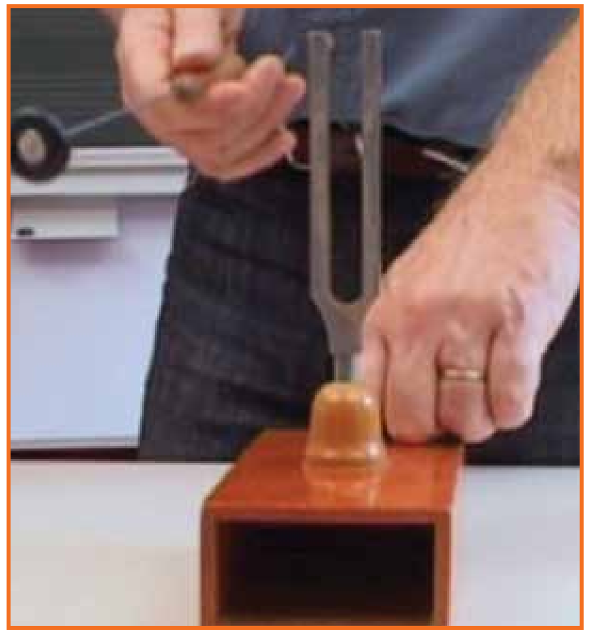
Students are invited to:

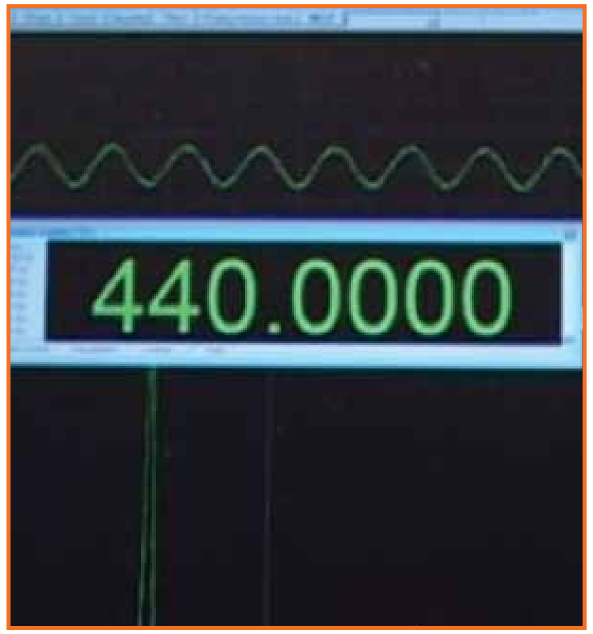
- To wonder about sound and hearing.
- To investigate the questions on the topic.
- To conduct experiments on these questions
- To confront their ideas with their experimental results.
- To understand the meanings of their findings.
- To summarize their conclusions.

Main activities:

In this practice, the scientific inquiry is understood as a process of scientific reasoning along following lines:

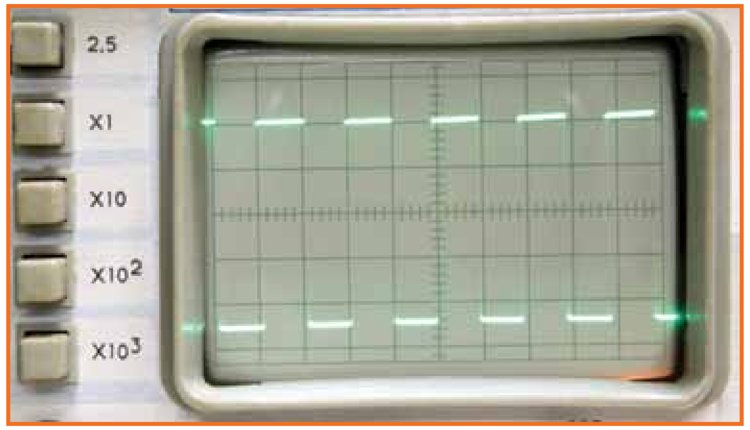
1. Raise awareness of a phenomenon by giving a brief introduction. Make the students aware of what they do not know.
2. Let them form hypotheses and collect their thoughts and solution suggestions
3. Let them test if their suggestion is in line with the results of a matching experiment.
4. Guide them to develop consistent scientific explanations when analyzing the data obtained by the use of inquiry scientific thinking.
5. Let them evaluate these explanations (metacognition), by reflecting them on the information they had before the experiment, and on the new information they gather during the process of the four course hours and beyond in their free time.





Experimental inquiry to explore the concept of tone and frequency of a tone with free sound analysing software

2.1 The hearing of sound



Narrative:

The "Hearing of Sound" consists of four interdisciplinary learning stations.

1. **What is sound?**
   In station 1 students discover that vibrations are the source of sound. These vibrations are transmitted in waves through a medium (like e.g. the air). This brings up the question of how sound is transported through the room. Students are encouraged to think about this by simple analogies like the Mexican Wave.
   Students measure noise and tone, using a PC and software that turns the sounds into graphs. Students discover that noise is called tone as soon as the wave repeats itself in time. From that moment on the notion of frequency makes sense. What we hear as higher and lower tones can be scientifically understood as the number of cycles per second.
2. **The anatomy of the ear**
   The investigation of the ear starts at the outer ear with the ear flap and by the hearing canal. With the ear drum the middle ear begins. From there the sound is conducted to the inner ear. But how does the sound information cross the middle ear? Thereto we need to learn about the ossicles that form a lever system. But what is a lever, and what is its function in the middle ear? Of course, to increase the sound impression. There is another system to increase this impression, the different size of the ear drum and the oval window. Students can explore these phenomena in experiments and link the underlying systems to the middle ear.
3. **How do we discriminate frequencies?**
   In this section the students focus on the phenomenon of Eigen frequency, which plays a special role in the inner ear. The mechanisms underlying, learned through an experiment about Eigen frequency, is then transferred to the properties of the inner ear. For this reason, equipment the students are already familiar with from the prior course lessons, is used again to symbolize the inner ear. The properties of the model and the actual inner ear are then compared by the students.
4. **The limits of hearing**
   Now that the hearing process is known to the students, they are sensitised for the risks for their hearing. First they learn about the natural limits of hearing and with that what ultrasound and infrasound is. Afterwards students learn about risks of sound sounds and how they can protect their ear. Furthermore they learn what happens to their inner ear in case of partial deafness.

End user:
The learning materials are meant for children of age 15-16

Involved actors:
biology and physics teachers of secondary schools

Location:
Classroom.

Connection with the curriculum:
Belgium science curriculum: The ear is in the curriculum of biology for students of age 14-15 (1st year of 2nd stage of secondary school; Belgium)
German science curriculum: In the school type Gymnasium the topic of hearing is taught in the 9th grade biology.

Languages available:
Dutch, English, German

Where to find the application or case:
The setups are stationed at University of Bayreuth, Germany and/or KHLim, Belgium.
The information about the course "The Hearing of Sound" is available on the PATHWAY website, under "Resources", "Inquiry Activities for Schools" or the following links:

- *http://www.pathway-project.eu/content/inquiry-activities-schools#overlay-context=user/1*
- *www.vakdidactiek.be/hearingofsound*

Evaluation parameters:
Evaluation from teacher side: The Hearing of Sound will be evaluated by teachers who get to know the course during the Pathway workshops and professional developments, with questionnaires provided by the EUN, aiming for teachers' opinion and satisfactory level.
Evaluation from student side: In 2013, the course "The Hearing of Sound" will be evaluated for the effectiveness of IBSE learning. Evaluated features will be mainly on the amount of Subject knowledge recalled after the course and after retention, as well as the motivation of student towards science. A small scale analysis of the IBSE lessons of the experiment included stations has been started in November 2011 to amend the stations and content, and was continued in 2012.

Duration:
The course lasts four lessons (á 45min) in class. The four course hours can be conducted in block, or split up to subdivisions of one hour each, allowing a flexible implementation of the course during normal school days. A block course of four hours can perfectly be done on e.g. Science Days or during an Experimental Week of the school.

Additional information or resources:
Contact Sarah.Schmid(at)uni-bayreuth.de for further information.

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	
7	Competencies related to self-reflection and meta-cognition	
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	x
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

1. Building interest in natural phenomena and scientific explanations:

Hearing is a phenomenon that scientifically can be understood in terms of physics and biology. Although present in our everyday life sound - as an interdisciplinary reality – in school it is often treated separately in physics and biology. The topics may even not be taught in parallel in the two subjects, or even worse, not even at the same class level. These circumstances makes in hard for the students to realize that these subjects teach about the same topic from different sides of views. The overlapping character of hearing in biology and physics often is lost by the current way of teaching. In the course "The Hearing of Sound" students connect on an inquiry manner, the basic concepts of sound, both of physics and biology point of view.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

This project aims at the connection between fundamental sciences, like biology and physics, which is meaningful for understanding our world. The understanding of nature is a deep human desire for which fulfillment cross scientific insights are needed like the ones of biology and physics in this case. By a better understanding of the sensitive organ of the ear, the society could not only benefit from these better insights but could profit as well from the risen health awareness that goes along with this practice. Especially the function of the cochlea that enables us to hear the rich spectra of sounds and voices is still very unknown and still poorly estimated by the average citizen. Lots of people who regularly visit loud concerts or who are used to hear their music too loud sooner or later do loose at least part of their hearing spectrum. Even expensive medical treatment later on, cannot give them back the full joy of hearing the timbre of music. Even the understanding of speech becomes a difficult task. Science is here once more in resonance with the quality of life.

3. Develop multiple goals:

- **understanding big ideas in science including ideas of science, and ideas about science**
- **scientific capabilities concerned with gathering and using evidence**
- **scientific attitudes**

The method of inquiry is at the forefront in this good practice: to foster a scientific attitude, to wonder about the phenomena in nature, to raise questions, to build hypotheses and to look for evidence. Scientific thinking and reasoning is the learning goal in this interdisciplinary project. Basic scientific ideas are deeply connected into this project and brought to learners.

4. Understanding students' concepts and learning style about science phenomena:

The pedagogical method of inquiry applied in the learning stations gives opportunities for learners of different learning styles. Wondering addresses the dreamers and fosters the desire for exploration. Looking for evidence and doing experiments addresses the doers and experimenters. Scientific reasoning and analysing addresses the thinkers. Drawing conclusions addresses the deciders and the planners.

5. Relevance of the content to the daily lives of students:

Sound is one of the main ways by which we communicate and express ourselves. The spectrum of sound, the timbre of music and voice opens a world of expression, art and beauty without which life is hardly imaginable. It is clear that the understanding of sound and hearing is a crucial point in gaining scientific literacy. Moreover the topic is at the basis for understanding other kinds of waves like water waves or electromagnetic waves which are all around us.

6. Understanding science as a process not as stable facts. Using up-to-date information of science and education:

The inquiry used in the 4 learning stations of "The Hearing of Sound" leads the students into a conceptual discovery tour in the world of sounds and music. By going to these stations, students do understand that new insights are always nearby: a next question and one further investigation away. In this manner the 'world of science' is brought into the classroom. Even just connecting the well-known school subjects like physics and biology give rise to deeper insights and give learners a broader and deeper sight on simple experiments. By this way science is experienced in this practice as no stable and closed book whatsoever but as a living invitation to join the scientific journey.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

The joy of finding out new connections is one of the basic motivations to do science. That is why it is better to give children space to wander around, to let them make mistakes and not to present science as a set of rules but as a quest and desire for knowing. The inquiry in these 4 learning stations gives them the pedagogical space to explore the world of sound.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

In the learning stations students are given the opportunity to analyze the results of experiments themselves, scientific thinking is fostered and at the end, students are expected to draw their own conclusions. The students goes through the inquiry their self and build up gradually a growing scientific understanding of sound and hearing.

9. Assessment: formative (of students' learning) and summative (of their progress):

The design of the learning station themselves are such that there is formative guidance of the learners in every learning station. At each station they are asked to draw write down their conclusions. At the end of the last lessons the learning outcome and motivational effect is measured through a summative questionnaire. The results of these questionnaires are compared to the results of a pre-test, and thus the progress can be measured.

10. Cooperation among teachers and with experts:

This practice is the result of a lasting corporation between the University of Bayreuth (Germany) and the KHLim teacher Education college in Hasselt (Belgium). Many schools, and therefore many science teachers, participate with the researchers together in this project. Teachers together with the researchers get the opportunity to learn about the pedagogy of interconnecting the sciences and to learn on the method of learning science by inquiry. Teachers of the participating schools are invited to a national congress where they interact with the researchers. These life interactions are sustained further over the website www.vakdidactiek.be/hearingofsound which contains a forum and shares the results of this practice. On a scientific level the results of this practice and of this educational research will be shared with the scientific community by articles in peer-reviewed journals and by talks on conferences of science education.

2.2 Inquiry primary

PATHWAY

Summary:

Since 2010 Russia has a new educational Standard for Primary Education. It requires: students' activity, projects, ICT-competence. There is already a course (subject) in primary school (2 lessons every week during the whole year) called "Surrounding world". It is obviously knowledge based and not suitable for the new standard. This scenario is aimed to design new content for this course that is based on inquiry. This requires a full reconstruction of the whole subject: new content (more science concepts but on pupils' level and with everyday language), new methods (more observations, investigations, experiments, open discussions), new aims, new activities, new tools (digital labs, online lab, computers), new environment (rich material and experimental environments; sets of experiments).

Aims:

Scientific capabilities concerned with gathering and using evidence; scientific attitudes.

Main activities:

Experiments and investigations; measuring with digital labs; discussions; communication in online GlobalLab; problem solving; concepts construction and reconstruction; working in school information environment.

2.2 Inquiry primary

Narrative:

The Implementation of the activities started in the 2-day class with 25 pupils. The teacher brought to the children a new generation of digital labs – Labdisc (www.globisence.com) - a wireless lab with 7 fully accessible sensors (5 built-in), with intuitive, large LCD digits, built especially for elementary students. It took only 10 minutes for the first instruction – and children were able to do their first measurements – the task was to measure the room size. The next problem for kids was already more challenging – how can we measure our height? Pupils must invent methods of using the tool themselves. They proposed different techniques, tried these in pairs, discussed and helped each other. Only one lesson – and they already know how to measure with digital lab!

Another module was temperature: how can we define it with our senses and with sensors. It started with tap water asking the following question: what is the coldest and the hot test water in our tap? The class was divided into groups and each group filled three vessels: the hottest and coldest water from the tap and their mixture in the middle. First, each child defined the temperature of cold and hot water with two hands and afterwards - in the mixture - with both hands at once. It was the first surprise! – Each hand feels a different temperature in the same water. What is the real temperature? Kids suggested to measure it with our digital hand – Labdisc. They did it and realised that it was about the same. The discussion immediately started with the question: Why do the hands feel different?

Measurements immediately revealed a number of mathematical problems: what to do with decimal digits? Can we understand the graph of temperature on a computer screen? (The Bluetooth connection between portable and light Labdisc and computer allows to show the data collected and all the results in real time – pupils saw the increase and decrease of temperature during experiment and could afterwards understand the graph).

There were also a number of modules without digital tools. *What happens when objects are immersed in water?* To answer this question kids do an experiment. *What happens when different objects are immersed in water?* New experiments but with marker to note the difference. *Where does this diference come from? What does it depend on?* – Pupils discuss and teacher makes notes on board: size, form, weight... *How we can decide what?* – Together with children we design new sets of experiments to answer the question. Afterwards came a question: *How does water act on objects when they sink?* – Lesson in the pool. The most important experiments: each pupil immerses a ball or basket into the water, and weight his friend in the water and in the air.

The third module regarding the online Globallab tool (a special tool to collect and compare data and communicate with other schools around the world) – the class had chosen a school area for future investigations – was brought into the Internet community. The class described this school area for the whole community. All data collected about this place (photos, temperature measurements, relief, animals and trees descriptions...) are collected their and open for the community.

End user:
Children grade 1-4 (primary school).

Involved actors:
Primary school teachers, students, researchers, curriculum developers. city farms.

Location:
School.

Connection with the curriculum:
According new Russian educational standards 2010 the content of the primary school must be based on: students activity, projects, ICT-competence from 1st class.

Languages available:
Russian.

Where to find the application or case:
Moscow School of the Future (#2030) and 10 other schools in Pilot project continuous science education leaded by Kurchatov institute, Moscow department of education, Moscow Institute of an Open Education.

Evaluation parameters:
This experience had evaluated on big Conference 19.11.2011 "Our new primary school"; it is included in in-service training of Moscow teachers since 2011; it is published this month in Report to Moscow Department of Education. It will be published in "Teachers Newspaper" in 2012.

Duration:
1-4 years (primary school time); it can also be partly introduced as a set of different independent modules during 2 – 6 lessons.

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	x
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

2.2 Inquiry primary

Mapping best practices with main principles

1. Building interest in natural phenomena and scientific explanations:

Active doing and experimenting, with exciting phenomena, paradoxes and experiments and their self constructed explanations build interest in natural science phenomena and explanations.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

The possibility to describe the phenomena with everyday language, constructivists learning, using science tools (digital labs) these are simple and similar to familiar devices like mobile phones brings science and society nearer to each other.

3. Develop multiple goals:

- **understanding big ideas in science including ideas of science, and ideas about science**
- **scientific capabilities concerned with gathering and using evidence**
- **scientific attitudes**

The inquiry method described above, if repeated, becomes a habit, an attitude. In constructivist issue and using adequate language and hearing and discussing children's ideas about phenomena of nature brings an understanding.

4. Understanding students' concepts and learning style about science phenomena:

The scenario uses pupils' mind's as a field where everything goes on – no concept can come from outside as into an empty vessel. Learning starts with questions. Discussion reveals students' concepts. Then comes an activity for children in which they seek evidence to answer the question. Doing activities and trying to solve the problems each pupil builds his / her own learning style.

5. Relevance of the content to the daily lives of students:

Science is everywhere: the world is full of phenomena whose laws are unknown to younger children. The scenarios start from this point – daily objects and experiences which we attentively observe with children.

6. Understanding science as a process not as stable facts. Using up-to-date information of science and education:

Children don't learn laws and concepts – they experience the world and construct their own knowledge. They investigate phenomena, discover regularity and construct the concepts. They solve tasks and problems with children. And children do it as scientist do.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

Children dont' play scientists – they do their job and take it honest. The teacher doesn't know the correct answer – he / she organises their work and helps them with experiments. Sometimes he poses questions, but pupils find the answers themselves. They do experiments and find evidence. They, not a teacher, discuss understand and explain phenomena.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

Children do science in this scenario: experimenting, analysing, interpreting, redefining explanations.

9. Assessment: formative (of students' learning) and summative (of their progress):

During each activity (experimenting for example) pupils must fill in the worksheet of tasks and questions. These worksheets, the results of projects and also the presentations and discussions give formative assessment for each pupil. Once a month, after finishing a certain theme, the teacher gives pupils a summative assessment through a written test where they must analyse a new situation with the help of acquired skills and knowledge.

10. Cooperation among teachers and with experts:

The scenario supposes cooperation among teachers, curriculum developers and experts: developers teach teachers new activities and tools and, at the beginning, help them during lessons as tutors. Experts evaluate the process and give feedback to developers and teachers. And big community of the primary school teachers of Moscow periodically looks at the process (during conferences and master-classes) and discusses it.

2.3 Interactive simulations in inquiry-based science education

Summary:
Different scenarios based on the integration of ICT with IBSE are included in order to advance students' understating of scientific concepts and use of ICT as Cognitive Tools for meaningful learning. Most of the scenarios are strongly connected to real life situations.

The scenarios will be implemented by teachers in their class aiming to investigate the impact of the integration of IBSE-ICT to students' learning performance and to affective-psychological issues towards Science Education.

Aims:
To demonstrate ICT-based scenarios that provide the opportunity for students:

a) to explore and investigate the validity and limitations of certain physical laws and properties using IBSE Instructional Methods and ICT-based learning environments, i.e. the use ICT tools as cognitive tools and

b) to conduct inquiries that enable them to actively engage with questions and problems associated with their subject or discipline, to explore scientific principles, to analyse data, to make hypotheses, to predict situations, to communicate the results of their involvement through the manipulation of the entities of the applications.

Main activities:
Teachers responsible for the implementation of the activities will apply the scenario in their classes. Teachers have the experience of developing scenarios based on the IBSE-ICT as they attended a training course for the exploitation of the use of ICT as cognitive tools for the didactics of science. Scenarios are already developed and refer to the categories: "what scientists do", since students will investigate the scientific phenomena by using scientific methods in order to explain aspects of the physical world; "how students learn", by pursuing scientific questions and engaging in scientific experiments by emulating the practices and processes used by scientists; and, a pedagogy, or teaching strategy, adopted by science teachers (designing and facilitating learning activities that allow students to observe, experiment and review what is known in light of evidence). The procedure is the following: teacher trainees are trained for the development of IBSE scenarios integrating PCK with ICT and they undertake the task to apply different scenarios based in inquiry-based Learning, integrated with the essential features of IBSE.

Narrative:
Educational scenarios developed and implemented by experienced teacher trainees. Each scenario integrates ICT, IBSE and PCK, while ICT is considered as a cognitive tool aiming to meaningful learning. The Scenarios are written in Greek and they have been developed in the form of a learning cycle implemented at schools and at specific teachers' training centers. Teachers involved were trained for 360 hours for the exploitation of ICT in Didactics, and will be the actors / agents / multipliers who will apply their scenario to their class. These scenarios are already evaluated during teachers' training courses and will form best practices for understanding Subject Matter (e.g., conservation of momentum, angular momentum and energy, the oscillation of the RLC electric circuit, Computational Chemistry, Biology). Students will engage in a series of guided / coupled inquiry and open inquiry (e.g. for the development of a Model using Autograph), the development of Basic Competencies Necessary to Do scientific inquiry (e.g., students make hypotheses, formulate and revise scientific explanations and models using logic and evidence). Through the applications students will be involved in gathering and analysis of data using simple representations (like the one provided inherently in Interactive Physics, Modellus and Multilog, IrYdium). All scenarios will provide the opportunity for students to solicit multiple approaches to solve specific scientific problems. All scenarios contain the main features of inquiry.

Indicative Scenarios:

Scenario1. Conservation of Energy using Interactive Physics - Grade 10®12. Main science-oriented question / problem: Conservation through the collision of particles

Scenario 2. The study of the Lorenz Force using Interactive Physics - Grade 11. Main science-oriented question / problem: Motion under the Lorenz Force

Scenario 3. Study of the Collisions with Friction using Interactive Physics - Grade 12. Main science-oriented question / problem: Motion after the collision and use of a frame of reference

Scenario 4. Conservation of Angular Momentum- Interactive Physics - Grade 12. Main science-oriented question / problem: Study of the conservation of angular momentum during the collision of a body with a solid bar

Scenario 5. Study of Oscillation using Mathematica Main science-oriented question / problem: develop a mathematical model in Mathematica

Scenario 6. Study of Oscillation-RLC Circuit using MultiLog and Modellus. Main science-oriented question / problem: Investigate the properties of oscillation and circuits

End user:
GRADE 10-12 Students for the Discipline of Natural Sciences.

Involved actors:
Teachers, students.

Location:
Schools / teachers training centers.
Connection with the curriculum:
All the activities cover the current curriculum for Grade 10,11,12 students. Slight modifications could apply to the applications to be appropriate for Grade 9 students.

Languages available:
Greek.
Where to find the application or case:
www.spsycharis.gr

Duration:
Variable (from a 1-hour course to several courses throughout the year).

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	x
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

2.3 Interactive simulations in inquiry-based science education

Mapping best practices with main principles

1. Building interest in natural phenomena and scientific explanations:

ICT-based scenarios will enhance the processes of observing, questioning, investigating and reasoning about evidence, through which knowledge and theories are developed and changed. Students will have the opportunity to change the methods and attributes of the entities used in the software and study the interactions of the entities under these changes and increasing their interest in Science.

2. Building up informed citizens: Students understanding the nature of Science and Science in society:

Specific scenario are well fitted to authentic tasks (like the one based on Authograph, and the one regarding beverages). The scenario developed in Computational Chemistry is related to the connection between Science and Society and deals with the preparation of chemical products used in everyday life.

3. Develop multiple goals:

- **understanding big ideas in science including ideas of science, and ideas about science**
- **scientific capabilities concerned with gathering and using evidence**
- **scientific attitudes**

During the running of the simulations, students are expected to develop skills of framing questions and finding ways of gathering data by observation and measurement to answer them, analysing and interpreting data, and engaging in discussion about findings and the process of arriving at them. For example using the MultiLog software, students collect data and plot them, examine the validity of well known laws (described in the textbook) and interpret data.

4. Understanding students' concepts and learning style about science phenomena:

All the activities involve modelling, simulation, mathematics. For example, in all applications based on Modellus, students have to write down the mathematical relations in the form of first-order differential equations. Scenarios combine the cognitive analysis of conceptual change processes in students with the examination of instructional dialogue integrating socio-cognitive methods.

5. Relevance of the content to the daily lives of students:

Scenarios are close to authentic situations. For example, using the MultiLog software students are engaged with different types of sensors to connect the activities with real life authentic problems. The scenario implemented in Autograph is purely related to real-life situations. The scenario concerning the measurement of the %v/v beverages' concentration is a situation confronted in everday life.

6. Understanding science as a process not as stable facts. Using up-to-date information of science and education:

Students' explanations will grow steadily during the instructional strategies as well as students' conceptual changes resulting to a sequence of intermediate models that become progressively more scientifically based. This suggests a model evolution where students are able to build on knowledge that they had developed in earlier stages.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

All modelling-based applications are scientifically concise and compact, while they involve a kind of Constructive modelling, i.e. a process of abstracting and integrating elements from successive models related to the target problem.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

All scenarios promote an inquiry-based and problem-solving learning approach. ICT is included as a cognitive tool and can serve as a fulfilment of certain inquiry features in the didactic scenario. For example, by analysing the data produced by real time simulation students will be able to redefine their explanations, to determine how ideas are related to one another, and understand the limitations of the theory.

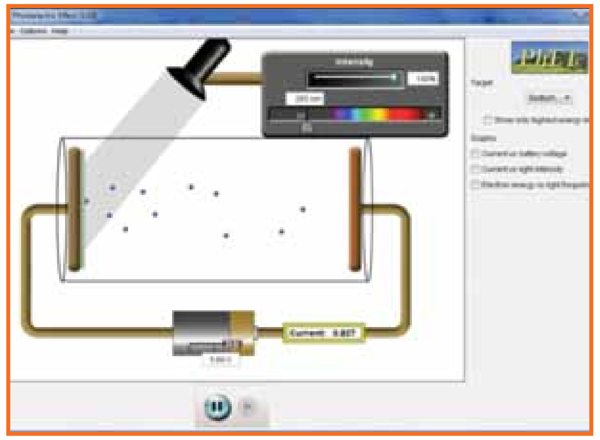
9. Assessment: formative (of students' learning) and summative (of their progress):

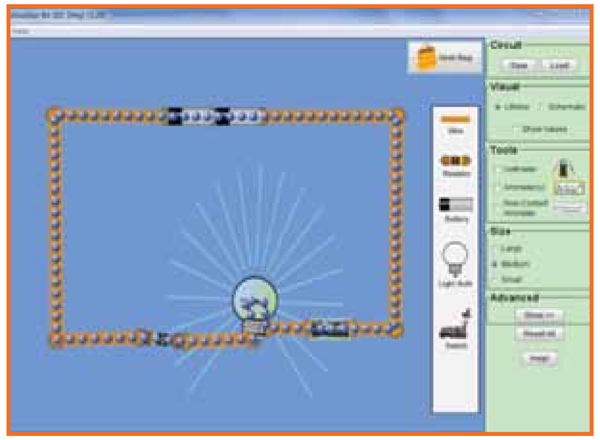
An initial assessment will be implemented in order to measure the effectiveness of the proposed Scenario, not only for the learning performance but also for the relation of ICT-IBSE with the learning styles and the motive for doing Science. Specific-well established- questionnaires will be used.

10. Cooperation among teachers and with experts:

During the training period, teachers triggered a discussion about the integration of ICT with IBSE and how the esential features of IBSE will be integrated with ICT tools, what kinds of ICT we are really need and how we can transformt he simulation and modelling in order to include IBSE. They also discussed issues like scafffoded based software.

2.4 Using ICT and PhET to support inquiry in physics lessons





Summary:

Within an existing continuing professional development (CPD) course designed to support both specialist and non specialist physics teachers, the PhET (Physics Education Technology), is used as a vehicle for their own learning as well as a model for classroom practice with inquiry potential.

Aims:

This is designed to model good classroom practice as well as develop their own understanding.

Main activities:

Group work and discussion around a web based software interface.

Narrative:

This session is designed to allow teachers to use the freedom and flexibility that the PhET software provides to explore both their own understanding of the content as well considering ways in which these tools can be used to support inquiry-learning back in their own classrooms. They will be provided with a minimum of information and then asked to explore the tools. To help frame their own inquiry, they will also have had the key ideas relating to inquiry-based science education presented to them and an opportunity for them to discuss these.

After they have worked individually, or in small groups, there will be an opportunity to share reflection and ideas across the group with the aim that these will be collated and shared within the group as well as back in the participants' schools when they return as you would imagine with any CPD activity.

By integrating this IBSE 'module' within an existing CPD event it is hoped that participants will see that IBSE is not simply an 'add-on' and can be effectively integrated into their own practice without significant challenge or barrier.

All simulations provide a number of tools for explorative work. However, many of them also have the opportunity to hide or reduce the availability of particular aspects of the simulation. This hence creates a simpler 'walled garden', which can help with orientation and enables students to develop a confidence with the core conceptual ideas before progressing further. For example, the moving man simulation allows students to look at displacement, velocity and acceleration graphs for the motion of an object, but also allows these to be seen individually and in isolation. This avoids the novice being forced to make sense of all three phenomena at once. The availability of rapid feedback from the simulation can facilitate dialogue between users who could be working on a simulation in pairs or small groups, constructing questions or hypotheses, testing them in the simulation, and then discussing the outcomes (or the observable relationship), with the simulation hence providing a focus and stimulation for peer-to-peer communication and collaboration. This can operate independently of the teacher's intervention. PhET is used widely across the physics community, nationally and internationally. It is well regarded, and there is some research evidence about its utility, and it has itself been derived from a research base: *(phet.colorado.edu/en/research)*

End user:
Experienced and novice teachers and students aged 11-18.

Involved actors:
Teacher trainers / CPD leaders and other teachers.

Location:
Training venue as appropriate, may be in school or out of school.

Languages available:
English.

Where to find the application:
Most materials are already available on PhET website.

Evaluation parameters:
Teachers complete formal or informal evaluation questionnaires, and the course itself is evaluated and assessed within the network of Science Learning Centers.

Duration:
Likley to be a short sessions of between 45 minutes and 70 minutes.

Additional information or resources:
The PhET website has extensive resources as well as links to research on its effectiveness.
phet.colorado.edu

Optimum number of participants:
Up to 20.

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	
3	Competencies in framing a discipline in a multidisciplinary scenario	
4	Competencies in knowledge of contemporary science	
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	
10	Competencies addressing students' common sense knowledge and learning difficulties	
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

1. Building interest in natural phenomena and scientific explanations:

The simulations create flexibility for exploration without imposing a rigid structure of discovery. They provide an opportunity for teachers and students to 'play' and explore, hopefully stimulating interest in the phenomena and the underlying explanations.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

By engaging in an inquiry process within the PhET environment, students and their teachers become more familiar with ideas about the nature of science.

3. Develop multiple goals:

- **understanding big ideas in science including ideas of science, and ideas about science**
- **scientific capabilities concerned with gathering and using evidence**
- **scientific attitudes**

The nature of the simulations in the PhET website are such that they are based upon the theoretical behaviour and relationships of variables to each other, and as such are a virtual manifestation of a perfect model of the relationships. This provides opportunities for students and teachers to explore the nature of models, their value in science education as well as the limitations they have as a replacement for practical work.

4. Understanding students' concepts and learning style about science phenomena:

The PhET tools enable exploration of modelled scenarios, from which students can collect data and make conclusions but the ways in which they do this are not necessarily prescribed (although could be if the teacher wished). This provides possible multiple routes to understanding that the students can follow.

5. Relevance of the content to the daily lives of students:

Many of the simulations model the physics of everyday situations. For example, the motion examples are all real-life contests such as removal men, people running, springs and static electricity involving balloons and jumpers, all things that they may have encountered in their lives and wondered about.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

By using PhET to model situations, teachers and their students develop an understanding of the rules which underpin behaviour of the animations, rather than reciting a simple set of facts, or simply undertaking demonstration practicals.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

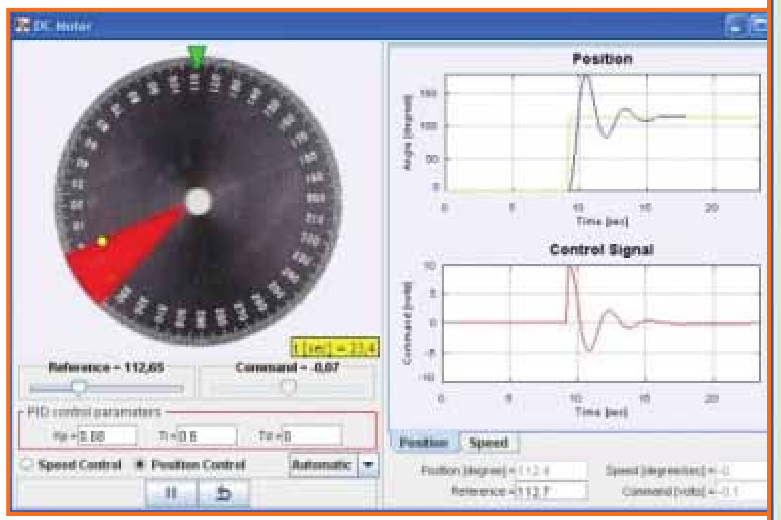
Most PhET tools do not enable the explicit processing of data sets within the simulation. However, some of them do enable the collection of discrete results, which could be analysed in a supportive similar parallel environment, such as spreadsheet modelling. This could enable predictions to be made, which could then be subsequently tested within the simulation and developed where appropriate.

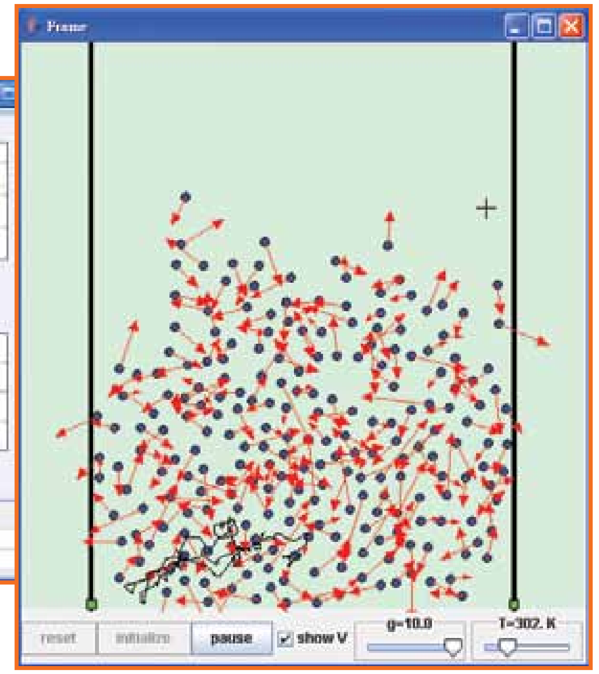
9. Assessment: formative (of students' learning) and summative (of their progress):

There are opportunities for teachers to create and save developed versions of the online tools (e.g. specific types of electric circuit), and hence the online tools can be tailored to individual needs or to facilitate exploration of particular questions. This creates a de facto dialogue between teacher and student. Likewise, working together with the online tools can promote students' discussion and peer support.

10. Cooperation among teachers and with experts:

The structure of the course session, collaboration and follow up sharing and development of ideas is specifically designed to harvest the variation of experience and skills within the group to generate something that would not have been possible has they worked individually. The hope is that this will also act to promote this way of working to the participants who may consider it further.





2.5 Education in science and technology

Aims:

Develop awareness of, and engagement in, science and technology.

Main activities:

Teacher training.
Preparation of educational kits.
Museum visits.

Narrative:

The main objective of Education in Science and Technology (EST) is to familiarise students and teachers with science, using resources available in Milan and around the Lombardia region, reinforcing cooperation between museums, schools and other local institutions, and promoting the development of a network of science museums. The objectives of the project are met through a wide range of activities, resources and methodologies, operating in juxtaposition: development of interactive educational workshops, Science Kits and Science Vans; use of the museum as resource for both teachers and pupils; use of hands-on learning and inquiry as the main methods for education in science and technology; in-service training of three teachers per school, development of a network of schools and science museums,. First of all, EST emphasises the importance of inquiry and constructivist learning for improving both teachers' and students' approach to science. The objective is not to provide mere "recipes" of science activities to replicate, but to build skills and knowledge in teachers and students which can be used more widely both at school and in everyday life. This approach is developed through a strong relationship between teacher and museum educator based on a community of practice. In this context, the Museum devised and realised three interactive laboratories (i.labs) for the EST Project: **a)** telecommunications, **b)** robotics, **c)** genetics and biotechnologies. The i.lab From Telegraph to Internet puts together an exhibition on telecommunications and interactive exhibits; The Robot Workshop examines learning processes through the creation of artificial creatures that interact independently with the environment; the i.lab From Cell to DNA uses experiments designed to address basic notions of genetics and biotechnologies clearly and accessibly. Choice of content was based on fields of current social interest. The methodology was based on the Museum's own educational approach (in line with the Project set objectives) which encourages active involvement of visitors in learning processes through the use of objects, hands-on activities, exhibits and experiments. The other activities and resources of the Project (training, Science Kits, Science Van) revolve around the three topics following a similar teaching and learning methodology.

Teachers resources

Activities on Telecommunications
www.progettoest.it/tycoon/light/viewPage/ProgettoEst/progetto
www.museoscienza.org/est/seconda_fase/anno0607/kit_biotecnologie.asp

Activities on Robotics
www.progettoest.it/tycoon/light/viewPage/ProgettoEst/progetto
www.museoscienza.org/est/dedicata/kit_robotica.asp

Activities on Biotechnology
www.progettoest.it/tycoon/light/viewPage/ProgettoEst/progetto
www.museoscienza.org/est/seconda_fase/anno0607/kit_biotecnologie.asp

End user:
Teachers and their classes primary and secondary, museum explainers.

Involved actors:
Regional Office for Schools, Lombardy. Region, museum staff from different museums, museums in Lombardy.

Location:
School, museum.

Connection with the curriculum:
Various.

Languages available:
Italian.

Where to find the application or case:
www.museoscienza.org/est

Evaluation parameters:
External evaluator, University of Milan and an external company. Tools used: questionnaires, observation, interviews. This best practice has been certified by the internal evaluation of the Museo Nazionale della Scienza e della Tecnologia "Leonardo da Vinci".

Duration:
All the project lasted 5 years. Every teacher works with the museum 1 year.

Additional information or resources:
www.progettoest.it/tycoon/light/viewPage/ProgettoEst/progetto

jcom.sissa.it/archive/06/02/Jcom0602(2007)A02/Jcom0602(2007)A02.pdf

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

2.5 Education in science and technology

Mapping best practices with main principles

1. Building interest in natural phenomena and scientific explanations:

The project is based on contemporary scientific topics and applications and first hand involvement of the teachers. It aims to raise interest in science and technology through exploration, experimentation, observation, collection of data, development of hypotheses.

2. Building up informed citizens:
Students understanding the nature of Science & Science in society:

Students are called to understand their own contribution to society as citizens. The activities aims at stimulating active participation and critical opinion. The focus is on raising the consciousness of how their choices can create an impact on the relationship between science and society. Moreover, the scientific evidence are discussed in connection with ethical, social and legal issues.

3. Develop multiple goals:

- **understanding big ideas in science including ideas of science, and ideas about science**
- **scientific capabilities concerned with gathering and using evidence**
- **scientific attitudes**

Participants investigate scientific phenomena with interactive activities. They are able to explore notions, phenomena, principles and transformations; they also use the different phases of the scientific method. This allows them to deepen into the science process which means build a scientific knowledge about a range of topics, but understand also how science works and what scientific research means.

4. Understanding students' concepts and learning style about science phenomena:

The project aims at the development of knowledge and skills in teachers but concentrates also on a metacognitive reflection, focusing on teachers as learners. On this basis, teachers are also invited to examine their own students' learning and involvement in science as well as problems they might face with the students.

5. Relevance of the content to the daily lives of students:

The choice of the topic is based not only on its scientific importance but also on its relevance with daily life. Also, the educational methodology adopted by the Museum in the training course (as well as in its education programs) puts at the centre the personal experience and knowledge of each individual. This means that everyday life experience of students is one of the main tools on which training builds. Moreover, the problem solving activities require teachers to use their background knowledge and consequently think of the students' own background.

6. Understanding science as a process not as stable facts.
Using up to date information of science and education:

Understanding science as an on-going, not consolidated process emerges from the very activity of experimenting and testing carried out by teachers during the course. On this basis teachers and the students are also encouraged to consider the process they chose to use in order to solve the problem and to collect data in order to confirm or not their hypotheses.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

The project is based on a mix of activities which aim to develop subject-knowledge and skills in science and technology also through the use of interaction, confrontation.
The project explores a specific topic not only in terms of its scientific and technological dimensions but also in relation to society, to everyday life and to individuals and the use of emotions. We know that the personal and emotional involvement of participants in the learning experience maximises the probability for effective learning.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

The activities start with an open scientific question; experiments are conducted to explore different answers following observation, data collection and interpretation, development of prediction and discussion of scientific ideas.
The scientific method is the basis of all the work done.

9. Assessment: formative (of students' learning) and summative (of their progress):

The museum is an informal environment of learning and has a role which is complementary to that of the school. Consequently, visitors' learning is not assessed like in schools. We do not use structured tools or processes for assessing the learning experience of our visitors (schools in this case) as this is not part of our education priorities. Informal, personalised, meaningful experiences for each person in a different way is the priority of our education programmes. At the same time, we run self-reflection sessions among education staff in order to analyse how our programmes are developed (education methodologies) and how interaction with the public takes place. The formative and summative assessment are left to the teachers.

10. Cooperation among teachers and with experts:

The training course builds close collaboration between museum experts and teachers as well as collaboration between teachers themselves. This collaboration continues also after the end of the course through update of training or distance support. Moreover, professionals from companies or universities with expertise in different fields are involved in the training. The teachers appreciate very much the discussion with the different experts.

2.6 Kicking Life into Classroom

Summary:

"Kicking Life into Classroom" (KLiC) is a system of wearable intelligent sensors (acceleration, body temperature, heart and respiration rate sensors) embedded in everyday objects (t-shirt, ball, vest, arm/leg straps). KLiC is based on the IBSE approach which bridges the gap between formal and informal education and brings science and scientific objects closer to the learners by engaging them in episodes of playful learning. The purpose of KLiC is to deepen the student's understanding of scientific concepts by effectively associating every day activities with scientific inquiry and experimentation, and strengthen their appreciation of scientific process and research. In order to achieve this goal the approach is enriched with educational material (lesson plans) following the inquiry-based teaching methodology.

Aims:

KLiC aims to demonstrate an inquiry-based science education approach that uses advanced technology for teaching science through every day activities, encouraging experimentation, data collection and analysis, and communication among students.

Main activities:

In terms of experimentation and collection of scientific data the main activities can be divided into two categories:

a. those where the KLiC system is used as a tool in a science laboratory demonstrating classical mechanics experiments (e.g. period of a pendulum, rigid body motion on an inclined plane, free fall).

b. those where the KLIC system is used as a tool for monitoring students' physical activities with the goal to associate various motions to scientific understanding of the world around us (e.g. physics of karate, physics of sky diving, science of sports)

In terms of data analysis and links to the school curriculum, KLiC has developed an inquiry-based structured set of guidelines on how students can experience their everyday activities in the context of science experimentation with the system enriched by a series of learning scenarios.

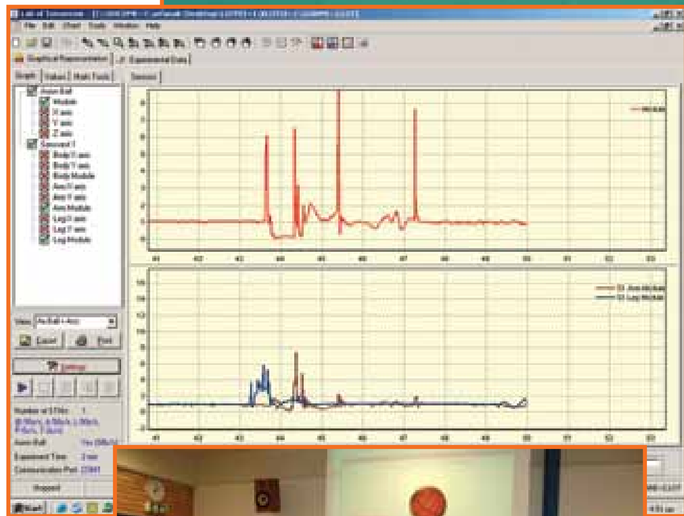
Narrative:

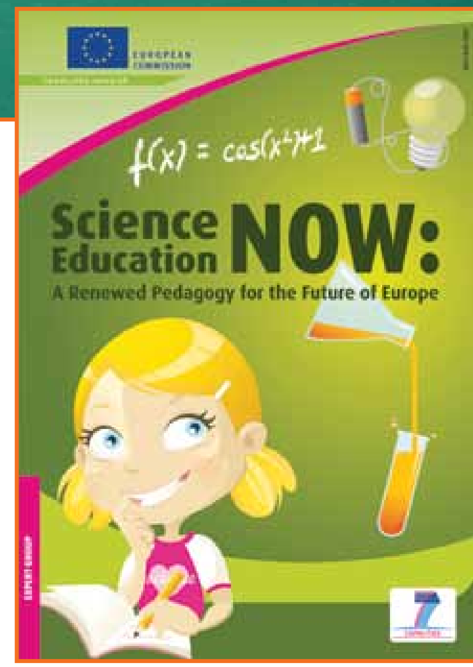
Within the framework of KLiC, learners perform experiments in which they produce their own data. Thus, their activities are transformed to scientific experiments and their classroom or sports ground is transformed into a scientific laboratory. Such activities are viewed by the young and adult learners as a craft that rewards dedication and precision but simultaneously encourages a spirit of creativity, exuberance, humour, stylishness and personal expression.

In order to do so the KLiC uses an innovative sensor data collection tool that consists of the following modules:

- SensVest - a vest, equipped with various sensors, designed to carry components that measure and transmit physiological data to the base station.
- Leg and Arm Accelerometer - small devices attached to the leg and/or arm that enable the 3-D measurement of the acceleration for the leg and/or arm.
- Ball Accelerometer - a ball with an embedded accelerometer, measuring three dimensions and a communication unit that enables the transmission of data packets to the base.
- Base Station - responsible for the collection of all transmitted data
- User Interface Software - user friendly interface, designed with a pedagogical frame of mind, that enables the process of data and actions such as plotting data on a graph or creating a mathematical model to fit the data.

In an implementation of the KliC system, Romanian





2.6 Kicking Life into Classroom

teachers designed and implemented a scenario in an informal environment, in order to study the Earth's gravitational acceleration. By means of the experiment coupled to a gravitational pendulum (experiment existing in the upper secondary physics syllabus) they performed measurements on the Turda salt mine.
At a first step, students determined the gravitational acceleration value on the platform in front of the salt mine entrance. Then, students and teachers went down into the salt mine, where the students repeated the experimental determinations, at the deepest point (112 m).
After analysis of the data, students were called to reflect upon whether the gravitational "constant" is really a constant and draw conclusions as to its dependence on the distance from the centre of the Earth.

End user:
Students grade 6-8 (ages 15-18).

Involved actors:
Science Teachers.

Location:
KLiC can be used in Schools (both in science classroom and in the sports facilities), in playgrounds, in amusement parks and generally everywhere outdoors.

Connection with the curriculum:
Physics, Mechanics, Sports, Physical Education.

Languages available:
www.klic-project.eu

Where to find the application or case:
The Woodlands Trust:
www.thewoodlandsfarmtrust.org/educationatrc.htm

Evaluation parameters:
KLiC has been extensively evaluated by the University of Bayreuth through online questionnaires (available in 4 languages: English, German, Greek and Romanian) specially designed for different end users of the system, mainly teachers/educators and students. Furthermore, interviews of stakeholders (school physical educators, university staff, science teachers etc) interesting in the KLiC approach have been collected and analysed.

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	
5	Competencies in mastering and implementing a variety of instructional strategies	
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	x
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

Mapping best practices with main principles

1. Building interest in natural phenomena and scientific explanations:

By bringing closer together the science laboratory with the pleasures and challenges students typically enjoy through play and sports, the KLiC boosts young people's interest in science. Its approach combines sports and education, a mix that brings the aspect of joy while learning.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

KLiC directly connects science to everyday life and improves the learner's understanding on how science works, contributing to the development of a new generation of citizens who are scientifically literate and thus better prepared to function in a world that is increasingly influenced by science and technology. KLiC offers the opportunity to the Life Long learners to have hands on experiences and real practices in the field.

3. Develop multiple goals:

- **understanding big ideas in science including ideas of science, and ideas about science**
- **scientific capabilities concerned with gathering and using evidence**
- **scientific attitudes**

The KLiC approach: a) Teaches science through the use of advanced technological applications. b) Transforms the classroom to an experimental laboratory for all. Students use their everyday life as the field where they conduct sophisticated experiments and thus deepen their understanding of the science concepts involved in the activities. c) Reinforces interdisciplinary approaches in the process of learning. KLiC supports that educational experiences should be authentic and encourage students to become active learners, discover and construct knowledge.

4. Understanding students' concepts and learning style about science phenomena:

The pedagogical approach of KLiC fosters state-of-the-art, learner-centred science teaching and learning approaches. The live capture of personal data and its analysis allows students to "visualise" their physical activity in terms of scientific parameters and fight misconceptions that they might have developed either from reading their science books or from the way they perceive things.

5. Relevance of the content to the daily lives of students:

The KLiC approach introduces innovative tools (systems of wireless sensors embedded in vests and balls) in science classrooms that allow for as many links of science teaching as possible with everyday life. Monitoring normal physical activity, collecting and analysing scientific data is something that is directly related to student's daily life.

6. Understanding science as a process not as stable facts. Using up-to-date information of science and education:

KLiC overcomes the barriers imposed by the traditional classroom setting by introducing to science teaching an innovative combination of a new approach to learning by applying new technologies. The learners perform experiments with their own data. In this way their activities are transformed to scientific experiments and their classroom or sports ground is transformed into a scientific laboratory.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

Utilisation of the KLIC system can be performed during various activities such as those in a) the school's sports ground (e.g. study of projectile motion with the KLiC ball) b) in the science laboratory (e.g. students performing vertical jump)
In perspective, the KLiC approach is based on authentic experiences that encourage learners to become active, discover and construct knowledge.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

A main characteristic of the KLiC approach is that it promotes an inquiry-based and problem-solving learning approach. The system allows learners to freely approach the physical phenomena or parameters they want to study. By composing their own scientific inquiring strategy, students are able to engage in motivating science-inquiry activities through the use of highly interactive instruments and data manipulation tools that allow for data collection, real time data analysis and graphical representation.

9. Assessment: formative (of students' learning) and summative (of their progress):

Since the KLiC innovative pedagogy provides to students direct interaction with scientific hands-on activities that guide them to new ways of understanding the laws of physics, it is necessary to monitor their individual skills or competencies. Given the fact that each student can perform an experiment on his own and thus can collect and analyze his/her personal data it is feasible to evaluate student's learning (through questionnaires and/or interview) and follow its progress during a series of activities that are based around the same science topic.

10. Cooperation among teachers and with experts:

KLiC brings together a real cross-disciplinary know-how, with complementary expertise among technology developers and science education experts. The implementation activities of KLiC were organised across many European countries involving large and heterogeneous groups of people. In addition, a group of science teachers has been formed, namely the KLiC User Group, that serves as a pool of ideas and exchange of practices.

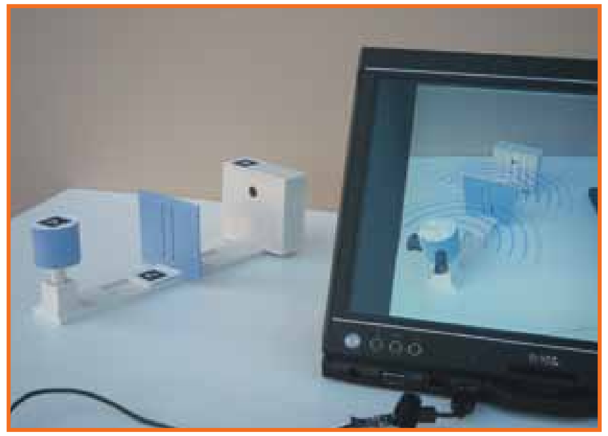
2.7 Science Center to Go

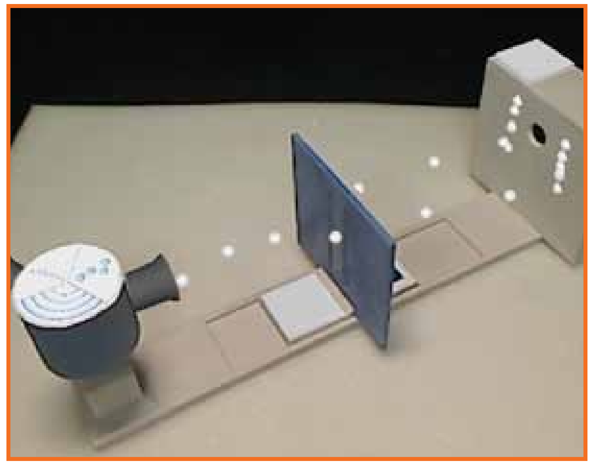
Summary:

Science Centers and Museums offer intriguing exhibits that enable their visitors to experience science first hand by actively manipulating the experiments, thus delivering natural ways of active playful learning. Modern technologies like Augmented Reality (AR) are often used to enrich the experience and display otherwise hidden phenomena. The SCeTGo approach goes one step further and aims to bring similar comprehensive learning experiences out of the Science Center into a school's classroom and/or everyone's home. Its miniature exhibits - by "fitting into a pocket" and operating with ordinary hardware - enable learners to experiment whenever and wherever they please. SCeTGo by using AR not only enriches the teachers' and students' optical view with relevant information but also allows them to interact dynamically with the miniature exhibits and teach/learn by doing. The SCeTGo system is easy to operate. As it is based on common devices there are no real obstacles that a potential learner has to overcome in order to use the system.

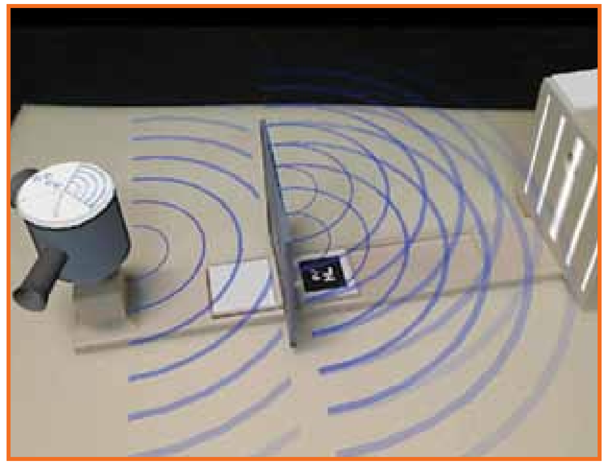
Aims:

The SCeTGo approach aims to bridge the gap between formal & informal education, to promote science learning at all levels, and to assist in ensuring that science not only holds a high place in teaching curricula but also promotes creative problem solving and learning-by-doing.





Double slit in large particle mode



Double slit in wave mode

Main activities:

The main activities that can take place when adopting the SCeTGo system are the following:

a) Introduction to Inquiry-Based Science Education (IBSE) as pedagogical methodology and presentation of educational scenarios that make use of AR as a way to teach certain Physics phenomena.
b) Demonstrations of each miniature exhibit contained in the SCeTGo suitcase.
c) Hands-on session within which the participants experiment with the miniatures.

Narrative:

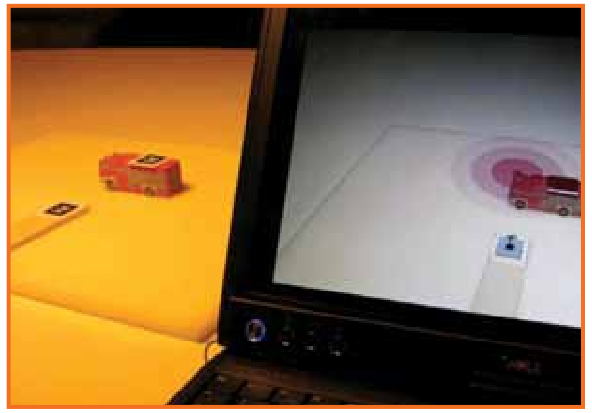
There is sufficient evidence to suggest that both the persistence and the quality of learning are highly enhanced when the potential learner is actively participating in the learning process. Science Centers (SC) adopt this philosophy by offering intriguing exhibits that enable their visitors to experience science first hand by actively manipulating the experiments, thus delivering natural ways of active playful learning. Modern technologies like Augmented Reality (AR) are often used to enrich the experience and display otherwise hidden phenomena. However, experiencing augmented reality requires visiting the Science Center.

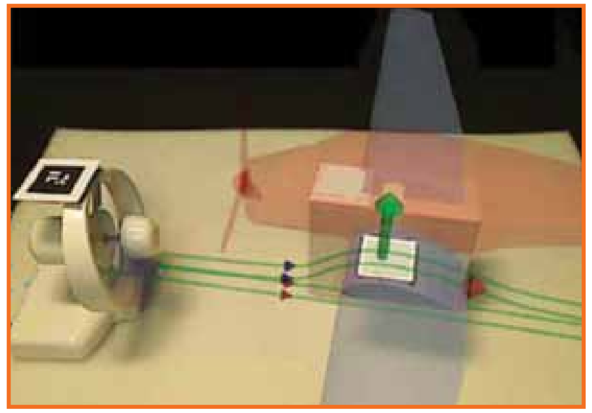
The Science Center To Go (SCeTGo) approach goes one step further and aims to bring similar comprehensive learning experiences out of the Science Center into a school's classroom and/ or everyone's home. Its miniature exhibits - by "fitting into a pocket" and operating with ordinary hardware - enable learners to experiment whenever and wherever they please. This way the consortium makes full use of the powerful capabilities offered by tailor-made exhibits combined with AR.

The SCeTGo project aims to bridge the gap between formal & informal education, to promote science learning at all levels, and to assist in ensuring that science not only holds a high place in teaching curricula but also promotes creative problem solving and learning-by-doing. The overall objective, through the exploitation of AR, is to integrate experiential learning & supporting materials provided by scientists & educators into a comprehensive knowledge base for learning open to the public.

SCeTGo's approach is based on an educational kit that is delivered in the form of a small suitcase and contains a tablet, a web camera, a series of 3-D printed miniatures and a user guide. These miniatures combined in various arrangements can form in total five mini- exhibits that illustrate various physical phenomena linked to secondary school curricula: sound wave propagation, rigid body (double cone) motion on an inclined plane, wing dynamics, wave-particle duality and gas particles' velocity distribution. Learners can interact dynamically with the miniature exhibits and by using AR enrich their optical view with information relevant to the physical phenomena shown. Examples of the physical phenomena include explanation of why do planes fly and why does the siren sound of a fire truck is different when it approaches an observer than when it moves away from him.

In the framework of the SCeTGo approach the have been developed, implemented and evaluated a series of learning activities in accordance with the current trends in science education, based on inquiry and problem based approaches that allow the actively participating learners to enhance their scientific literacy and critical thinking skills. Educational scenarios following the inquiry-based teaching methodology have been designed for all miniature exhibits. These scenarios by making use of AR introduce new ways of interaction between learners & the real world.





End user:
Students grade 6-8 (ages 15-18)
Involved actors:
Science Teachers, Secondary School Students, Teachers Trainers, Science Museum Staff, University Educators and students
Location:
The SCeTGo system fitting in a suitcase can be used in the science classroom, in laboratories, and generally everywhere. No electricity is required as it can run only on the system's laptop for as long as its battery lasts (minimum2 hours)
Connection with the curriculum:
Physics, Mechanics, Quantum Optics, Waves, Aerodynamics
Languages available:
SCeTGo User Guide has been created in English. Educational materials (scenarios etc) are available in various languages: English, Greek, Romanian, Finnish, Spanish and Swedish.
Where to find the application:
www.sctg.eu
Evaluation parameters:
The SCeTGo technology and educational approach has been extensively evaluated in the following countries: Finland, Greece, Spain, UK, Romania, Germany and Sweden. The evaluation was performed through online specially designed questionnaires (available in 4 languages: English, German, Greek and Romanian) and on-site interviews of teachers/educators and potential users of the system. A detailed report has been published as a special chapter in the SCeTGo Guide of Good Practice (available online at the official SCeTGo website).

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

1. Building interest in natural science phenomena and explanations:

Recent research in science centres indicates that informal educational activities appear to have a positive effect on motivation of students of both genders and on career choices of students. SCeTGo promotes young people's interest in science through the introduction of its informal character in formal educational environments.
More specifically it has been shown that the merge of miniature exhibits with existing advanced AR technology demonstrated to learners new ways of interacting with scientific concepts and phenomena. The implementation of a set of learning activities in accordance with the current trends in science education, based on inquiry and problem based approaches, allows the actively participating learners to enhance their scientific literacy and their critical thinking skills.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

The main objective of the SCeTGo's approach is the implementation through the use of AR technology of an innovative learning system that can be used in various learning environments (schools, universities, SCs) for improving science education.
The SCeTGo system highlights key trends in the adoption of digital technologies for better understanding how science works. An extensive evaluation of both, the educational design of SCeTGo and the technology that supports it, has unveiled that this approach raises the wider public's interest and awareness on science.

3. Develop multiple goals:

- **understanding big ideas in science including ideas of science, and ideas about science**
- **scientific capabilities concerned with gathering and using evidence**
- **scientific attitudes**

The SCeTGo approach integrates the AR technology in science teaching both in formal & informal educational environments aiming to facilitate lifelong learning by offering to learners the opportunity to gain exposure to everyday science in a way that is appropriate to their individual level of understanding.
The SCeTGo introduces a learning approach that :

a) Makes use of advanced visualization technologies (AR) that not only have the potential to enrich the learners optical view with relevant information but also allow the learners to interact dynamically with the miniature exhibits
b) Demonstrates the possibilities that students will experience in the future during their educational training in respect to AR technological applications.
c) Promotes the importance of scientific attitude to all European citizens through a journey of entertainment & learning.
d) Contributes to the development of a new generation of citizens who are scientifically literate and thus better prepared to function in a world that is increasingly influenced by science & technology.

4. Understanding students' concepts and learning style about science phenomena:

The pedagogical approach of SCeTGo promotes an inquiry-based and experiential learning approach. AR is used in order to demonstrate to students new ways of interacting with scientific concepts and phenomena. Students experience science first hand at their own leisure and engage in activities where information is discovered by them rather than passively transmitted to them. By interacting with the miniature exhibits students they can not only visualize invisible physical quantities but can also control the conditions that need to be met in order for an phenomenon to occur (e.g. learners by rotating a miniature wing, namely the prototype miniWing, at different angles can see through the augmentation of the airflow on the wing when the ideal condition is met for the plane to take-off as well as why when this condition is met the plane flies). Moreover, the implementation of a set of learning activities (lesson plans) in accordance with the current trends in science education, based on inquiry and problem based approaches, allows the actively participating students to enhance their scientific literacy and their critical thinking skills.

5. Relevance of the content to the daily lives of students:

SCeTGo's approach is based on an educational kit that is delivered in the form of a small suitcase and contains a tablet, a web camera, a series of 3-D printed miniatures and a user guide. These miniatures combined in various arrangements can form in total five mini- exhibits that illustrate various physical phenomena linked to daily life: sound wave propagation (e.g. that can answer the question: why does the siren sound of a fire truck is different when it approaches an observer than when it moves away from him?), rigid body motion on an inclined plane, wing dynamics (e.g. that can answer the question: why do planes fly?), light interference and gas' expansion over heat. Students can interact dynamically with the miniature exhibits and by using AR enrich their optical view with information relevant to the physical phenomena shown.

6. Understanding science as a process not as stable facts. Using up to date information

The proposed approach covers a set of phenomena that largely differ one from the other, i.e. from the double cone uphill runner from the 17th century that was at first perceived as a strange and magical effect, through the Doppler effect observable in everyday life, and to the double slit experiment that is the basic of modern quantum physics. Some of the proposed educational scenarios provide also historical background and show to the students the relevance of science to their life. In this way, the approach is equally inclusive towards students that may later become scientists and to those who may not do so. With the use of SCeTGo the teacher can stimulate students' observation, reasoning, and interest in science in general.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

SCeTGo merges miniature exhibits and existing advanced AR technology in order to demonstrate to students new ways of interacting with scientific concepts and phenomena. The proposed approach enhances science learning at all levels, and assists in ensuring that science not only holds a high place in teaching curricula but also promotes creative problem solving and learning-by-doing. Activities aiming to integrate experiential learning and supporting educational materials into a comprehensive knowledge base for learning include a) AR presentations (where videos or images are enriched by augmentations) of phenomena that cannot be observed with naked eye (e.g. airflow around an airplane's wing or the wave-particle duality in quantum mechanics) and/or b) scientific explanations during a phenomenon based on augmentation of physical parameters (e.g. sound-wave propagation emitted by a source moving towards or away from an observer).

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

SCeTGo miniatures and educational scenarios are designed with the central goal to support experimentation. Active experimentation with the miniatures is performed by the students who should be stimulated to observe the changes of parameters that are represented by the augmentation. The AR system supports the investigation by focusing students' attention on those variables that influence on the phenomena. Students are encouraged to collect the appropriate data and interpret it in connection to his/her observation during the alteration of various parameters. Moreover, each educational scenario contains the full set of IBSE activities, including phases such as define hypothesis, plan and conduct investigation, gather evidence, explain, consider alternative explanations, etc.

9. Assessment: formative (of students' learning) and summative (of their progress):

In order to develop a pedagogical approach with quality an assessment of the designed SCeTGo learning activities in extended cycles of work is necessary. School communities continuously give feedback about their students experiences gained in the implementation of the SCeTGo approach. This not only increases the motivation of the students, and gives weight to their practical experiences, but also provides the necessary cross-links between theory and practice and improves the effectiveness of the SCeTGo learning approach.

10. Cooperation among teachers and with experts:

The SCeTGo approach by forming collaboration between technological & pedagogical research institutions, science museums and science teachers training centres across Europe contributes to the cooperation among teachers and with experts allowing them to communicate science in supporting formal & informal learning. Through such cooperation AR technology is linked to science curricula, tested and validated locally in schools & universities, with the aim of being replicated in the future in different environments world-wide.

2.8 F1 in schools

PATHWAY

Summary:

F1 in Schools is a global multi-disciplinary initiative that challenges secondary-school students to design, build and race miniature compressed-air powered balsa wood Formula One cars. The competition inspires students to use IT to learn about physics, aerodynamics, design, manufacture, branding, graphics, sponsorship, marketing, leadership, teamwork, media skills and financial strategy, and apply them in a practical, imaginative, competitive and exciting way.

Aims:

The overall aim of F1 in Schools is to bring the excitement and motivation of Formula One racing to school whilst also delivering the curriculum in a real and meaningful way.

Main activities:

F1 in Schools is a unique technology challenge that enables second-level students to learn science by getting their hands on the latest technology from the worlds of engineering and manufacturing. The six main steps that are implemented in this hands-on approach are:
Plan: Form an F1 team and brainstorm. Put your best ideas together in a five-page plan. **Design:** Team members use CAD software to develop their ideas and model them in 3D. **Analyse:** Virtual Wind Tunnel software predicts the effects of drag and lift on the car design. **Make:** CAM software and a CNC system converts the car design into a physical car.
Test: Wind and/or smoke tunnels used to test and improve the car's performance.

Narrative:

F1 in Schools is a global multi-disciplinary challenge for students aged from 9-19 to use CAD/CAM software to design, analyse, manufacture, test and race their miniature F1 car made from balsa wood and powered by compressed air cylinders.
Working in teams of between three and six, the students prepare a business plan and develop a budget as well as raising sponsorship. Teams are encouraged to collaborate with Industry and forge business links. By using 3D CAD (Computer Aided Design) software, the team designs and evaluates the most efficient machining strategy to make their racing car (a Formula One car of the future). Furthermore, aerodynamics are analysed for drag coefficiency in a virtual reality wind tunnel using Computational Fluid Dynamics Software (CFD).
The challenge inspires students to learn about science, mathematics, aerodynamics, design, manufacture, branding, graphics, sponsorship, marketing, leadership, teamwork, media skills and financial strategy, and apply them in a practical, imaginative, competitive and exciting way. F1 in Schools Challenge is not all about speed; competing student teams are also judged on the quality of their engineering, graphic design, resource management, portfolio, media skills, handling of sponsorship and verbal presentation of their work.

Besides using this initiative for teaching science the formed teams are given the opportunity to compete regionally, nationally and internationally for the Bernie Ecclestone F1 in Schools World Championship trophy.

Methods of learning supported:
Project-based learning, Inquiry-based teaching methods.

End user:
Students grade 4-8 (ages 11-19)
Involved actors: Science Teachers, Secondary School students, University Educators and Students.

Location:
F1 in Schools takes place in Schools (preparation, design, initial testing etc) while visiting a certified center might be required for the final testing of the mini race car.

Connection with the curriculum:
Physics, Mechanics, Engineering, Mathematics, Geometry.

Languages available:
F1 in Schools is an initiative that is implemented in 34 countries and its educational resources are available in more than 20 languages.

Where to find the application:
www.f1inschools.co.uk

Evaluation parameters:
F1 in Schools has been evaluated by the National STEM (Science, Technology, Engineering and Mathematics) Centre based in York, UK and is promoted to many schools, colleges as a practice that advances science learning.

Additional information or resources:
The F1 in Schools Curriculum Resource provides 70 lesson plans for staff to deliver a cross-curricular project through art and design, citizenship, design and technology, English, enterprise education, ICT, mathematics, PE and science. All resources can be found at: *f1inschools.co.uk/page--curriculum-resources.html*

Number of participants:
Students work in teams of between 3 and 6, each student is assigned roles.

Time frame:
The F1 in Schools Challenge usually covers a period of several months of work for completing all tasks assigned to a group of students. Thus, it can be considered open ended.

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	x
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

2.8 F1 in schools

Mapping best practices with main principles

1. Building interest in natural phenomena and scientific explanations:

The engaging nature of the activities and the glamorous topic (F1 racing) make pupils want to learn. The offered resources enable teachers to make links between their classroom teaching and one of the most glamorous and exciting sports in the world. Some activities may even involve pupils contacting those involved in Formula One racing.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

The F1 in Schools process simulates many facets of real F1 racing. The worldwide popularity of F1 racing lends excitement while providing a relevant background for simulating critical elements of engineering in the real world.

3. Develop multiple goals:

- **understanding big ideas in science including ideas of science, and ideas about science**
- **scientific capabilities concerned with gathering and using evidence**
- **scientific attitudes**

The F1 in Schools approach allows students not only to have a sneak preview on the science behind Formula One racing but also to develop personal thinking, leadership and teamwork skills and encourage self-study. The development of these skills is essential in generating scientific attitudes among pupils.

4. Understanding students' concepts and learning style about science phenomena:

Students have the opportunity through advanced software to initially test their design and theoretical approach and afterwards to learn by trial and error (hands-on) about science phenomena related to aerodynamics, engineering and physics.

5. Relevance of the content to the daily lives of students:

F1 in Schools along with the educational material that come with it enable students to make links between their classroom teaching and one of the most glamorous and exciting sports in the world. In addition, the science behind this approach is directly related to students' everyday experiences with friction, acceleration and laws of motion in general.

6. Understanding science as a process not as stable facts. Using up-to-date information of science and education:

Students form their own F1 teams to research, design, manufacture, and ultimately race their own scale model F1 cars. In their quest for the ideal design for their race car and collection of best experimental data they make use of all available, up to date scientific information. Moreover, understanding the science behind racing is crucial for achieving, through hands-on experimentation, excellence in science.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

From a design and manufacturing perspective, students use CAD (computer-aided design) software to create virtual 3-D models of their cars and translate their designs into reality by means of CNC milling machines. They promote their cars through a variety of efforts: developing sponsorship decals and producing a design folder with initial design ideas, design development information, testing evidence, and graphical renderings.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

The F1 in Schools initiative is based on hands-on experimentation (design, manufacture and test racing cars), data analysis and interpretation (monitoring the racing car's behavior) and redefining explanations (seeking ways to improve physical parameters for higher performance).

9. Assessment: formative (of students' learning) and summative (of their progress):

The assessment of students' learning and their progress in understanding science is an ongoing process. It continues through all phases of the challenge and besides evaluating each team separately, one can monitor each students learning based on his success in completing the scientific tasks that were assigned to him/her (each student has a specific role well defined role within the team).

10. Cooperation among teachers and with experts:

With Formula One reaching out to all corners of the globe, and its teams made up of a variety of nationalities working together to win the Formula One World Championship, F1 in Schools looks to replicate this scenario by bringing international science and business communication to the forefront and promoting global teamwork amongst young people and their teachers.

2.9 Racing academy

Selecting engines and picking car colours with Racing Academy

Summary:

Racing Academy is a serious game prototype. Its subject matter is in the science behind automotive technology. It covers aspects of Newton's second law, interpretation of graphs, friction, gear rations and mechanical advantage / velocity ratios and scientific inquiry.

Aims:

The aims are multifaceted: At its simplest Racing Academy provides an opportunity for students to encounter scientific phenomena in the context of automobile engineering. However, the main aim is to get students talking about science and engineering activity in constructive ways.

Main activities:

Students select components to build and race a drag racing car as part of a computer game. The students then compete in the game against an AI racer. By making the correct choices and learning from the telemetry students can learn to win the game. After the game the students are given a rich and complex open-ended simulation of racing cars and the surfaces they run on.

Narrative:

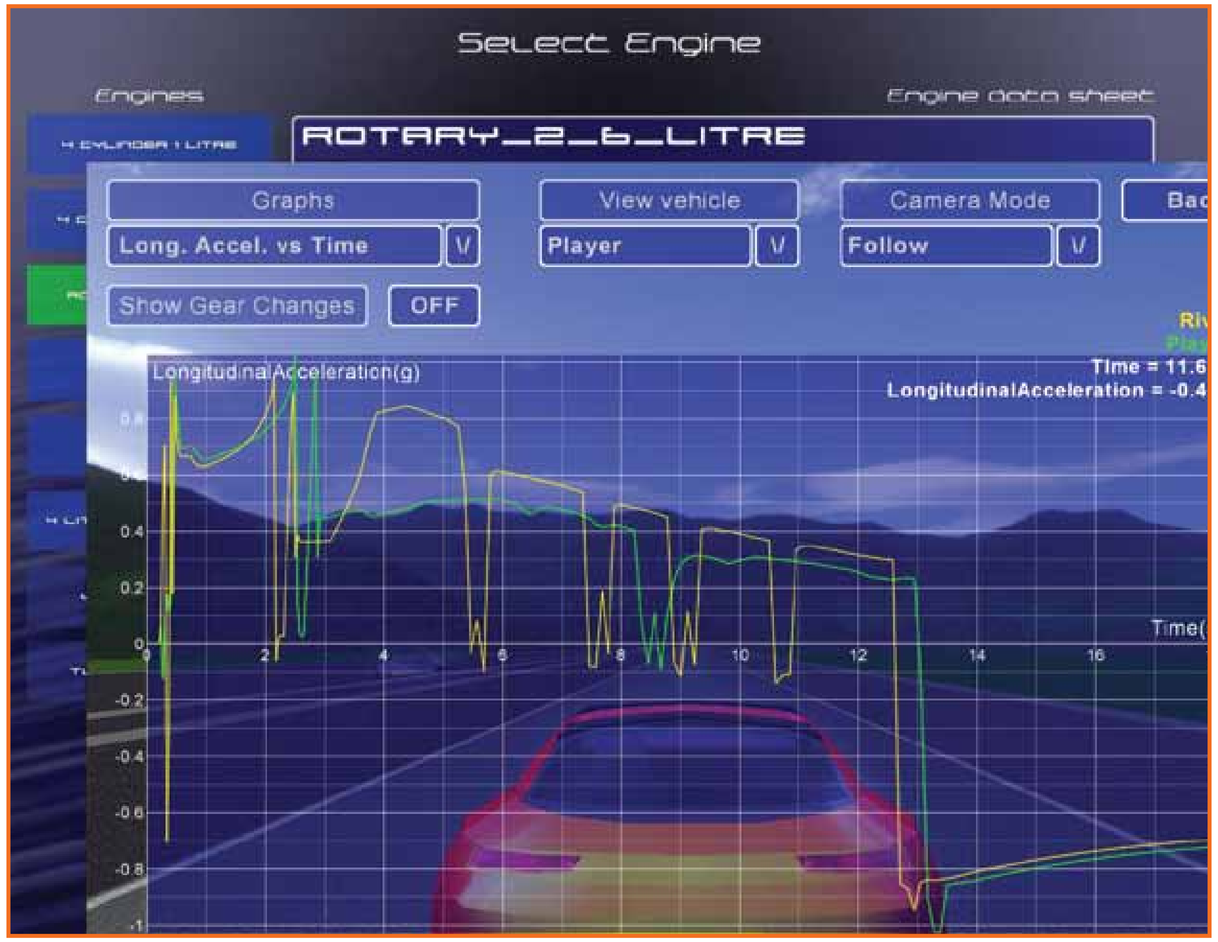
Racing Academy provides an opportunity for students to encounter scientific phenomena in the context of automobile engineering. More significantly it was designed to encourage students to act in particular kinds of ways:

- It provides rich opportunities for graphical interpretation and decision making about data visualisation and telemetry
- It provides opportunities for decision-making based on data in which the consequences of decisions are realised within the real world simulation
- It provides opportuniti es for students to discuss, with each other, problems with scientific solutions using appropriate scientific engineering language
- It encourages engineer-like behaviour

The resource is self-contained and can be used (and indeed has been used) in many different scenarios with different age ranges. One scenario is thus with 14 -15-year-old high school students.

a. Students are organised into teams of three – mixed or equal ability. They are put into teams to encourage discussion about the problems, sharing

2.9 Racing academy



of information, peer-to-peer teaching, sharing of both science, automobile and game-play skills. In cases where there were sufficient computer resources to have more than one computer per group we augmented the conversation with an instant messaging system (IMS)- that recorded the students interactions for further use

b. The challenge for students is to minimise the total time for all three members of the team in the 3rd phase of the competition. Ie it is not enough to have one expert; the expertise needs to be shared.

c. The students are encouraged to produce a report on the decisions they make and give reasons for their choices. This provides an assessment opportunity on:

- The ability to chose the salient information to report
- The ability to make appropriate choices in data visualisation
- The ability to make appropriate conclusions from evidence presented.

There are some **very important** points. The teacher is strongly **discouraged** from

- teaching the "right answer" in advance
- teaching **anything** about the game in advance

The teacher is strongly **encouraged** to

- Let students look up and discover the meanings of the technical language
- Answer student's questions with **other** questions.

The game is best played when there is one computer per three students – however the game play does take place in quite short interludes and therefore other systems of managing the activity is possible. Access to things like Wikipedia – that might make explanations of words like "torque" might be useful.

After students have "won" all three races, a new environment is opened up with many more parameters and many other forms of telemetry to use. The students are also given a "race track". The student is offered many, many possibilities for experiment and "play" with physics and engineering.

End user:
Racing Academy has had successful use with different age ranges from 13 years of age to Master's degree Mechanical Engineering. It was originally designed for 14 -18-year-old students.

Involved actors:
Teachers, students.

Location:
This is best used where a group of students can discuss in close proximity to a computer.

Languages available:
English.

Where to find the application or case:
http://www.racing-academy.org/

Evaluation parameters:
The development of Racing Academy had two cycles, firstly as a Futurelab activity and secondly funded by UK JISC. In both cases extensive classroom and laboratory trials were carried out and are the subject to public reports published by Futurelab and JISC
See

- www2.futurelab.org.uk/resources/documents/project_reports/Racing_Academy_research_report.pdf
- www.jisc.ac.uk/media/documents/programmes/elearninginnovation/racingacademyfinalreport.pdf

Duration:
In the basic implementation each "race" in Racing Academy only takes 15 seconds. The game can be played in its entirety within 1 hour. However, that does not necessarily give enough time to talk through the problems together and to devise the best reporting system. Taking about 2 hours would be more appropriate – with additional time for teams to revise and present their reports.
Other uses of the resource (e.g. teaching circular motion) can be structured or open ended according to needs.

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	x
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

2.9 Racing academy

Mapping best practices with main principles

1. Building interest in natural phenomena and scientific explanations:

The activity is based around competitive game play within a quasi-authentic setting. Students can be given unlimited opportunity to test and fail in the developing of hypothesis. The real application of physics to vehicle dynamics can be explored.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

Students are asked to perform like scientists and engineers in a simulated environments. The consequences of their decisions can be tested. For instance, in advanced use of the simulation provided it is possible to build the fastest car for given circumstances or build the car that runs on the least fuel.

3. Develop multiple goals:

- **understanding big ideas in science including ideas of science, and ideas about science**
- **scientific capabilities concerned with gathering and using evidence**
- **scientific attitudes**

The big idea is Dynamics. The activity is entirely evidence-based and sophisticated telemetry tools are provide for gathering evidence. Decision-making consequent on the evidence and the consequences of those decisions are also testable.The game is intended to be played collaboratively. Therefore, scientific and technical "talk" is an important factor.

4. Understanding students' concepts and learning style about science phenomena:

When a 14-year-old girl asks her teacher 'this friction stuff - is it good to have when a car is in a drag race?' one begins to realise that setting up situations where cognitive dissonance happens in a convivial learning environment powerful conceptual development can take place.

5. Relevance of the content to the daily lives of students:

Cars and motor sport are very popular. We have conducted research on gender bias in this game and we found that females were more successful than males.

6. Understanding science as a process not as stable facts. Using up-to-date information of science and education:

Progress in Racing Academy is based on making decisions of data supplied, experiments performed and the telemetry gathered.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

Our evaluation seemed to indicate that elements of what Mihaly Csikszentmihalyi described as flow – deep engagmenet with the activity. Students do learn about dynamics – they have to solve complex problems and create theories and test them – but our intention is that they are entertained by doing science in the process.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

The whole activity is about experimenting, analysing, interpreting, redefining explanations and in addition it is about solving problems. A significant factor is that we use real data from real situations. Because of this graphs are not the sanitised examples students usually encounter in text books – this makes analysis and interpretation realistic.

9. Assessment: formative (of students' learning) and summative (of their progress):

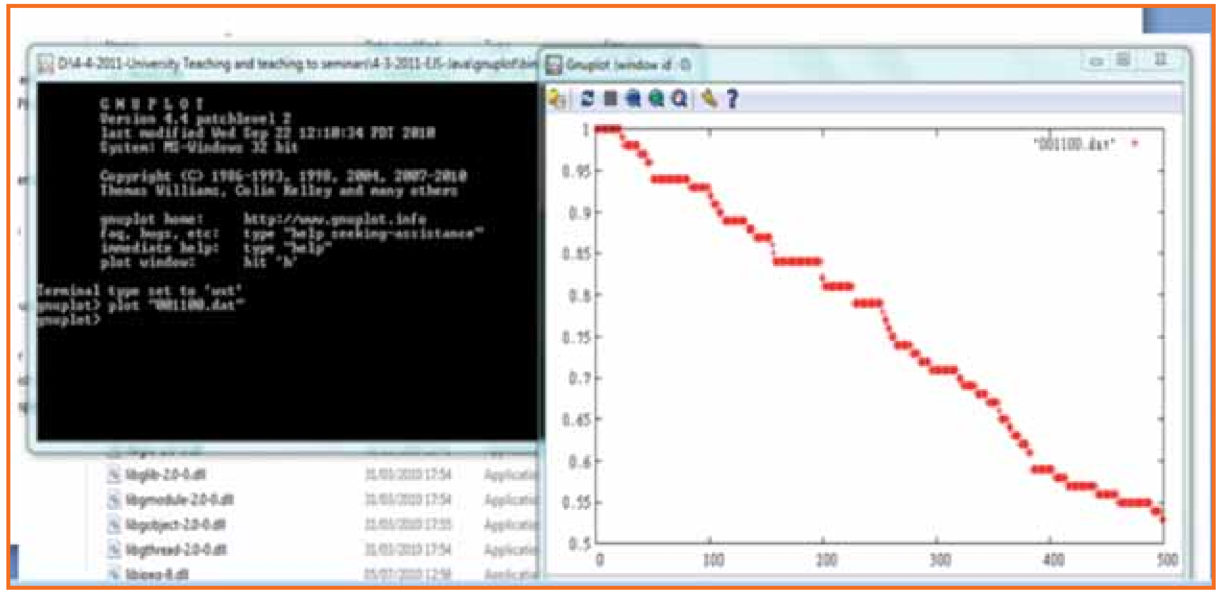
The assessment is intrinsic in the activity. If students master the problem, they win the race in the early stages. All actions the student takes have a visible, measurable action – with the assessment self-administered.

10. Cooperation among teachers and with experts:

We recommend that real automotive engineers, mechanics and expert drivers be available for students to enrich the experience.

2.10 Computational experiment and its relation to inquiry-based science education and pedagogical content knowledge

PATHWAY



Summary:

Initially, the scenario implemented the principles of the Computational Experiment (CE) combined with IBSE Education during a training course of Natural Science teacher trainees for the exploitation of the use of ICT in Didactics and Pedagogy. The scenario will be tested by the teacher trainees as they will train teachers acting as multiplier agents of Natural Sciences for the study of the influence of the CE principles to the algorithmic approach, the use of Modeling Indicators and to affective issues of teachers like motives and metacognitive reflection characteristics.

Aims:

1. To explore the views of in-service teacher trainees on various components of their training in the use of ICT based Scenario, which integrates the Computational Science-CE-approach with IBSE.
2. To enhance teachers' ability to improve students' high order thinking skills and meaningful learning, through self-reflection and metacognitive knowledge.
3. To follow-up discussions of trainees' attitudes, for the impact of the Computational Experiment process in subject teaching and the motives for IBSE.

Main activities:

The development of scenarios based on the principles of the Computational Experiment (CE) with emphasis on Modelling, Simulation, Numerical Methods and Algorithms.

Narrative:

A scenario will be implemented at teacher training centers by experienced teachers already trained in the use of the Computational Experiment.

A scenario will develop including:

a) The modeling phase.
b) The simulation phase
c) The computational phase.

Features of IBSE will be included in:

a) The hypotheses space.
b) The experiments space.
c) The predictions space

In our Best Practice we developed an application based in Java simulation writing the model, the simulation and the algorithm for the decay of nuclei. Teachers realised that the laws physics as they are presented in the textbooks lack of certain discussion, as for example the change of the decay parameter (probability) results to a stochastic process not presented in the textbook.

End user:
In-service teachers.

Involved actors:
Teacher trainees.

Location:
Teachers training centres.

Languages available:
English.

Where to find the application:
www.spsycharis.gr at the module dedicated to PATHWAY.

Evaluation parameters:
In-service teachers have already been trained about the principles of the CE during a training program using a particular scenario based on the use of stochastic Monte Carlo techniques and results indicate a strong shift to the consideration of the added value of the Computational Experiments. Computational experiments will be implemented by them through a teacher training program for the exploitation of ICT in the Didactics to in-service teachers.

Duration:
5 hours.

Additional information or resources:
www.oracle.com/us/sun/index.htm
www. physics.org

Landau, R. H. Paez, J. and Bordeianu, C. (2008). A Survey of Computational Physics Introductory Computational Science, Princeton University Press, Princeton and Oxford.

Sloot, P. (1994). Lecture on Parallel Scientific Computing and Simulations. In CERN school on computing, Sopron, Hongary August.

Tobochnik, J. and Gould, H. (2008). Teaching statistical physics by thinking about models and algorithms. Am. J. Phys. 76,(4-5).

Yasar, O. and Landau, R. (2003). Elements of Computational Science and Engineering Education. SIAM Review, 45(4), 787-805.

Optimum number of participants:
20

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

2.10 Computational experiment and its relation to inquiry-based science education and pedagogical content knowledge

3. Develop multiple goals:

- **understanding big ideas in science including ideas of science, and ideas about science**
- **scientific capabilities concerned with gathering and using evidence**
- **scientific attitudes**

Teacher trainees realised that the principles of the Computational Experiment involve different spaces that fit well with the essential features of inquiry.
During the training, the hypothesis space, the experimental space and the prediction space were used while teachers realise that even in school textbooks there are processes that they need to be understood in more scientific way. For example, they realised that the exponential decay does not always obey the law described in the textbook but is rather a stochastic process.

4. Understanding students' concepts and learning style about science phenomena:

There have been few systematic studies in Science Education that focus on the relationship between psychological and cognitive factors in learning, while learning is considered as a generative process involving human cognitive, metacognitive and motivational processes. Computer-based learning environments impose challenges to learners by leaving the locus of control mainly in the hands of the learners and are strongly related to motives, regulation of learning and learning performance. The aim of the training is to investigate the impact of the computational experiment to use of modelling construction indicators namely systemic structure, geometric structure, temporal structure and interaction structure and the shift to certain psychological structures, i.e. locus of control, self esteem, motives and metacognition. From the experiment the learning styles of students could be investigated and classified.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

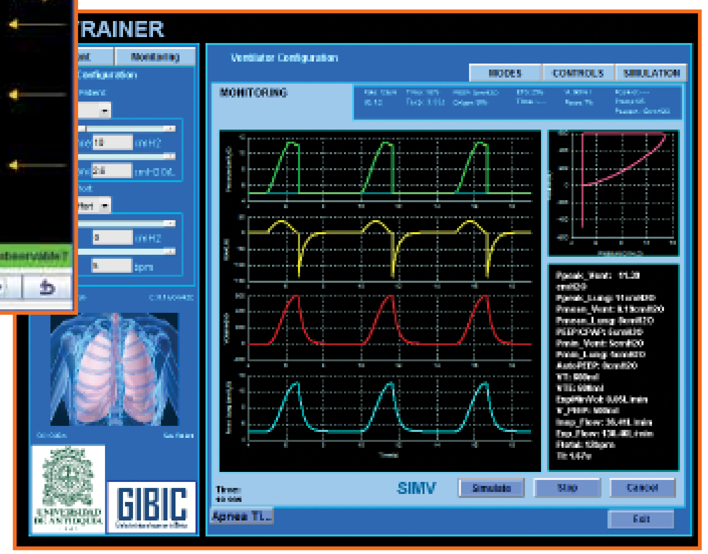
During the training, teacher trainees realised that the computational experiment (CE) involves Modelling, Simulation and Experimentation which reflect the nature of science; they considered that as strongly connected to learning concepts and processes. For example, by analyzing data produced by the real time simulation, teachers were able to redefine their explanations, to determine how ideas are related to each other, and the limitations of the theory. Modelling included the cognitive processes of differentiating, organising, and attributing.
Computational Sciences (CSE) are generally considered to be a – if not *the* – key technology of the future and should therefore be incorporated in physics teaching at levels of Education. The core of CSE may be thought of as its collection of computational tools and methods and its problem-solving mindset, which uses knowledge in one discipline to solve problems in another. This CSE core is now being incorporated into computational science courses and books that combine scientific problem solving with computation and into curricula at various levels of education.

9. Assessment: formative (of students' learning) and summative (of their progress):

A preliminary evaluation was implemented during a teachers training program for the exploitation of the use of ICT in the Didactics for the formation of scenario using the Computational Experiment. The Evaluation concerned the use of modelling indicators and teachers trainees shift for motives in science education. Results were presented at a conference (Psycharis, S. & Botsari, E. (2011). The impact of the Computational Experiment to Inquiry-Based Science Education and Pedagogical Content Knowledge. GUIDE INTERNATIONAL CONFERENCE 2011. "E-learning innovative models for the integration of education, technology and research", Università degli Studi "Guglielmo Marconi", Rome, 18-19 November 2011

10. Cooperation among teachers and with experts:

During the training period, teachers triggered a discussion about CE, the connection between the phases of CE with a didactic scenario based in IBSE. Cooperation was implemented through the step-by-step writing of the algorithm and the source code of the application. Scaffolding was implemented among teachers and between teachers trainees and the expert. We observed that scaffolding faded out at the end of the process.



2.11 Computation science activities

Summary:

In the twenty-first century many scientists practice their profession sitting in front of computer screens. They have gathered data using sophisticated electronic instrumentation that may be situated on the surface of a distant planet. There is a need for analysis of this data. There is a need for this analysis to be presented in a visualisation that enables scientists to create narratives to explain the data. There is a need to create computational models that embody theory and hypotheses that can be compared with the empirical data. There is a need to create simulations that communicate this knowledge. This is computational science.

Aims:

Computational Science Activities aim to provide students with the means to practice science as it is currently practiced – to use computers to gather and analyse data, to create models of scientific phenomena and to learn to communicate and gain scientific knowledge through simulations.

Main activities:

Activities are in three broad categories:

- tools – which either provide the means of analysing and manipulating data
- modelling software – that allows the creation of scientific models
- simulation software- that interactively represents a sceintifc model that allows users to explore phenomena.

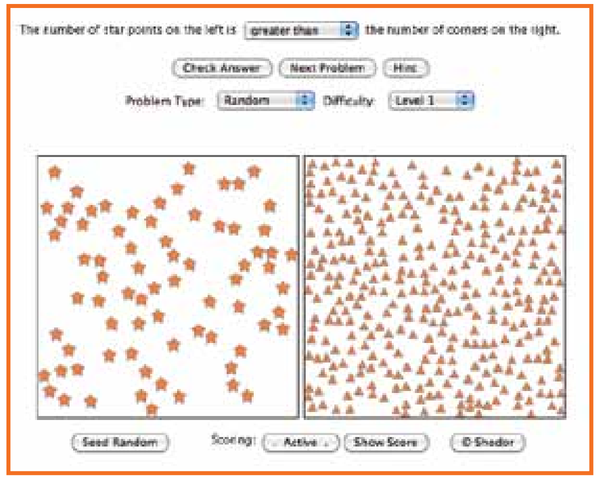
Narrative:

The most significant introduction to computational science activities is through the Interactivate resources on http://www.shodor.org/interactivate/. This is a gateway to resources which have a multiplicity of indexing allowing teachers to select appropriate sources for their IBSE Each element of an Interactivate resource has tabs for

- Learner resources: that describes the activity from the learners viewpoint
- Activity: the computational element of the resource
- Help: the specific guide to the hands-on use of the resource

Instructor: that provides further details for the teacher

The three broad categories of activity: tools, modelling software, software map onto an early but useful paradigms of learning with computers (Kemmis et al 1977) which describe how students learn with computers: revelatory, conjectural and emancipatory. Simulations can be considered an example of the revelatory paradigm. The computer program presents a model of a phenomenon or scenario. Through interacting with the model, the model gradually becomes revealed to the learner. It requires the learner to have a hypothesis about how the model will behave when given an input by the learner. The simulation reacts according to the students input and allows the student to form some understanding about the validity of their hypothesis. By applying more and more tests on the model, the learners hypothesis is confirmed or the need for some modification of hypothesis is needed. When the student has gained mastery over the simulation, in a very powerful sense the student will understand the phenomenon that has been simulated.



In the conjectural paradigm, the learner is provided with modelling tools. The tool enables the learner to create computational models of their hypothesis and test them with empirical or hypothesised data. Modelling is now one of the key methodologies of working scientists. There are a variety of tools in the Interactivate software, and related activities like VerSim which provide learners with opportunities to build and test models. In the emancipatory paradigm, the learner uses the computer as a "labour saving" device. The paradigm distinguishes between authentic labour in learning – activity that is directly concerned with that that is to be learned compared to inauthentic labour in learning – activity that has to be carried out but does not contribute directly to learning. Thus using coloured pencils to carefully construct bar charts may be necessary but does not contribute to understanding. Similarly adding up columns of numbers may be necessary part of a statistical analysis – but it is the actual result is where the learning happens. The tools in Interactivate assist in creating charts and doing statistical analysis etc.

End user:
Students grade 4-8 (13-18) and beyond.

Involved actors:
Science Teachers, Secondary School Students, Teachers Trainers, Science Museum Staff, University Educators and students

Location:
Computational Science approaches require students to have access to computers,. Activities can be done in science labs, computer labs or done as independent study in libraries or at home.

Connection with curriculum:
A large catalogue of computational science resources are available for the whole of scientific activity from Astronomy to Zoology.

Languages Available:
English

Where to find the Application:
www.shodor.org

Evaluation Parameters:
There is a large body of evaluation of Shodor activities and resources and a lit can be found on http://bit.ly/UwaLZS

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	x
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

2.11 Computation science activities

Indegrating online computational models for IBSE: A practice example

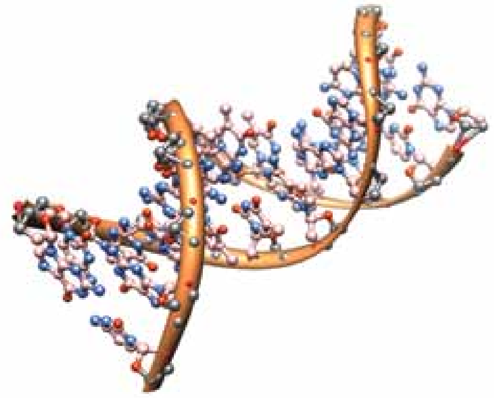
The purpose of this workshop is to explore a number of online computational models and to investigate how these models can be used by teachers and students as tools of inquiry. The participant beliefs and values about teaching, learning, and the purpose of education will be explored at the start of this workshop.

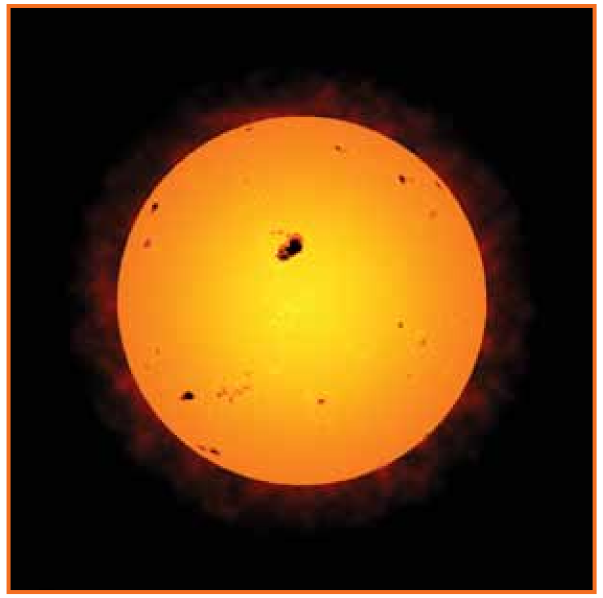
The aim of this workshop is:

- To focus on the computational models on the Shodor website (http://www.shodor.org/).
- To explore, in groups, these models and their capabilities.
- To reflect, in groups, on how these models can be used as tools for IBSE.
- To focus on specific examples of the online models.
- To examine aspects of their teaching that they have worked on to improve and focus on the claims made about improvements.

The main activities include:

- Participants are introduced to an example of a Computational Model from the Interactivate section (http://www.shodor.org/interactivate/) of the Shodor website.
- Participants are then asked to engage with a model and relate it to the School Science Curriculum. This activity can be done in pairs/groups.
- Participants reflect in small groups on how this model can be used by teachers and learners as a tool for inquiry.
- Reflect on how they can improve their teaching and articulate the kinds of data they would need to collect to make a judgement on the effectiveness of their actions.





Pairwork: One person talks to partner about something in their teaching/practice that they have worked on to improve. Other person listens to see if they can understand the values that are motivating them to improve. Feedback time.

Pairwork: They focus on the claims made about and the kinds of data required that enable them to make a judgement on the effectiveness of their actions. Feedback time.

Introduction to the java based online resources.

There are a number of java based online resources on the Shodor website which are very suitable for engaging with particular concepts.

The Graphing Model Multi-Function Data Flyer allows the user to graph functions in the form of Y= (x). The user can then use slider bars to manipulate constants and examine the effects. The user can use this tool to explore linear, quadratic, exponential and trignometric functions.

The Rabbits and Wolves Model allows the user to simulate a simple ecosystem and explore how nature keeps its balance with a predator/ prey simulation. The user can set parameters and then run the model and watch a graphical represention of poluation change over time. The user is also able the change parameters and explore graphically the effects of changing these parameters.

The Gas Model is a microscopic representation of an "ideal Gas" with a number of parameters than can be modified and the user can observe a visual and a quantiative representaion of the changes that occur. Users can change the Number of molecules, velocity and pressure. This enables the user to explore the Gas laws

The range and type of examples used in the workshop depends on the background of the participants. Teacher-Educators, Pre-service Teachers, In-service Teachers and curriculum developers can explore these models and reflect on how they might be useful to a student and also to consider how these models can be incorporated into their teaching.

Methods Of learning Supported:
Inquiry-based, Reflective practice.

End User:
Pre-service teachers, In-servie teachers.

Involved Actors:
Teacher Educators, Teachers Student Teachers, Curricum Developers.

Location:
Universities, Education Centres. Computer Lab or classroom with laptops, Internet access required.

Connection with Curriculum:
Science, Biology, Physics and Mathematics

Languages available:
English

Where to find the Applications:
http://www.shodor.org/interactivate/activities/
http://www.shodor.org/talks/ct-ibse/idealGas/index.html

Additional Information:
Each of the models is accompanied by technical help files and information for both the learner and the instructor. The models could be used in a classroom setting or during independent study

Time Frame:
1 to 2 hours

Number of participants: 30 max

2.11 Computation science activities

Mapping best practices with main principles

1. Building Interest in natural science phenomena and explanations

There are a broad selection of simulations that cover a range of activities They provide an opportunity for teachers and students to 'play' and explore, hopefully stimulating interest in the phenomena and the underlying explanations.

2. Building Informed Citizens: Students understanding of science & society

Computational Science is the actual practices of current practicing scientists, however it is not currently part of many science curricula.

3. Develop multiple goals:

- **understanding big ideas in science including ideas of science, and ideas about science**
- **scientific capabilities concerned with gathering and using evidence**
- **scientific attitudes**

Many of the big ideas in content of science – from the collision of galaxies to the nature of epidemics and spread of disease are covered. However the modeling tools and the scientific visualization tools are important introductions to students to the day-to-day practice of twenty-first century scientists.

4. Understanding students' concepts and learning style about science phenomena:

All the activities involve modelling, simulation, mathematics. As described in the narrative above – a variety of teaching styles are employed across the range of activities.

5. Relevance of the content to the daily lives of students:

Modelling tools can be applied to any phenomena that the student chooses to model. Some of the models are essentially beyond experience – such as the ability to collide galaxies.

6. Understanding science as a process not as stable facts. Using up-to-date information of science and education:

The wide range of simulations, tools and modeling allows for a progression form simple understanding to advanced scientific concepts. The modeling tools use up-to-date modeling techniques.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

All modelling-based applications are scientifically concise and compact, while they involve a kind of Constructive modelling, i.e. a process of abstracting and integrating elements from successive models related to the target problem.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

All scenarios promote an inquiry-based and problem-solving learning approach. ICTs used provide cognitive tools. For example, by analysing the data produced by real time simulation students will be able to redefine their explanations,to determine how ideas are related to one another, and understand the limitations of the theory. MOdelling tests their own hypotheses. Tools allow the exploration of their own data.

9. Assessment: formative (of students' learning) and summative (of their progress):

There are suggestions for assessment in the Instructor's notes. The simulations and models are inherently self assessing. The mastery of the simulation or the accuracy of the models are learning that the learner recognizes for themselves.

2.12 Modeling rotating bodies

Summary:

Modelling Rotating Bodies presents an example of application of modeling in teaching mathematics with the help of IT. With the help the software Google SketchUp, a software available for all, and a given readymade file the students have the opportunity to construct rotating bodies by themselves. With the support of IBSE in the given methodology students can, without having a profound knowledge of the options of Google SketchUp, create rotating bodies based on a model from the surrounding real world (apple, candy, hat, etc) as well as experiment and therefore creating a variety of bodies via rotation of different figures.

Aims:

With the help of this BP we are aiming at:

- Students to explore the surrounding environment.
- Students to raise a hypothesis for the figure which should be rotated in order to have a certain rotating bodies and check these hypotheses
- To encourage students' artistic talents for creating a product that relates the surrounding environment and imagination with math and technology
- To make connections between subjects.

Main activities:

Students are introduced to several of the instruments of Google SketchUp. Students model objects with the support of an already made file in which there has been modeled an axis and a rotation has been set up with the help of a circle. Students explore the surrounding environment and recognize rotating bodies. Students construct their own models of rotating bodies and participate in the contest for most interesting body.

Narrative:

The BP Modelling Rotating Bodies is flexible enough to be applied in a different way. One of the options according to the basic phases of IBSE scenario is the following:

1. The teacher offers to the students to look through a number of objects – angular and rotational bodies with different colours and application.
2. With the help of a discussion the students classify the bodies based on various grounds while the teacher focuses on the differentiation between angular and rotational.

Methods of learning supported:
Inquiry-based Teaching methods

End user:
Students grade 5-6 (ages 11-12)

Involved actors:
Designers-students

Location:
Modelling Rotating Bodies can be used in schools and at home as individual investigation.

Connection with curriculum:
Mathematics, ICT, Home Techniques and Economics, Art&Design.

Languages Available:
The ideas about using Google SketchUp in math lessons are available in Bulgarian, Russian and English.

Where to find the Application:
http://www.osrportal.eu/en/node/96045, - scenarios and support files
http://sketchup.google.com/download/ - software
http://dox.bg/files/dw?a=8aec092d1d – support file

Evalaution Parameters:
A number of surveys about using Google SketchUp were carried out among teachers in different subjects. Modeling with Google SketchUp in math lessons has been evaluated very positively by math, ICT and design teachers.

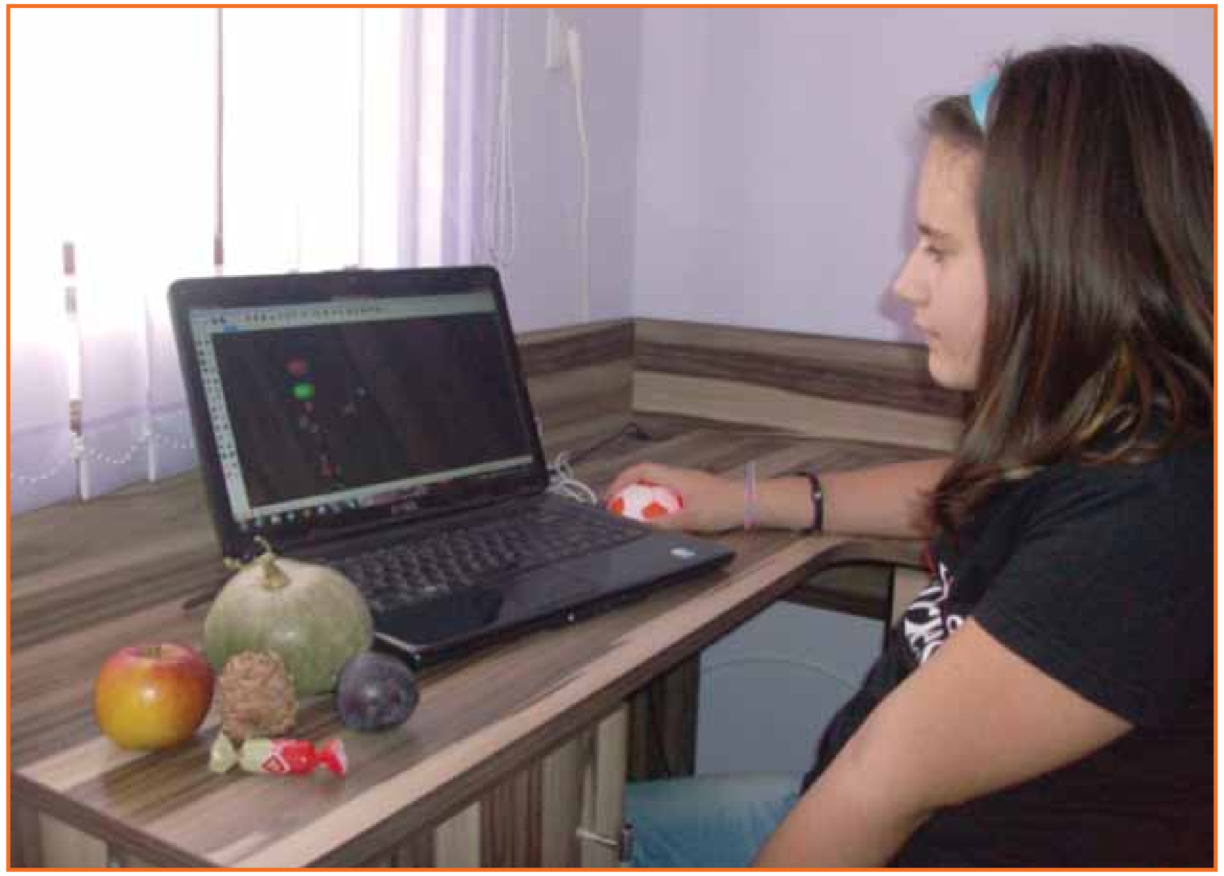
Duration:
This example is for 1 hour investigation in class, 1 hour individual homework and competition (it could be about 10 - 20 min in class or using social networks).

Additional information or resources:
edenserver.bme-tk.bme.hu/.../OCLR_2011_Athens_Proceedings.pdf,
http://www.science-journals.eu/edu/9/contents-isp-ea-9.pdf
Toncheva, N., Software technology to create teaching materials in mathematics education, University Press "Bishop KonstantinPreslavski", ISBN: 978-954-577-577-2, Shumen, 2011, 140p.

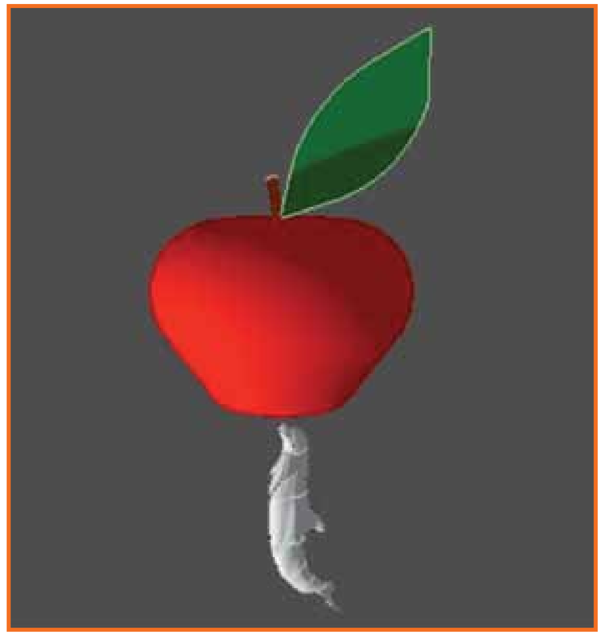
Teachers' competencies

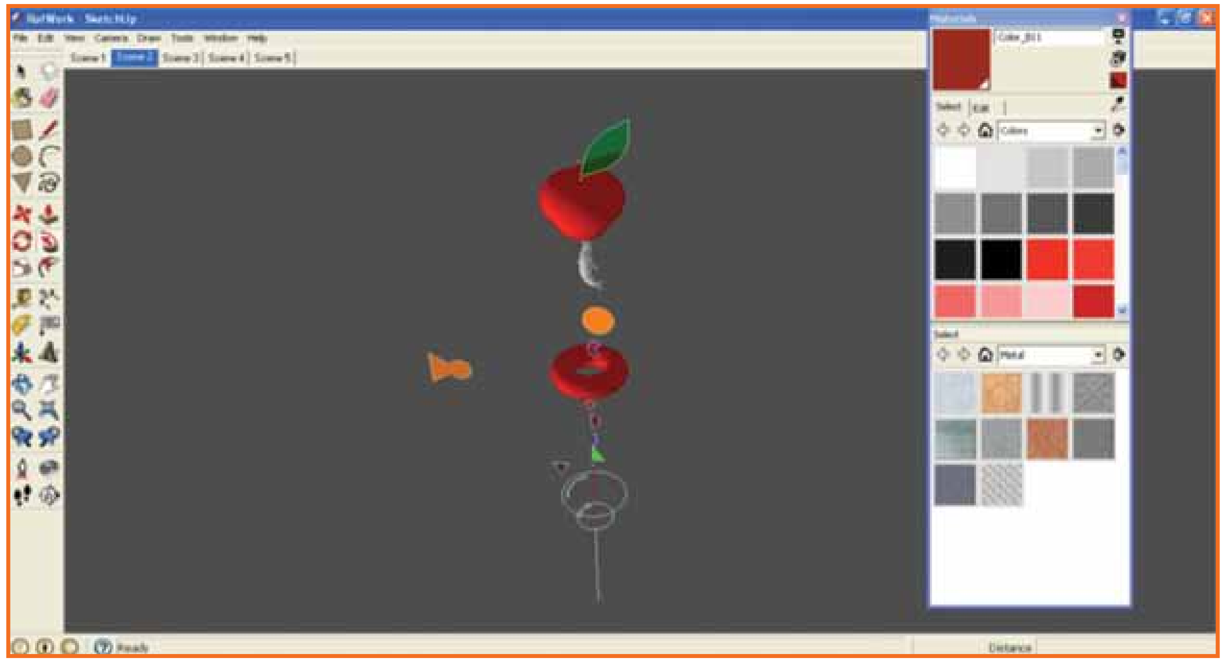
1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	x
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

2.12 Modeling rotating bodies



3. Students give examples for other similar bodies from the surrounding environment.
4. A question is raised: How are all these bodies obtained? – students' discussion. **(Phase 1)**
5. While forming the idea for figure rotation around an axis the teacher demonstrates the process with the help file RotWork.
6. For 5 minutes the teachers shows the students how to does the instrument Follow Me Tool works and draws lines and figures.
7. Students model the chosen rotating body (apple, pen, hat, etc) with the help of the support by themselves. The one who succeed creates their own models of rotating bodies. **(Phase 2)**
8. Students examine and analyze the models of their classmates. **(Phase 3)**
9. Students comment on how the shape affects the resulting shape. **(Phase 4)**





10. Students summarize the results of the carried work. **(Phase 4)**
11. A task is given for homework to construct an interesting rotating body which will be presented in a contest and will be assessed by the whole class. **(Phase 5)**
12. The contest results are discussed during the next lesson. **(Phase 6)**
13. The help of the software to understand the nature of rotational bodies is declared and commented are the options of Google SketchUp to solve other tasks. **(Phase 7)**

According to the Bloom's taxonomy the aims which are fulfilled with the given approach are as follows:

- **Cognitive domain**
  - **Knowledge** - Students get acquainted with constructing three-dimensional figures by rotating plane figures.
  - **Comprehension and evaluation** - Students think critically and creatively and develop their observation skills. They have to find rotating bodies observing real life objects. They should choose items that meet certain criteria.
  - **Analysis** - Students develop their analytic skills.

Students have to find what kind of plane figure they have to choose to construct rotating body that they had found among the museum objects or in stuff around.

  - **Synthesis and application** - Students

create their own attractive rotating bodies. They are experimenting with different shapes and axes.

- **Affective domain** Students have the opportunity to see the application of mathematics in practice. They see objects from nature and everyday life depicted by mathematical models.
- **Psychomotor domain** Students are introduced to software that is applicable to other subjects. Students are encouraged to share their models and have fun with the possibilities of the product.

2.12 Modeling rotating bodies

Mapping best practices with main principles

1. Building Interest in natural science phenomena and explanations

Through the usage of an attractive software in Math lessons, mainly used for design students can see clearly the relationship between mathematics and practice and to be motivated to work independently.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

Students explore and model the surrounding environment with the help of mathematics and IT.

3. Develop multiple goals:

The BP Modelling Rotating Bodies is aimed at:

- Students to explore the surrounding environment.
- Student to raise a hypothesis and to experiment.
- Stimulation of the artistic skills of the students.
- To make cross-curricular relations.

4. Understanding students' concepts and learning style about science phenomena:

Students have the opportunity through Google SketchUp software to design real and imaginary objects. They can analyse their structure.

5. Relevance of the content to the daily lives of students:

The proposed BP is directly linked to the surrounding environment as an additional motivation for work there is the possibility for the students to share the designed bodies in http://sketchup.google.com/3dwarehouse/ or to share and comment them with friends in the social networks.

6. Understanding science as a process not as stable facts. Using up-to-date information of science and education:

During their work on Modelling Rotating Bodies students realize the facts that ideal rotating bodies are rare in the real life but they acquire skills to modernize and stylize these bodies with the available instruments and the already acquired skills how to use them.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

In the given practice students introduced with a new software which if they are willing can learn, they can analyze the structure of the different bodies, make conclusions and construct models (on a given body or a body of their own choice)

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

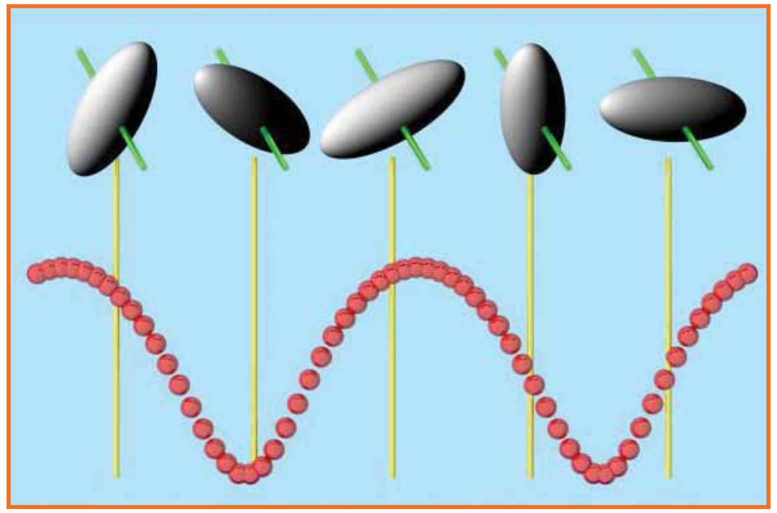
In BP Modelling Rotating Bodies the lesson can be designed on the basis of the 7 phase model of open IBSE scenario. Students go through all levels of the experiment – form giving of the scientific question through raising and checking of the hypotheses to the reflection on the implemented activities.

9. Assessment: formative (of students' learning) and summative (of their progress):

In the given BP the assessment is of entertainment nature because it's conducted as a competition and mutual assessment by the students themselves.

10. Cooperation among teachers and with experts:

The BP Modelling Rotating Bodies is designed for the purpose of mathematics lessons but in case of necessity there is an opportunity for a joint work together with a teacher in IT or Home techniques and economics.



2.13 Exploring nature and biodiversity

PATHWAY

Summary:

During a five-day ecology programme 4th and 5th graders explore and experience the natural forest and the animal world of a national park in Germany. Everyday trips within the park allow the students to observe and learn directly and with hands-on practices about the importance of nature and species conservation.

Aims:

The five-day outdoor ecology programme is designed to foster individual environmental attitudes and behaviour regarding conservation and nature. Direct experience and playful encounter is supposed to improve the individual understanding of natural forests' importance. A field trip of an included wide range animal ground provides substantial knowledge about mammals originally living in the mountainous environment– like the lynx and the wolf. Original encounter will additionally enhance the individual connectedness to nature as well as animal empathy and knowledge about nature conservation.

Main activities:

The programme consists mainly of games conducted directly in nature, they support active and collaborative learning. Outdoor educators foster the communication competencies and experiential learning while students discover their environment. Additionally, a contest composed of topic specific riddling and games motivate the students in self-directed learning and may lead to a substantial knowledge increase.

Narrative:

4th to 5th graders get introduced in the natural area of the national park. Through the first activity (explore the forest with your own senses), the curriculum knowledge about the forest is repeated and (further) confirmed. The students are supported to undertake hands-on inquiries and scientifically approach their environment. The topics of the project are "the nature and species conservation", "the characteristics of the national park's ecosystem" and "the characteristics environmental action". All issues are mainly presented as outdoor simulation games (e.g. "storage strategies of squirrels", "mapping of noises", "lynx and deer", "touch a tree") by specifically elucidating the connection of nature with humans and other species.
The animal ground with its large enclosures allows a discovery of real living environments of the animals in question. Outdoor educators explore the animal park with the students and let them scientifically approach the animals within an inquiry-based discussion (including central questions). Observation of different species introduces in animal's natural behaviour in natural habitats. In a discussion with the outdoor educators the conflicting situation between reintroducing predators and humans is explained. The hike to a "dead" forest region which was due to a bark beetle infestation offers an opportunity to explore the regeneration process of a forest. Hands-on examples explain the biology and procedure of a bark beetle infestation. In the evening, in an individual national park diary all experiences made over the day are drawn up.. based in Java simulation writing the model, the simulation and the algorithm for the decay of nuclei. Teachers realised that the laws physics as they are presented in the textbooks lack of certain discussion, as for example the change of the decay parameter (probability) results to a stochastic process not presented in the textbook.

End user:
4th and 5th graders.

Involved actors:
Outdoor educators, rangers and experts of the National Park

Location:
Jugendwaldheim, "Wessley Haus" (field centre of the Bavarian National Park)

Connection with the curriculum:
Native species and plants, as well as the ecosystem forest are part of the regular Bavarian curriculum.

Languages available:
German

Evaluation parameters:
The programme "Exploring Nature and Biodiversity" is evaluated with regard to knowledge impact and shifts in environmental attitudes and behaviour and attitudes towards conservation and nature.

Duration:
Five days (in general: Monday to Friday)

Additional information or resources:
Programme information is available as a flyer. Additional materials are games specifically developed for the programme.

Teachers' Competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	

2.13 Exploring nature and biodiversity

1. Building Interest in natural science phenomena and explanations

The outdoor ecology programme offers the opportunity of real experiences in nature. Natural science phenomena are explored on site and explained with carefully chosen examples in the form of games or investigations. The students are engaged to develop a practical understanding of nature and species conservation.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

An individual understanding the importance of nature and species conservation is supported. Example cases maintain an understanding of human's influencing consequences on nature. The knowledge of a healthy forest and environment is communicated with facile methods, which exemplify the task humans have to fulfil in the future and for the next generations. Potential conflicts between reintroducing predators and humans interests is elucidated and discussed with students.

3. Develop multiple goals:

- understanding big ideas in science including ideas of science, and ideas about science
- scientific capabilities concerned with gathering and using evidence
- scientific attitudes

The national park's philosophy "let nature be nature" is highlighted as the overall umbrella for environment protection and respect for nature and species. Small case studies, like scientifically research within and outside of the national park, show the students the cooperative work of many different people, which is needed to reach this aim.

4. Understanding students' concepts and learning style about science phenomena:

Playful hands-on inquiry games carefully connect theory with reality and science phenomena. Methods like "environment exploration", "discussions" and "scientifically approach" foster both self- and team-orientated learning and understanding. Thus, potential misconceptions are addressed and directly clarified.

5. Relevance of the content to the daily lives of students:

The functions of a forest, like "natural cycles for instance of the seasons", "air purification", "decomposition and the biology of different species", are revealed to the students with hands-on examples. Everyday activities, which are useful for everybody to help changing our environment to the better, are explained.

6. Understanding science as a process not as stable facts. Using up-to-date information of science and education:

Scientific research in the national park is explained as basis for the national park management, especially for methods of forest conservation and forest tending. This research demonstrates the natural process of self-reintroducing plants and animals, and their evolving biodiversity in a "dead" forest after a bark beetle infestation

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

This environmental programme aims to impart most of the theory and knowledge in a playful way. Simulation games and hands-on inquiries enable the students to learn the theory seemingly with no effort. Through the daily use of a national park diary a consolidation phase of the learned theory during the day is given.

8. Cooperation among teachers and with experts:

Curriculum knowledge is connected with real life experiences in the national park, where outdoor educators and experts use the opportunity to explain the real life and scientifically backgrounds.

2.14 Illuminating chemistry – investigation of fluorescence and phosphorescence as scientific phenomena

PATHWAY

Summary:
The module "illuminating chemistry – investigation of fluorescence and phosphorescence as scientific phenomena" consists of interdisciplinary (combining chemistry and physics) experiments where pupils of age 14-15 can learn about sound and the colours and luminescence phenomena by inquiry. In the project the effectiveness of the learning by inquiry are measured by pre- and post-questionnaires. All materials were used in the ELAN-student laboratory as project materials and in chemistry lessons of different schools as well.

Aims:
The aim is threefold:

(a) To foster **interdisciplinary scientific thinking** in order to connect disciplines which may be seen as separated ones on student`s perspective. The context luminescence is the field where questions are raised and explored using knowledge of chemistry and physics.

(b) To apply the **pedagogy of Inquiry Based Science Education** (IBSE) in concrete learning activities. Students are invited:

- i. To wonder about colourful and luminously subjects in the natural world.
- ii. To investigate the questions rose in the wondering.
- iii. To confront their ideas and findings with scientific insights.
- iv. To summarize their conclusions.

(c) To measure the effectiveness of the **pedagogy of Inquiry** in this concrete interdisciplinary learning opportunity.

Main activities:
In this practice, the scientific inquiry is understood as a process of scientific reasoning along following lines:

1. **Wondering** about the phenomena by brief introductions, little experiments… (Make them aware what they don't know…)
2. Out of the wondering about nature, **scientific questions** are raised and hypotheses formed in a cycle from general ones to more specific ones (by inquiry reasoning)
3. To look out for **evidence** based answers (by experimental inquiry)
4. To think of explanations by constructing **consistent scientific models** (by inquiry scientific thinking)
5. To **evaluate** these explanations (metacognition): reflecting further in the light of consistent scientific understanding that brings together all insights.

Content:
In school, pupils learn the basics of chemical reactions, its composition, structures and properties. Unfortunately, there is not much time for a side to different topics (like interesting phenomena of color). This module offers opportunity to make the scientific way of thinking and working visible for students in the field of colors and surrounding issues. The aim of this project is to establish understanding of chromaticity and diversified topics like e.g. electric magnetic wave, luminescence and food colorant by inquiry.

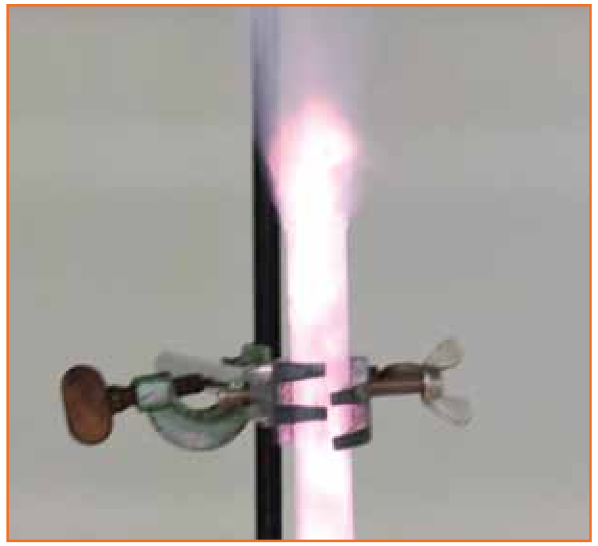
The module offers full-color worksheets and practical task for scientific deepening this topic. Furthermore the participants are mainly free and independent during the course. As active workers they can develop and conduct experiments nearly on their own.

The following questions are under examination:

What are dyes and pigments?
Why objects appear colored?
How a glow stick works?

These principles are investigated in little groups with the help of a supervisor. After an introduction students are free to work first with these five experimental stations. Later on they have the opportunity to investigate own ideas.

1. What is color? Fundamentals of optics
   In this part students discover that electromagnetic radiation which is visible to the human eye is the source of color.
2. Food dyes from the view of chemist
   Questions concerning food colorings are investigated in little experiments.
3. Organic and inorganic dyestuffs
   Students investigate and explain the colour and change of colour using chemical explanations based structure and corresponding property of materials.
4. Pigments and its application
   Questions concerning food pigments are investigated in little experiments.
5. What is luminescence?
   In this part students discover the fundamentals of phenomena like fluorescence and phosphorescence.



End user:
The learning materials are meant for children of 8th /9th grade as well as students of upper secondary school, age 15-18.

Involved actors:
Lecturers and Researchers of Humboldt-Universität zu Berlin
Teachers of involved schools

Location:
In school or laboratory of Humboldt-Universität zu Berlin

Connection with the curriculum:
Colours, phenomena like luminescence (fluorescence and phosphorescence are implemented in the curriculum of chemistry for pupils of age 12-14 and 16-18 (1st year of 2nd stage of secondary school)

Languages available:
German

Where to find the application or case:
The information about the good practice is available: www.tiemann-education.de

Evaluation parameters:
It was evaluated
(a) with questionnaires of Humboldt-Universität zu Berlin, department of chemistry education filled in by teachers and students.
It is evaluated
(b) by the Pathway Questionnaire by the teachers involved.

Duration:
The duration of the case for the students is up to 2 lessons (depends on local needs).

2.14 Illuminating chemistry – investigation of fluorescence and phosphorescence as scientific phenomena

1. Building Interest in natural science phenomena and explanations

Colors and phenomena of luminescence are phenomena that scientifically can be understood in terms of chemistry and physics. Although present in our everyday life - as an interdisciplinary reality – these principles are covered very little in the German curriculum. In reality there is not much time to deal with these phenomena. In this practice the pupils connect on an inquiry manner, the basic concepts of color, both of chemistry and physics.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

This project aims at the connection between fundamental sciences are important for a better understanding of scientific questions and finally our world. By a better understanding of color, the society could benefit from these better insights but could profit as well from the risen health awareness that goes along with this practice (covered mainly by the topic of food colorings).

3. Develop multiple goals:

- understanding big ideas in science including ideas of science, and ideas about science
- scientific capabilities concerned with gathering and using evidence
- scientific attitudes

The inquiry-method is at in the foreground of this good practice: to foster a scientific attitude, to become wondered about the phenomena in nature, to raise questions, to build hypotheses and to look for evidence. Scientific thinking and reasoning is the learning goal in this interdisciplinary project. Basic scientific ideas are deeply connected into this project and brought to learners.

4. Understanding students' concepts and learning style about science phenomena:

The pedagogical method of inquiry applied in the learning stations gives opportunities for learners of different learning styles. Wondering addresses the dreamers and fosters the desire for exploration. Looking for evidence and doing experiments addresses students which learn easier by practical task and learning opportunities. Scientific reasoning and analysis addresses students which learn by theoretical tasks and thinking opportunities. Drawing conclusions addresses deciders and planners.

5. Relevance of the content to the daily lives of students:

Phenomena of color directly correspond with ways we communicate and express ourselves. It is clear that the understanding of color and phenomena of luminescence are a crucial point in gaining scientific literacy. Moreover the topic is at the basis for a deeper understanding of electromagnetic waves which are all around us.

6. Understanding science as a process not as stable facts. Using up-to-date information of science and education:

The inquiry used in 5 different learning stations. That leads the students into a conceptual discovery tour in the world color and luminescence. By going to these stations, students can understand that new insights are always nearby: a next question, a new hypothesis and the further investigation is often very close to the last one. In this manner the 'world of science' is brought into the classroom. So that students can experience investigation and experiments in this practice as no stable and closed book whatsoever but as a living invitation to join the scientific journey.

7. Doing science: experimenting, analyzing, interpreting, redefining explanations:

Students are given the opportunity to analyze the results of experiments themselves, scientific thinking is fostered and at the end, pupils are expected to draw his/her own conclusions. Students go through the inquiry themselves with the help of supervisors and build up gradually a growing scientific understanding of colors.

3.

Educational activities connecting

formal and informal learning settings

3.1 Natural Europe

Natural history & environmental cultural heritage in european digital libraries for education

PATHWAY

Summary:

This best practice links the natural history museum to the classroom through engaging, hands-on, physical or virtual educational activities that promote a greater appreciation of nature and understanding of science.

Aims:

- To increase the student involvement in the educational process. Students hold the most significant role in this procedure, as they manage the activities organised according to their educational needs. The teacher acts as facilitator, supervising students' interaction and assisting when necessary.
- To connect formal and non-formal learning in real-world and digital environments. Based on entertainment and education, this approach allows school students to enjoy an educational experience tailored to their own needs and expectations, under the guidance of their teacher.
- To provide fascinating opportunities for interaction with natural history related physical and digital objects and resources. Digital and physical museum exhibits, being an integral part of the educational procedure, influence positively the students' curiosity and urge to learn, and thus enhance their interest towards natural sciences.

Main activities:

Teachers and museum educators work closely to design stimulating lesson plans, corresponding to the national curriculum, and adaptable to the students' personal needs. These lesson plans are based on a museum visit, whether physical or virtual, to engage students in hands-on activities leading to realistic experiences directly connected to classroom-taught science. In the same context, each lesson plan includes activities to be carried out prior to the visit and others following it. A major part of this procedure is student to student collaboration, a fact that reinforces assimilation of knowledge in a constructive way.

Narrative:

This educational approach aligns with the recommendations of the High Level Group on Science Education (Rocard, 2007) for the provision of increased opportunities for cooperation between formal and non-formal educational institutions for enhancing motivation and participation. An educational activity includes three phases: the pre-visit phase including actions that are being carried out prior to the museum visit, the visit phase regarding activities to be actualised in the museum (whether virtually or physically) and finally the post-visit phase concerning follow-up activities to take place upon return to classroom. Each of the three phases is divided in carefully designed steps. The overall procedure is very well structured to ensure maximum learning results; when following closely all the steps, students can obtain knowledge and develop an understanding on the issues discussed.
Overall, students work in teams to explore theory, make observations and collect data within realistic contexts. This procedure allows them to identify and fill gaps in their knowledge base through hands-on activities. Students work out relationships of cause and effect, using reasoning ability, to interpret collected observations.

e.g. Renewable, Green, Clean? Wind Energy and Solar Energy (PV) [education.natural-europe.eu/natural_europe/exhibits/pathway-slug-53/to-begin-with]. This activity, which is addressed to students of Key Stages 2-3, regards two renewable energy forms (solar power and wind power) and their advantages and disadvantages. Students work collaboratively to investigate the issue, pose questions according to prior knowledge, make their own connections to the information discovered and reach conclusions. All the steps revolve around a visit to a science centre for environmental education, where students can engage in creative activities and achieve deep understanding on the issue examined.

Methods of learning supported:
Inquiry-based – game-based.

End user:
Students of primary and secondary education.

Involved actors:
Primary and secondary education students and teachers, museum educators, science communicators.

Location:
Formal – non-formal – informal contexts (schools, Natural History Museums, Science Centres, Botanical and Wildlife Gardens, other fields e.g. forests, rivers, excavation sites).

Connection with the curriculum:
Natural Sciences (Physics, Biology, Chemistry etc.).
Languages available:
English.

Where to find the application:
education.natural-europe.eu/natural_europe/

Additional information or resources:
The handbook and manual, addressed to teachers and aiming to exemplify the creation of educational activities in the context of this best practice, can be found following these two links:
- www.natural-europe.eu/files/Natural_Europe_Pathway_Authoring_Tool_Manual_151211.pdf
- www.natural-europe.eu/files/Natural_Europe_Educational_Pathway_Handbook_151211.pdf

Time frame:
1 hour to 2 weeks.

Number of participants:
up to 20.

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	x
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

1. Building interest in natural phenomena and scientific explanations:

The focus of the educational activities is set on the educational needs of students in primary and secondary education in the fields of natural history, environmental education and science. Whether through web access to the portal or through physical visits to local NHMs, participating students engage in hands-on and minds-on educational activities that effectively link the modules taught in the classroom to practical, everyday life, issues.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

Students engage in activities regarding the natural environment and natural history, which help them to become active and responsible citizens, both locally and globally. This way, an integrative approach is developed, building up networks to exchange new ideas and expertise and to create a common pool of new specific media. Moreover, they follow a clearly scientific approach to perform research and reach conclusions, and thus learn to appreciate the nature of science. The process involves understanding different perspectives of boys and girls and aims to boost gender equality.

3. Develop multiple goals:

- understanding big ideas in science including ideas of science, and ideas about science
- scientific capabilities concerned with gathering and using evidence
- scientific attitudes

The Natural Europe educational model is thus structured to promote research initiated by the students. In this context, students are encouraged to work on their questions and explore cooperatively to gather the required information and propose possible responses. A crucial part of this procedure is the students' own experiences, further enriched during this process, to allow them to develop thorough understanding on the issue examined. This way, engaged students comprehend the importance of scientific research for forming scientific answers to scientific questions.

4. Understanding students' concepts and learning style about science phenomena:

The learner-centred approach is well-structured and aims at building knowledge on issues related to environmental protection, science, biology and chemistry. Following the inquiry-based model, the activities promote active, collaborative and community-based learning. Seeing that learners understand the messages of interest according to their experiences and interactions during the learning procedure; therefore, they are allowed to investigate the issues of their choice, answering their own questions.

5. Relevance of the content to the daily lives of students:

This is achieved by organizing field trips to museums to engage students in hands-on experiments and minds-on activities related to everyday life, as well as problem-solving approaches, heavily involving "real-life" experimentations in the user-friendly and engaging environment of the museum. The field trips are organised in such a way to enable users to live their individual learning experience. During the activities the initial predictions of the visitors can be tested against data made available to them during the visit.

6. Understanding science as a process not as stable facts. Using up to date information of science and education:

The educational procedure followed requires completion of certain steps in order for students to understand the issues discussed, and examination of the initial predictions made against understanding obtained in later stages of the learning process. Moreover, the activities require use of digitised cultural resources from the European NHM community, as well as of state-of-the-art digital tools.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

Hands-on and minds-on activities are at the core of this approach. Following it, students comprehend the issues discussed, and perform research according to their individual needs. The three-phase approach involves examination of the issue discussed by carrying out activities both in formal and non-formal environments, allowing for knowledge to be obtained progressively.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

Students are expected to engage in hands-on activities, analyse their results, engage in discussions, and re-examine their beliefs as new information is being obtained. Both genders equally participate in this process of scientific experimentation and research, thus boosting gender equality.

9. Assessment: formative (of students' learning) and summative (of their progress):

Carrying out the activities, students always find themselves in the position of constantly evaluating their progress, investigating additional resources and looking for alternative answers. In the closing step, they are expected to examine the information retrieved and come up with a conclusion to be presented to their peers and their teacher who can understand and evaluate the process followed, the overall engagement and the understanding obtained.

10. Cooperation among teachers and with experts:

Teachers work collaboratively with museum educators in order to construct and carry out appealing educational activities. Putting together their expertise, they manage to engage students in truly interesting learning activities.

PATHWAY

3.2 OpenScienceResources

Towards the development of a shared digital repository for formal and informal science education

Summary - Aim:

"Open Science Resources" (OSR) aims to promote effective science education, by connecting in-class teaching with museum visits and field trips and by harvesting the potential of digital science education materials. To succeed in connecting formal and informal learning, a large pool of educational digital content has been created that offers to teachers access to the finest science museum collections of Europe as well as numerous respective educational activities that follow the (IBSE) approach.
All the educational content and the educational activities are gathered and organised in an easy-to-use open repository. In this repository, a set of tools and respective manuals are also available to users in order to facilitate them in designing their own educational activities.

Main activities:

The main activities included are the following:

- Introduce to teachers the use of digital educational resources and help them integrate their use in their everyday teaching so as to make their lessons more effective and interesting for their students.
- Promotion of the IBSE approach and student-centred practices through training workshops and presentation of respective good practices.
- Design of IBSE activities that are connected to the school curriculum and combine in-class teaching with science museum visits and hands-on activities for students through training workshops, related supporting materials and demonstrations.
- Implementation of the produced educational activities in different learning contexts so as to demonstrate their multicultural aspect and their effectiveness on different levels of students.

Narrative:

The content of the OSR repository consists of high quality educational activities that follow the IBSE approach and focus on modifying current teaching practices in order to make science teaching more effective and interesting for students. By connecting the in-class teaching with museum visits and hands-on activities, teachers are given the opportunity to transform their lesson into an exciting for students activity that will help them learn through a student-

centred procedure that allows them to be actively involved in the learning process instead of being simple spectators. This educational approach is in accordance with the recommendations of the High Level Group on Science Education (Rocard report: "Science Education Now: A New Pedagogy for the Future of Europe", 2007).
The proposed activities offer unique experiences to the users, by expanding a simple presentation of artifacts to an interactive presentation of facts. Students may interact with exhibits and through their inquiries they learn about the subject at hand and the interconnection between different principles and phenomena.
Additionally, the proposed approach aims to raise the wider public's interest and awareness on science. The aim is to demonstrate an innovative methodology that involves visitors in extended episodes of playful learning. As the content of the OSR repository is expected to be used from a quite heterogeneous group of people (youngsters, adults, professionals, educators, school groups, families), the educational activities proposed vary significantly in order to cover the different users' needs and their objectives. These scenarios are one of the basic vehicles for the promotion and the dissemination of the proposed approach to the user communities.
The content of the OSR best practice covers all subjects of natural science from the most fundamental principles of physics, like for example Newton's laws to advanced subjects like quantum mechanics and genetics. The activities involved cover all stages of education, from kinder garden to higher education.

Example activities:

Foucault's pendulum
(www.osrportal.eu/en/node/93935)
This educational activity targets students of primary and secondary education. Primary school students may find out about Earth's rotation and how a pendulum works whereas secondary education students may also practice adding and analyzing vector and forced oscillations.

History of flight
(www.osrportal.eu/en/node/94455)
Students may find interesting information about the history of flight and learn how airplanes fly, the gravitational force and Newton's laws.

The Double Slit experiment - Wave-Particle Duality
(www.osrportal.eu/en/node/94689)
This activity allows students to interact with an augmented reality exhibit and learn about the concept of wave - particle duality, the cornerstone principle of quantum mechanics.

Methods of learning supported:
IBSE model, hands-on activities and field trips.

End user:
Teachers and students of primary and secondary education, museum curators, lifelong learners.
Involved actors:
Students, teachers, researchers, museum visitors, informal learning web visitors, museum curators, stakeholders in education.

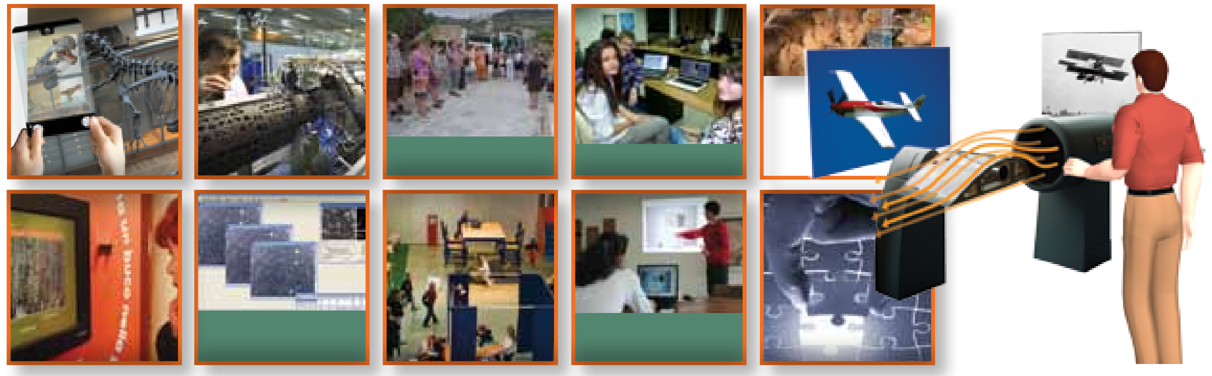
Location:
Schools, science museums, science centers and on the web.
Connection with the curriculum:
Natural Sciences.

Languages available:
English – Greek – German – French – Italian – Portuguese– Finnish – Hungarian

Where to find the application:
www.osrportal.eu

Additional information or resources:
www.openscienceresources.eu

Number of participants:
Not limited number of students using the material at a time.



Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	x
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

1. Building interest in natural phenomena and scientific explanations:

OSR practices connect in-class teaching with respective field trips that are supported by the content of the repository and the use of experimental devices and documentation, as well as innovative interactive applications. The activities are student-centred; they focus on having students become little scientists themselves and carry out their own guided inquiries and experiments so as to come up with their own explanations.

2. Building up informed citizens:
Students understanding the nature of Science & Science in society:

The OSR approach aims to meet the challenge of "science for all", by providing activities designed for families and general museum visitors that follow a more open format. Moreover, in the framework of OSR several 'science days' are also organised in different European countries in order to improve the citizens' attitude towards science.

3. Develop multiple goals:

- **understanding big ideas in science including ideas of science, and ideas about science**
- **Scientific capabilities concerned with gathering and using evidence**
- **Scientific attitudes**

The OSR learning approach is based in the idea that problems drive the learning. Within the context of a field trip, children try to interpret the problem, gather needed information on site, identify possible solutions, experiment, and evaluate options and present conclusions. The interconnection between different activities allows students to see the bigger picture; how different phenomena and principles are connected to each other and, ultimately how, the world around us works.

4. Understanding students' concepts and learning style about science phenomena:

The OSR learning approach suggests that learning contexts and learning methods should be mixed, in order to provide an effective blend of learning experiences. Students are trained to be self-responsible learners who decide over their individual learning paths, actively search relevant information, and simultaneously develop problem-solving as well as critical thinking skills.

5. Relevance of the content to the daily lives of students:

The OSR best practice is in line with the modern pedagogy, according to which teaching should be guided by a holistic planning process. Thus, students learn science in meaningful ways that allows them to see connections to familiar problems which are relevant and important in their daily lives.

6. Understanding science as a process not as stable facts. Using up to date information of science and education:

Museum trips and relative activities allow students to learn on-site using exhibits and to acquire complete apprehension not only of the stable facts but also of the connection between different facts and phenomena, how science works and its connection to everyday life.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

Learners use their background knowledge along with their science process skills to construct new explanations which allow them to understand the natural world. Thus, learning is confronted as the result of on-going changes in our mental frameworks as we attempt to make meaning out of our experiences.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

The heart of every activity is a hands-on task that allows students to learn by doing. Learners are expected to work directly with exhibits that concern natural phenomena. They use their senses in order to observe and they use instruments to extend the power of their senses. Thus, students begin to form a better understanding of the natural world through all the parts of the activity that include problem-solving approaches and 'minds-on' experiments that involve "real" experiments in the "user-friendly" and engaging environment of the science museum.

9. Assessment: formative (of students' learning) and summative (of their progress):

By comparing students' knowledge before the realisation of the activity to the results they produce, the teacher may assess the cognitive impact of the activity on students. Several game-based on-line applications help teachers understand the impact of the activity through relative quizzes. Furthermore, student's behavior and performance over a series of activities allows teachers to record and assess the summative progress of their students.

10. Cooperation among teachers and with experts:

Teachers may cooperate with the staff of science museum and science centres that will guide them and give them detailed information about the exhibits they plan to use. Thus, teachers have the opportunity to fully prepare their visits and refine their activities and make them as effective as possible.

3.3 Outdoor, environment - based science inquiry

Summary:

This best practice involves students from Key Stage 1 to Key Stage 4 in active, hands-on, outdoor inquiries that support the development of their inquiry skills and science subject knowledge via interaction with outdoor-educators.

Aims:

Outdoor, environment - based science inquiry provides valuable links to school curricula and authentic learning environments in order to develop students' subject knowledge in areas such as biology, ecology, biodiversity and food production. It aims to:

- Provide learning opportunities that are "beyond the classroom", underpinned by theories of learning that stress the way such activities (including engaging in problem solving in a wide range of "beyond school" environments) enhance learning by directly engaging learners in 'active' learning.
- Support students to make links between classroom science learning and science in the "real world" / their lives by providing a 'real-life' context in which science matters.
- Raise and give students the opportunity to undertake ethical inquiry into issues of worldwide significance/concern especially around sustainable futures in food production and food security, by involving young people in the realities of producing food.

Main activities:

Outdoor educators work with teachers to create and deliver inquiry-based sessions for students which are closely linked to the curriculum and in-school learning. The focus of the sessions is hands-on, active and engaging learning through a carefully structured programme that allows students to develop their critical questioning and inquiry skills whilst also reflecting on the science subject knowledge that they are drawing on and developing. There are often both pre - and post - visits by the outdoor educator to the school which supports the flow of learning across both sites. Theory is carefully integrated into all the sessions and assessment is through observation and conversations with students about the key scientific concepts they are exploring.

3.3 Outdoor, environment - based science inquiry

Narrative:

Students are supported to undertake active, hand-on inquiries that involve collecting and analysing data from around the outdoor environment, for example using data loggers to gather environmental data or measuring populations and using quadrats:

"*Learn about different survey techniques that can be used to measure population sizes or biodiversity (seasonal - may include a timed search, quadrats, small mammal trapping, reptile refugia). Work in groups and choose techniques to compare the biodiversity of two habitats on the farm and report back findings*". (Woodlands Farm Trust, 2011)

Outdoor inquiry not only links the classroom study of science to "real-world" science' but also supports students to explore the links between the outdoors, their lives and science. The most obvious link is through food. This can be done with very young children using simple concepts such as 'where does my dinner come from?' right up to GCSE and A-level

Science students who can explore for example the ethics of modern farming or the science of soil and crop survival:

"*How do farm animals provide the food we eat and how should we care for them in return? In this workshop we investigate egg, milk, or wool production and explore the needs of animals through games and investigations.*" (Vauxhall City Farm, 2011)

"*Children explore the farm's gardens and allotments and play games to learn about what plants need to grow and be healthy. This session encourages the children to use their senses and examine their local environment in a new way, encouraging teamwork and observational skills. To finish the workshop the children will sow seeds to care for at home.*" (Vauxhall City Farm, 2011)

Technology is used to support the recording of data / observations e.g. digital cameras, video cameras, data-loggers, probes, sensors. Teachers and farm educators support students to draw on and develop their science subject knowledge in order to make sense of their data and analyse it.

Students can also undertake ethical inquiry into matters of both local and global significance, such as food security and in such controversial areas as GM food and climate research. Students gain the critical skills enabling them to engage in ethical debates, arguments, controversies and contests about science, and to engage with philosophical ideas and questions about science.

End user - involved actors:
Key Stage 1, 2 and 3 students.
Students, teachers, farm educators.

Location:
Primary and secondary schools - City farms.

Connection with the curriculum:
There is growing interest in the UK in learning which takes place beyond the classroom. City/local farms provide sites of learning that give hands-on opportunities for students to explore the science curriculum in a real-life setting. Workshops include curriculum links to biodiversity, sustainability, life of animals and plants and soil chemistry.
There is also an increasing focus on healthy eating in schools (the Healthy Schools agenda) as part of a brief to encourage broadly more healthy lifestyles. The outdoors can also provide first hand resources for diet, food types and cooking techniques that can be integrated into the school science curriculum.
There is a growing political and social awareness about the distribution of food resources globally and the way climate change might influence how and where food is produced. This has prompted a sharper focus on the need to introduce young people to issues of food production, sourcing and distribution. City / local farms provide the stimulus for raising and undertaking ethical inquiries into food security.
The recent introduction of the Environmental and Land-based Science GCSE (OCR: *www.ocr.org.uk/qualifications/type/gcse_2011/science/elbs*) is also particularly relevant.
The GCSE focuses on the practical application of Science to the care of animals and the production of food with students studying topics such as:
Animal Husbandry

- the application of recent scientific advances to the breeding of livestock and animals
- welfare issues
- modern farming methods
- day to day care of animals

Plant cultivation

- soil and environmental factors affecting growth
- growing a healthy crop
- plant reproduction

Languages available:
English
Where to find the application or case:

- Vauxhall City Farm: *tinyurl.com/VCFschools*
- The Woodlands Trust: *www.thewoodlandsfarmtrust.org/educationatrc.htm*

Evaluation parameters:
This best practice has been certified by the internal evaluation of Futurelab.

Duration:
Variable: one week to one term.

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	x
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

3.3 Outdoor, environment - based science inquiry

Mapping best practices with main principles

1. Building interest in natural phenomena and scientific explanations:

The hands-on, outdoor learning is engaging and enables the students to develop a practical understanding of natural science phenomena by "doing" and by linking learning to a specific site and subject areas of interest, such as animal care. Teachers and outdoor educators ensure links are made between in-school learning and the learning outdoors.

2. Building up informed citizens:
Students understanding the nature of Science & Science in society:

Students undertake ethical inquiry into matters of both local and global significance, such as food security and in such controversial areas as genetically modofied food and climate research. Students gain the critical skills enabling them to engage in ethical debates, arguments, controversies and contests about science, and to engage with philosophical ideas and questions about science.

3. Develop multiple goals:

- **understanding big ideas in science including ideas of science, and ideas about science**
- **scientific capabilities concerned with gathering and using evidence**
- **scientific attitudes**

Students can be supported to undertake active, hands-on inquiries that involve collecting and analysing data from outdoor environments, for example using data loggers to gather environmental data or measuring populations and using quadrats.

4. Understanding students' concepts and learning style about science phenomena:

Theory is carefully integrated into the practical sessions by the teachers and outdoor educators. Students are encouraged to discuss the science phenomena they are exploring and to explain in their own words the connections between science theory and farm practice. These discussions enable both students and teachers / farm educators to address misconceptions.

5. Relevance of the content to the daily lives of students:

Outdoor inquiry not only links the classroom study of science to "real-world" science but also supports students to explore the links between the outdoors, their lives and science. The most obvious link is through farms and food. This can be done with very young children using simple concepts such as "where does my dinner come from?" right up to GCSE and A-level Science students who can explore for example the ethics of modern farming or the science of soil and crop survival.

6. Understanding science as a process not as stable facts.
Using up to date information of science and education:

Outdoor Sessions are kept up to date and are often based on contemporary scientific issues.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

The activities are engaging and sometimes entertaining but the enhancement of science knowledge and scientific principles remain at the core of the activities.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

Students undertake observations or data collection as part of their inquiries, often using ICT to support the recording of data, e.g. digital cameras, video cameras, data-loggers, probes, sensors. Teachers and outdoor educators support students to draw on and develop their science subject knowledge in order to make sense of their data and analyse it.

9. Assessment: formative (of students' learning) and summative (of their progress):

Teachers make the learning that is happening explicit within the investigations, and students reflect on this. Whilst the students are involved in practical inquiries teachers and outdoor educators talk to pupils and listen to pupils talking to each other, matching their understanding to level descriptors.

10. Cooperation among teachers and with experts:

Outdoor educator and teacher plan the visit together to ensure there is meaningful continuity between the classroom and the outdoor learning site. Farm educators, for example will often do a pre- and post- visit to the classroom, especially if the purpose of the visit is for the students to learn about growing so that they can grow their own plants / vegetables in school.

3.4 Encouraging open-ended practical work in key stage 3 science

Summary:

This best practice case study is a project in which a science centre (At-Bristol) worked in collaboration with teachers and students from local schools to develop open-ended practical work / inquiry in Key Stage 3 (11 - 14-year olds) science teaching.

Aims:

The aim of the project was to improve pupils' enjoyment of, enthusiasm for and attainment in science via open-ended investigations. Also, to give students opportunities to explore possible answers to scientific questions that are related to real life via practical, hands-on experimentation.

This was achieved through:

- Genuinely open-ended and investigative practical work that is motivating and interesting for pupils (and teachers)
- A series of school-based hands-on workshops that bring real science into the classroom
- Emphasising hands-on investigation, thinking skills and class discussion to inspire pupils to learn and fully engage with science
- A focus on teachers' skills, ensuring that the project had an impact on students beyond this project.

The aim of the project was to improve teachers' knowledge and understanding of key scientific concepts and processes and to support teachers to develop their skills of planning and running open-ended practical work and to carry this out in their classrooms.

This was achieved through:

- Working in partnership with science education specialists.
- Providing opportunities for teachers to discuss key scientific concepts and processes with experts in the field.
- The use of innovative hands-on exhibits as learning tools to develop teachers' scientific enquiry skills.
- Providing opportunities for teachers to work as peer-buddies in schools with support from Learning Advisors and At-Bristol staff.
- Providing the opportunity for teachers to apply their knowledge and understanding of key scientific concepts and processes during the gap-task.

Main activities:

Teachers worked with science centre educators at the science centre to create and plan open-ended investigations for their students. The science centre educators then supported the teachers to carry out these plans in the classroom.

Students carried out open-ended practical work that was closely linked to the curriculum and to their everyday experiences of science.

Theory was carefully integrated into the practical sessions by the teachers and assessment was through observation and conversations with students about the key scientific concepts they were exploring.

Narrative:

In this project a science centre (At-Bristol) worked in collaboration with teachers and students from local schools to develop open-ended practical work/ inquiry in Key Stage 3 (11 - 14-year olds) science teaching.

The project was developed in response to changes in the curriculum outlined below. The project capitalised on At-Bristol's expertise in hands-on exhibits and discovery based learning, and used their portable, interactive, out-reach exhibits as an original and inventive learning tool to support teachers' skills and confidence in open-ended investigatory work. Teachers co-developed open-ended practical work with science educators/communicators from At-Bristol. The science centre educators then supported the teachers to carry out these plans in the classroom.

Students carried out open-ended practical work that was closely linked to the curriculum and to their everyday experiences of science. For example one investigation asked students "What makes a good toothpaste?". Students were given the ingredients for making toothpaste, explored and recorded the properties of each of the substances and investigated what happened when the substances were combined in varying amounts. Another group of students investigated "How does bread rise?", Experimenting with different yeasts and sugars. In another

3.4 Encouraging open-ended practical work in key stage 3 science

classroom students were giving the task of designing a boat that would support a certain downward force, using a selection of raw materials and a paddling pool to test their prototypes.

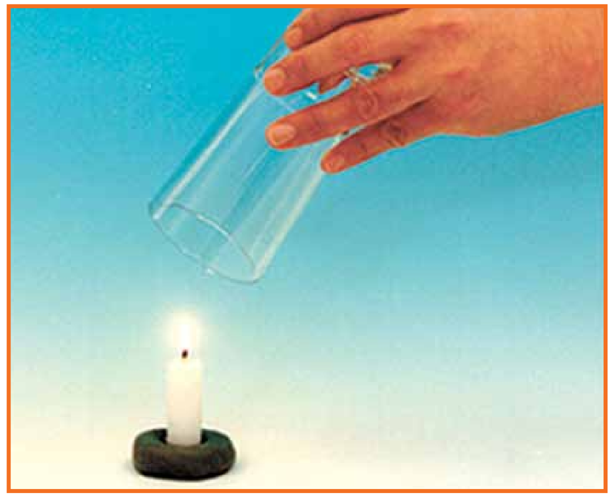
This sort of investigation empowers the students by giving them a degree of freedom to come up with their own results. They are not simply replicating the results of others; they are not directed towards a pre-determined outcome.

Each group of students may use underlying scientific theories to come up with slightly different solutions to the problem presented to them. Theory was carefully integrated into the practical sessions and made explicit by the teachers.

Throughout the investigations, teachers supported the development of students' experimental skills including: hypothesis testing, observation, repeat measurements, and controlling variables. Students also modified their processes to refine and develop their outcomes.

Assessment was through observation and conversations with students about the key scientific concepts they were exploring.

Teachers also engaged in professional inquiry, videoing and reflecting on their open-ended practical investigation lessons, with the support of their peers and the At-Bristol science teachers.



End user:
Key Stage 3 students.

Involved actors:
Teachers, teacher-trainers, science centre educators.

Location:
Local secondary schools Science centre, At-Bristol.

Connection with the curriculum:
There was a significant change in the National Curriculum for England, Wales and Northern Ireland at Key Stage 3 (KS3) and Key Stage 4 (KS4) phased in from September 2008, with a much greater emphasis being placed on the processes of science (Key Concepts and Key Processes).
This change resulted from of a number of drivers related to the quality of science education in schools, the need for future scientists in an increasingly technology dominated world and for increasing engagement between science and society.
This project was developed with this in mind and aimed to provide a fully supported CPD model that enabled teachers to develop their pedagogic skills, therefore leading to a sustainable change in practice.
Through the use of interactive exhibits teachers examined how the underlying science principles of three themes: Energy, Forces and Structures, could be explored through open-ended scientific investigation.
Teachers focused on their students' experimental skills including: hypothesis testing, observation, repeat measurements, and controlling variables.

Languages available:
English.

Where to find the application or case:
- www.azteachscience.co.uk/projects/encouraging-open-ended-practical-work-in-key-stage-3-science-at-bristol-science-centreinnovative-project.aspx
- www.at-bristol.org.uk

Evaluation parameters:
This best practice has been certified by the internal evaluation of Futurelab

Duration:
Several months.

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	x
11	Competencies in the use of ICTs	
12	Competencies in the knowledge, planning and use of curricular materials	x

3.4 Encouraging open-ended practical work in key stage 3 science

Mapping best practices with main principles

1. Building interest in natural phenomena and scientific explanations:

The hands-on open-ended investigations are engaging and enable the students to develop an understanding of natural science phenomena by "doing". Teachers are careful to ensure that the explanations are made explicit and are discussed.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

All of the open-ended inquiries were related to students' lives and involved everyday items such as bread or toothpaste. This highlights to students the science that can be found in daily life. Undertaking their own practical, open-ended investigations allows students to develop an understanding of the nature of science and what scientists might do when trying to find solutions to problems.

3. Develop multiple goals:

- **understanding big ideas in science including ideas of science, and ideas about science**
- **scientific capabilities concerned with gathering and using evidence**
- **scientific attitudes**

The practical work in this project includes ideas of science and about how science and scientists work – as detailed above. Throughout the investigations, teachers supported the development of students' experimental skills including: hypothesis testing, observation, repeat measurements, and controlling variables.

4. Understanding students' concepts and learning style about science phenomena:

Theory was carefully integrated into the practical sessions by the teachers and assessment was through observation and conversations with students about the key scientific concepts they were exploring. This enabled both students and teachers to address misconceptions.

5. Relevance of the content to the daily lives of students:

All of the open-ended inquiries were related to students' lives and involved everyday items such as bread or toothpaste. This highlights to students the science that can be found in daily life.

6. Understanding science as a process not as stable facts. Using up to date information of science and education:

The very nature of open-ended practical work is that not all students are directed towards a pre-determined outcome. Each group of students may use underlying scientific theories to come up with slightly different solutions to the problem presented to them. They may also modify their processes to refine and develop their outcomes.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

In open-ended practical work students are not simply imitating results, they are developing their knowledge of scientific theories by applying them to investigations that do not have a predetermined outcome.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

Throughout the investigations, teachers supported the development of students' experimental skills including: hypothesis testing, observation, repeat measurements, and controlling variables. Students also may also modified their solution to develop a better ones.

9. Assessment: formative (of students' learning) and summative (of their progress):

Teachers make explicit the learning that happens within the investigations and students reflect on this. Whilst the students are involved in practical work teachers talk to pupils and listen to pupils talking to each other, matching their understanding to level descriptors.

10. Cooperation among teachers and with experts:

Teachers worked with science centre educators at the science centre to create and plan open-ended investigations for their students. The science centre educators then supported the teachers to carry out these plans in the classroom.

3.5 Integrative science education courses at HEUREKA - The finnish science centre

Summary:

The course, Integrative Science Education Courses at HEUREKA, consists of an introductory lecture, laboratory workshops, science theatre shows, augmented reality workshops and exhibition tour. The course integrates different natural sciences in a way that promotes an active learning process and intrinsic motivation.

Aims:

The aim of the course is to introduce teacher students the pre-visit – visit – post-visit-model. The model activates informal learning during science centre visit by including both pre-visit and post-visit phases of learning.

Main activities:

Participating lectures, doing laboratory workshops, participating Science Theatre shows, doing Augmented reality workshops.

Narrative:

The course, Integrative Science Education Courses at HEUREKA, consists of an introductory lecture, laboratory workshops, science theatre shows, augmented reality workshops and exhibition tour. The course that highlights the role of informal learning uses the Pre-visit – Visit – Post-visit –model as a pedagogical approach. The course integrates different natural sciences in a way that promotes an active learning process and intrinsic motivation.

- **Lecture: Science Centre as an Open Learning Environment**
  - introducing the Pre-visit – Visit – Post-visit – model
- **Laboratory workshops (Open laboratory and Children's laboratory)**
  - visit phase of the model
  - taking part to the laboratory workshops in a role of learner
  - doing experiments, cooperative learning, learning by doing, increasing motivation, the host of the show gives explanations based on evidence, other possible explanations are considered
- **Participating Science Theatre shows (Why does the cow not fly?, Gas World)**
  - pre-visit and visit phases of the model
  - taking part to the shows as a learner
  - pre-visit phase: teacher students' curiosity is provoked, they are asked questions of current knowledge, they are proposing preliminary explanations or hypotheses, proposing simple investigations
  - visit phase: teacher students do observations, the host of the show gives explanations based on evidence, other possible explanations are considered
- **Doing Augmented reality workshops**
  - content: Doppler effect (see details in www.osrportal.eu/en/node/95848) and Double Cone on the Tracks or Uphill Runner (see details in www.osrportal.eu/connect.php?m=thenewviewer&nid=95914)
  - all phases of the model: pre-visit – visit – post-visit
  - taking part to the Augmented reality workshops as a learner
  - same kind of phases of pre-visit and visit like in participating Science Teacher shows
  - post-visit phase: Communicate explanation, Follow-up activities and materials
- **Familiarizing with the Heureka Classics exhibitions**
  - all phases of the model
  - see: www.osrportal.eu/connect php?m=thenewviewer&nid=95849

End user:
Teacher students.

Involved actors:
Researchers and science centre staff.

Location:
Heureka – The Finnish Science Centre.

Connection with the curriculum:
Learning natural sciences at primary school, wide scope: www.oph.fi/english/sources_of_information/core_curricula_and_qualification_requirements/basic_education

Languages available:
Finnish.

Where to find the application or case:
Science Centre Heureka.

Evaluation parameters:
The pedagogical approach, Pre-visit – Visit – Post-visit –model, is based on so called 5E-model that includes the main aspects of IBSE-learning. Teacher students give feedback of Augmented Reality workshops by a feedback form. In addition, they answer to an inquiry of science center and open learning environments. This best practice has been certified by the internal evaluation of the University of Helsinki.

Duration:
Two-day-course.

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	x
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

3.5 Integrative science education courses at HEUREKA - The finnish science centre

Mapping best practices with main principles

1. Building interest in natural phenomena and scientific explanations:

The course follows Pre-visit – Visit – Post-visit –model that activates students' interest and supports the knowledge structuring process through different phases similar to scientific method. During the course the students get to know different natural phenomena by taking part in the laboratory workshops in a role of learner, doing experiments and learning by doing together with other students. See also principle 8.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

The whole course is organised in a science centre. During the course the students get to know different aspects of nature of Science: geology, mechanics, chemistry and biology. Science in society is approached e.g. from the standpoints of crime, traffic and economy: Murder in Heureka, Heureka Classics, About a Coin, Intelligent Traffic. See also principle 3.

3. Develop multiple goals:

- understanding big ideas in science including ideas of science, and ideas about science
- scientific capabilities concerned with gathering and using evidence
- scientific attitudes

- to understand different aspects of doing science in different fields of phenomena (e.g. exhibit "Science Changing the World" or planetarium show "Journey to the Stars")
- to learn to use scientific method and discuss about science (e.g. The Children's Laboratory Colourful Chemistry and Science Theatre Gas world, Augmented reality Mechanics)

4. Relevance of the content to the daily lives of students:

During the course, students get a chance to approach the natural phenomena from many perspectives familiar to daily life. For example exhibits of traffic (Intelligent Traffic) and economy (About a Coin), science theatre of flying (Why does the cow not fly?) offer a new stand point for science in daily life.

5. Understanding science as a process not as stable facts. Using up to date information of science and education:

The main learning results related to informal learning and especially to science centre education are related to the motivations' effect on learning. Intrinsic motivation refers to a real interest in the topic studied. Furthermore, the course also supports students' knowledge structuring process through different phases of concept formation. During the course the students learn processes of natural sciences for example in Augmented reality Physics workshops.

6. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

The course supports active learning by 1) guiding to empirical concept formation and 2) promoting intrinsic motivation. During the course students learn how to make observations, how to apply empirical testing and hands-on experimenting. These activities together with the multifaceted tour through the science center also increase students' levels of intrinsic motivation. Especially hands-on workshops guide students to the direction of active knowledge gaining. For example: In the laboratories, The Open laboratory and Children's Laboratory, the aim of the laboratory programmes is to introduce children to and interest them in experimental natural science observation and teach them about chemical research topics and work methods. In the Children's Laboratory and the Open laboratory teams of two work together under the guidance of a Heureka inspirer.

7. Doing science: experimenting, analysing, interpreting, redefining explanations:

The pedagogical approach, Pre-visit – Visit – Post-visit-model, includes following phases:

1. Pre-visit: Provoke curiosity, Define questions from current knowledge, Propose preliminary explanations or hypotheses, Plan and conduct simple investigation
2. Visit: Gather evidence from observation, Explanation based on evidence, Consider other explanations
3. Post-visit: Communicate explanation, Follow-up activities and materials

8. Assessment: formative (of students' learning) and summative (of their progress):

As an assessment tool is used Hermant's (2003) New educational model or paradigms –cycle. The aspects of 1) Changes in learning environments, 2) Role of ICT and 3) Innovative learning approaches are evaluated.

9. Cooperation among teachers and with experts:

The course is planned and organised in cooperation with researchers of Science Center Pedagogy Unit in Teacher Education Department of HU and educators of Science Center Heureka.

3.6 From the land to the table

Summary:

The activities of the training course focus on a) the food nutritional properties, in particular milk, derivates and commercial products and b) on methodologies for science education.

Aims:

To investigate food properties and raise teachers' and students' awareness about food and correct lifestyle, to help teachers develop their role as facilitators of students' learning, to support IBSE.

Main activities:

Lab experiments about the evolution of biotechnologies from ancient times to today, discussions.

Narrative:

One of the two main aims of the course is to investigate the science of food. The starting point is to invite teachers to reflect on the conscious choices each of us is called to make about eating and food, based on scientific knowledge. For this, milk and its nutritive components are analysed as a case study. Teachers work on experiments focused on the contribution of milk to healthy living and the elements that influence our food choices. The lab activities investigate the complexity and richness of milk and compare it with other kinds of food. The investigation starts from raw milk and then analyses other commercial milk products. The aim is to stimulate consciousness and knowledge about how many products are made with milk even if this is something not many people perceive immediately

The lab experiments test the different types of milk that can be found in the supermarket: fresh milk, long-life milk, low fat. The information given in the label is tested through scientific experiments.

In the final part of the course, the evolution of biotechnologies is presented and experimented with, taking the example of cheese and yogurt as the most traditional 'biotechnological' products and arriving to contemporary ones such as lactose-free milk.

All activities that are used during the course can be reproduced in the class by the teacher.

The second fundamental aim of the course is to examine and experiment with teaching and learning methodologies for science education helping teachers to strengthen their competences and role.

For this, the course invests in the teachers as learners, as educa tors of the young and as reflective practitioners.

Teachers contribute their own points of view to the discussion, bringing their personal experience to the development of the experiments. At the same time, they are called to think about their students' point of view and learning needs. In this, the parents can also be regarded as important agents, as they often influence food choices. Their role in learning is discussed, too.

The learning and experimentation process within the course starts with a question posed by the museum experts which leads to initial hypothesis, identification of the parameters to experiment and a first evaluation of the already-acquired notions by the participants. The teachers work in groups expressing questions and hypotheses, aiming to find out the answers on the basis of the data collected through experiments. Group work allows for negotiation of choices, discussion of results, understanding of errors and (indirect) evaluation of the learning methodologies. The final results of the different groups are shared among all the participants. At the end, museum experts facilitate a general discussion about the methodology adopted as well as about the topic itself. They encourage teachers to focus also on how to adapt the activities to the work in class.

Sharing of experiences among the participants is an important part of the course. The teachers discuss among colleagues and with the museum experts sharing experience, solutions of possible problems and ideas for projects that integrate the topic of the course in the class activities

As part of the course the teachers receive an educational kit with materials and suggestions of experiments to conduct in class.

The course is part of the activities in preparation of the Expo 2015 which will be hosted in Milan.

The course is developed in collaboration with Lombardy Region, Agriculture Department.

Methods of learning/training:
Inquiry, experimentation, collaborative learning, scientific method, discussion.

End user:
In-service secondary school teachers.

Involved actors:
Teachers,the Region of Lombardy authorities, private company.

Location:
National Museum of Science and Technology Leonardo da Vinci.
Languages available:
Italian.

Where to find the application:
www.museoscienza.org/scuole/corsiFormazione.asp

Evaluation parameters:
Discussion with teachers. This best practice has been certified by the internal evaluation of the Museo Nazionale della Scienza e della Tecnologia "Leonardo da Vinci".

Duration:
2 days, 16 hours.

Optimum number of participants:
20.

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	x
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	

3.6 From the land to the table

Mapping best practices with main principles

1. Building interest in natural phenomena and scientific explanations:

In this training course, interest on natural science phenomena is achieved through the focus on lab experiments on food, in particular milk. The topic allows teachers to deepen their knowledge on the scientific aspects of food and to understand the relation between science, the individual and society. Teachers are called to work and reflect at different levels, as individual learners and as facilitators of the learning of their students. The tools used are practical activities, observing, questioning and investigating to stimulate their curiosity and the learning process.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

The discussion about commercial products derived from milk stimulates the teacher and the students to become aware of how food is not an abstract scientific concept but is part of our life and is influenced by the market. The course aims to show how food science and technology are part of the choices we make every day, for example at the supermarket, and how it is influenced by a range of different stakeholders.

3. Develop multiple goals:

- understanding big ideas in science including ideas of science, and ideas about science
- scientific capabilities concerned with gathering and using evidence
- scientific attitudes

Group work and negotiation, as well as the hands-on scientific experiments, help teachers – and later on students – to understand what is meant by scientific method and to develop skills for reasoning on the basis of evidence. This leads to an understanding of the issues addressed by science and scientists themselves, but also aims to encourage a scientific mode of thinking by people in their own lives. Food is a very common topic and also a scientific one. Teachers are asked to recognise the scientific and every day meaning of words referring to food, for example: additives, artificial, natural.

4. Understanding students' concepts and learning style about science phenomena:

All teachers have a personal and social background knowledge about food. This is the starting point of all the activities. The training focuses on the connection between the participants' background knowledge and the activities experienced in the course, all of which aim to develop a wider idea of science.

5. Relevance of the content to the daily lives of students:

The course has chosen the topic of milk and milk products exactly because they are very common, well known and widely used in everyday life. They also directly connect to everyday choices that people make, choices which affect their lives, in one or the other way.

6. Understanding science as a process not as stable facts. Using up to date information of science and education:

The experiments conducted do not always reach the results expected by the teachers. One of the most important learning tools in this course is the "error" if treated in an adequate way. The error is addressed and analysed by tutors and participants not only so that teachers can reflect on what did not work, but also in order to develop awareness of science as a continuing process.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

Curiosity and enjoyment are used not as aims in their own right, but are integrated in the learning process as tools to gain new knowledge.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

The scientific method in all its developmental phases lies at the basis of the training course, and is then brought into the teaching process in the classroom. It is used to analyse and understand the topic, it is used as a learning method for teachers as facilitators.

9. Assessment: formative (of students' learning) and summative (of their progress):

The museum is an informal environment of learning and has a role which is complementary to that of the school. Consequently, visitors' learning is not assessed like in schools. We do not use structured tools or processes for assessing the learning experience of our visitors (schools in this case) as this is not part of our education priorities. Informal, personalised, meaningful experiences for each person in a different way is the priority of our education programmes. At the same time, we run self-reflection sessions among education staff in order to analyse how our programmes are developed (education methodologies) and how interaction with the public takes place. The formative and summative assessment are left to the teachers.

10. Cooperation among teachers and with experts:

The teachers collaborate with their colleagues and the experts of the museum during the course and after the course. On-line collaboration is not widely used among Italian teachers. All training courses are followed by structured meetings between museum staff and teachers, in order to offer additional support as well as by distance help each time is needed by teachers. The collaboration between teachers and with the museum experts aims at solving common problems and adapting the proposed activities to their classes and their experience.

3.7 Nutrition and vitamins

Summary:
The activities aim at discovering science and technology behind the nutrition, vitamins in particular.

Aims:
- To investigate nutrition and vitamins.
- To help teachers develop their role as facilitators of students' learning.
- To support diffusion of IBSE in school.

Narrative:
The activities aim at supporting nutrition education in schools with the support of the families. The topic is: vitamins and nutrition. The activities are: teacher training, interactive activities for classes, developing of educational projects by teacher with the support of the museum, educational kits and activities for families during the weekend.

Methods of learning/training:
Inquiry, experimentation, collaborative learning, scientific method, discussion.

End user:
In-service teachersof primary and secondary school.

Involved actors:
Teachers.

Location:
Milan, Turin, Trieste, Perugia.

Languages available:
Italian.

Evaluation parameters:
Discussion with teachers. This best practice has been certified by the internal evaluation of the Museo Nazionale della Scienza e della Tecnologia "Leonardo da Vinci".

Duration:
3 days, 17 hours.

Optimum number of participants:
20

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to	x
10	Competencies addressing students' common sense knowledge and learning difficulties	
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

3.7 Nutrition and vitamins

Mapping best practices with main principles

1. Building interest in natural phenomena and scientific explanations:

The training course is built on a scientific topic and its applications. Through exploration, experimentation, observation, collection of data, development of hypotheses, and first hand involvement of the teachers, the course aims to raise interest in science and technology. Discussion in group aims at developing explanation of the phenomena observed.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

Participants are called to understand their own contribution as citizens, the importance of their own participation and critical opinion and how their own choices create an impact on how science and technology are perceived and integrated within society. Moreover, in the course scientific evidence is discussed in connection with ethical, social and legal issues.

3. Develop multiple goals:

- **understanding big ideas in science including ideas of science, and ideas about science**
- **scientific capabilities concerned with gathering and using evidence**
- **scientific attitudes**

Teachers investigate scientific phenomena with interactive activities. They are able to explore notions, phenomena, principles and transformations; they also use the different phases of the scientific method. This allows them to deepen into the science process which means build scientific knowledge about a range of topics, but also understand how science works and what scientific research means.

4. Understanding students' concepts and learning style about science phenomena:

The courses aim on the development of knowledge and skills in teachers but also concentrates on a metacognitive reflection, focusing on teachers as learners. On this basis, teachers are also invited to examine their own students' learning and involvement in science as well as problems they might face with them.

5. Relevance of the content to the daily lives of students:

The choice of the topic is based not only on its scientific importance but also on its relevance with daily life. Also, the educational methodology adopted by the Museum in the training course (as well as in its education programmes) puts at the centre the personal experience and knowledge of each individual. This means that everyday life experience of students is one of the main tools on which training builds. Moreover, the problem solving activities require teachers to use their background knowledge and consequently think of the students' own background.

6. Understanding science as a process not as stable facts. Using up to date information of science and education:

Understanding science as an on-going, not consolidated process emerges from the very activity of experimenting and testing carried out by teachers during the course. On this basis teachers are also encouraged to consider the process they chose to use in order to solve the problem and to collect data in order to confirm or not their hypotheses.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

The training course is based on a mix of activities which aim to develop subject-knowledge and skills in science and technology also through the use of interaction, confrontation, enjoThe course explores a specific topic not only in terms of its scientific and technological dimensions, but also in relation to society, to everyday life and to individuals. yment and the use of emotions. We know that the personal and emotional involvement of participants in the learning experience maximizes the probability for effective learning.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

The activities start with an open scientific question posed by the museum trainer. The teachers conduct experiments to explore different answers following observation, data collection and interpretation, development of prediction and discussion of scientific ideas. The scientific method is the basis of all the work done.

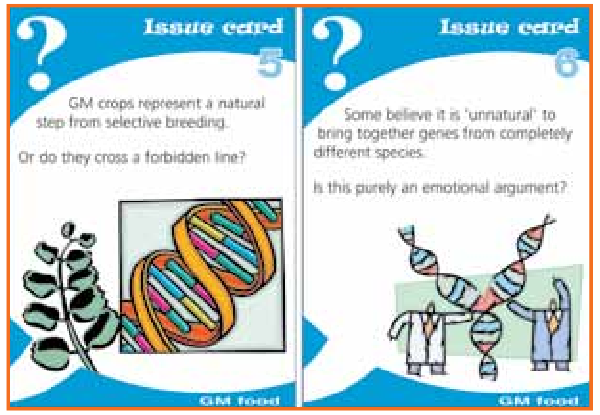
9. Assessment: formative (of students' learning) and summative (of their progress):

The museum is an informal environment of learning and has a role which is complementary to that of the school. Consequently, visitors' learning is not assessed like in schools. We do not use structured tools or processes for assessing the learning experience of our visitors (schools in this case) as this is not part of our education priorities Informal, personalised, meaningful experiences for each person in a different way is the priority of our education programmes. At the same time, we run self-reflection sessions among education staff in order to analyse how our programmes are developed (education methodologies) and how interaction with the public takes place. The formative and summative assessment are left to the teachers.

10. Cooperation among teachers and with experts:

The training course builds close collaboration between museum experts and teachers as well as collaboration among teachers themselves. This collaboration also continues after the end of the course through update of training or distance support. Moreover, professionals from companies or universities with expertise in different fields are involved in the training. The teachers appreciate very much the discussion with the different experts.

3.8 Genome generation



Summary:

The Wellcome Sanger Institute in collaboration with the Faculty of Education in Cambridge has developed a new IBSE discussion resource for 11-18 year students. The activity is based on an existing UK debating game DEliberate Meetings Of Citizens' (DEMOCS).

Aims:

Teachers are trained in using the discussion activity in a workshop that places them in the role of teacher as learner. By role-playing the activity as students, teachers learn how they can use the resource to help students to think critically about ethical issues surrounding advances in genetics and genomics research and explore the implications of this research for people's lives.

This resource aims to facilitate teachers and trainee teachers in running the activity with their students, and in using it to support students' understanding of the nature of scientific inquiry and the implications of such inquiry in society.

Narrative:

This resource is a card-based discussion activity. It comprises a suite of scenarios; each designed to stimulate open dialogue and help facilitate discussion of ethical dilemmas that may arise through whole genome sequencing and a person finding out about information in their DNA.

Students are first given a backstory surrounding a particular scenario. The story introduces different perspectives of a number of different characters and prompts initial discussion. Fact cards are introduced to help facilitate further discussion as questions start to arise. Issue cards are supplied in the final stages. By passing through a series of stages in the game, each of which requires decision-making based on science, the nature of science, and the impact of science on society, students come to understand that scientific progress cannot take place outside of its society. The activity helps them to understand more about the role of scientists in making their findings and the implications and benefits of their findings more accessible to the public at large.

Methods of learning/training:
Participants attend a workshop in which they play the Genome Generation game in role as students using one of the eight scenarios. They then reflect on how they might use the game in their own classrooms and review the other seven scenarios.

End user:
Pre-service and in-service teachers from 11-18 comprehensive schools. Education professionals from science museums and science centres.

Involved actors:
Teacher trainers, University researchers and Education Officers from the Sanger Wellcome Institute.

Location:
Cambridge Faculty of Education and the Wellcome Sanger Institute.

Languages available:
English.

Where to find the application:
Booking information:
www.pathwayuk.org.uk
Resource available from:
www.sanger.ac.uk

Evaluation parameters:
Teacher complete formal evaluation questionnaires. Implementation of the game is monitored in situ, with evidence drawn about its efficacy from their students.

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	
10	Competencies addressing students' common sense knowledge and learning difficulties	x
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	

1. Building interest in natural phenomena and scientific explanations:

By playing the games, students are forced to understand the scientific knowledge behind the game, and to engage with it by being presented in a real-life context which is relevant to their everyday lives.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

The aim of this game, as outlined above, is to understand the relationship between science and the way in which scientific discovery is assimilated by society at large.

3. Develop multiple goals:

- **understanding big ideas in science including ideas of science, and ideas about science**
- **scientific capabilities concerned with gathering and using evidence**
- **scientific attitudes**

Each game focuses on one big idea in science, and asks students to assimilate and take judgments on evidence (and aspects purporting to be evidence), to develop their understanding and attitude to particular scientific discoveries, to understand how others form their attitudes on scientific discoveries, both in particular and more generally.

4. Understanding students' concepts and learning style about science phenomena:

This game exposes children's misconceptions and beliefs about particular aspects of science and enables pupils to come to understand the nature of scientific evidence.

5. Relevance of the content to the daily lives of students:

The content is set within contemporary issues in science, which are frequently reported in the news.

6. Understanding science as a process not as stable facts. Using up to date information of science and education:

The games provide up to date information about Science, and they provide some sense of the history of scientific discovery in each context.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

These activities enable students to build knowledge collaboratively, and to test their understanding of Science, and the influence of their own ethical framework on the acceptance of scientific discovery.

9. Assessment: formative (of students' learning) and summative (of their progress):

By monitoring students' contributions, and by examining the outcomes of each group's game, it is possible to take judgments on students' understandings of science, and to intervene in such understandings where appropriate.

10. Cooperation among teachers and with experts:

By running this training with the education officers of the Sanger Centre Genome Campus, and with Faculty of Education lecturers, teachers are enabled to gain expertise both in the science addressed, and the educational benefits to be derived from participation in the games.

3.9 Science education as a tool for active citizenship

Summary:

Collaboration between formal and informal education institution to support science education as a tool for citizenship.

Aims:

Support both teachers and students in becoming socially-responsible citizens by improving skills and abilities to engage with socio-scientific issues.

Main activities:

Interactive activities, survey on motivation, recommendations for practitioners, pedagogy document, teacher resources.

Narrative:

SETAC (Science Education As a Tool for Active Citizenship) is funded by the European Union Lifelong Learning Programme and focuses on science education as one of the fundamental tools for developing active citizens in the knowledge society. It is aimed at teachers, students, museum explainers and explores the themes of Health, Energy, Climate Change.

The project is coordinated by the National Museum of Science and Technology Leonardo da Vinci in Milan, Italy within a consortium of by 8 partners consisting of institutions in the field of formal and informal education (schools, museums, teacher training centres, universities) from 5 European countries (Belgium, Denmark, Germany, Italy and Hungary).

The products of the project have been developed for teachers and education professionals and are free to download from the project website.

1. **New pedagogy for science education.**
   The pedagogy suggested by SETAC draws on different fields (psychology, museum education, scientific research, civic responsibility) and methods (observation, inquiry, experimentation, chidren'smisconsceptions, authentic questions, dialogue and debate) and considers museums and science centres as fundamental resources. www.museoscienza.org/setac/resources.asp
2. **Teaching resources.**
   The partners devised a series of activities for schools focusing on health, energy and climate change and using inquiry, debate and direct participation in experiments. The activities aim at developing contents, awareness of the role of science in contemporary society, and at stimulating the engagement of young people in dialogue about science. These have been tested with schools in each country and produced resources available for wider use. www.museoscienza.org/setac/activities.asp
3. **Better understanding of student's motivation in dealing with topics of science.**
   A survey of primary and secondary school students was carried out by the partners aiming to understand motivation and its role in engagement with science. www.museoscienza.org/setac/resources.asp
4. **"Quality Science Education: Where do we stand? Guidelines for practice from a European experience".**
   This is the concluding manifesto that presents the results of the SETAC work in the form of recommendations for practitioners working in formal and informal science learning institutions. www.museoscienza.org/setac/resources.asp

End user:
Teachers and museum staff.

Involved actors:
Teachers and museum staff.

Location:
School and museum.

Connection with the curriculum:
Multidisciplinary.

Languages available:
English.

Where to find the application or case:
www.museoscienza.org/setac/default.asp

Evaluation parameters:
Evaluation took place through two specific actions: research of students' motivation in science and research of students' misconceptions. The studies used observations, questionnaires and testing of the SETAC tools. This best practice has been certified by the internal evaluation of the Museo Nazionale della Scienza e della Tecnologia "Leonardo da Vinci".

Duration:
3 years.

Additional information or resources:
- www.museoscienza.org/setac/resources.asp
- www.museoscienza.org/setac/activities.asp
- www.museoscienza.org/setac/resources.asp
- www.museoscienza.org/setac/resources.asp

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

3.9 Science education as a tool for active citizenship

Mapping best practices with main principles

1. Building interest in natural phenomena and scientific explanations:

The education activities, the games and the materials for the teachers (quality guidelines, authentic questions, misconceptions) are all focused in makding a difference for the relationship between students, science and technology.

2. Building up informed citizens: Students understanding the nature of Science and Science in society:

The project – therefore all outputs – had as a prime objective to enhance active citizenship in relation to science and technology so all materials and outputs were focused to meet such objective. The main tools for that were: active engagement and discussion of science and technology, involvement in issues of current research (health, climate change, energy), experimentation and exploration of the scientific method, connection of science and technology with the social context and implications.

3. Develop multiple goals:

- understanding big ideas in science including ideas of science, and ideas about science
- scientific capabilities concerned with gathering and using evidence
- scientific attitudes

Activities, tools and resources deal with scientific method and science contents. They also invite students to engage actively with specific topics of science – health, energy, climate change, which they explore developing skills and competences, such as observation, problem-solving, development of hypothesis and testing, etc.

4. Understanding students' concepts and learning style about science phenomena:

A specific study on students' misconceptions and on their motivation in science (published on-line) has given the basis for understanding.

5. Relevance of the content to the daily lives of students:

All resources have been based on the relationship between science and everyday life.

6. Understanding science as a process not as stable facts. Using up to date information of science and education:

The best resource to look at for this is the study on children's misconceptions and also MyTest. Also the education activities that have been designed invite students to experiment actively and reflect on their mistakes.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

All activities combine knowledge building and enjoyment. Active involvement means using students' everyday experience and already acquired knowledge, therefore also involving their imagination, emotions, interests and personalities.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

All resources proposed by SETAC build on this.

9. Assessment: formative (of students' learning) and summative (of their progress):

The project is built on the informal learning approach (through the use of museums and science centres) therefore assessment of students' learning is not among the priorities. However, the project included two research studies which focused on students' misconceptions and on their motivations in science. The studies looked into these concepts and also evaluated how SETAC contributed to their improvement.

10. Cooperation among teachers and with experts:

The whole project was based on cooperation between formal and informal learning institutions.

3.10 Inquiry learning through objects

Summary:

Teachers work with museum educators who are specialised in object-based learning through inquiry to practice techniques which can be used both within the classroom and informal learning settings.

Aims:

This activity aims to support teachers in:

- developing teaching approaches which promoteIBSE
- developing opportunities for learning science outside of the classroom.

Main activities:

Out-of-school training for in-service and initial teacher trainees.

Narrative:

1. This training has been developed and applied by the Horniman Museum and Gardens in London, which delivers a successful object-based learning programme to 23,000 students each year. In collaboration with the University of Cambridge, the Horniman Museum has developed specific teacher training in how object-based learning can be used to promote inquiry learning both within the science classroom and within informal learning environments such as museums, zoos, botanical gardens, science centres and aquariums.

The training approach:

1. Uses a teacher-as-learner model to introduce teachers to object-based inquiry. Teachers conduct their own object-based investigations with a workshop leader modeling best practice in facilitating object-based inquiry.
2. Demonstrates how to build on natural curiosity to explain things in the world around us.
3. Role-models student-directed learning approaches where there may be multiple different outcomes and answers.
4. Encourages the discussion and evaluation of multiple hypotheses and lines of inquiry.

5. Challenges teachers to reflect on their own practice - self. The training session includes collaborative group tasks in which participants are given opportunities to develop and share ideas for how the approach could be used to promote inquiry-based learning in their own classroom practice.

End user:
Pre-service and in-service teachers of students aged 5-18.

Involved actors:
Museum education officers, informal learning officers.

Location:
Horniman Museum and Gardens, London. National Museum of Science and Technology Leonardo da Vinci, Milan

Languages available:
English, Italian.

Where to find the application or case:
www.horniman.ac.uk
http://www.museoscienza.org/english/

Duration:
Teacher training workshops last from 2 to 10 hours. The length depends on the experience of teacher taking part to the workshops, on the science topic to exploit and on the variety of the activities presented. They usually take place after school.

Additional information or resources:
Training will be advertised on the museum website at www.horniman.ac.uk and through the London STEMnet networking channels.

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	
3	Competencies in framing a discipline in a multidisciplinary scenario	
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	
10	Competencies addressing students' common sense knowledge and learning difficulties	
11	Competencies in the use of ICTs	
12	Competencies in the knowledge, planning and use of curricular materials	x

3.10 Inquiry learning through objects

Mapping best practices with main principles

1. Building interest in natural phenomena and scientific explanations:

By selecting objects deliberately designed to generate curiosity, awe and wonder about the world, participants experience first-hand how engagement with scientific inquiry is sparked by personal interest and a desire to find out more. By using objects that may be unfamiliar to the participants, they will be placed in the position of the learner and will experience a student-directed, discovery learning approach.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

Participants reflect on the role of museum and museum science collections as centres for science research and knowledge. The objects themselves are also used to demonstrate how individual objects can be a powerful tool to spark dialogue and debate about contemporary science and society issues e.g. species decline and sustainable living.

3. Develop multiple goals:

- **understanding big ideas in science including ideas of science, and ideas about science**
- **scientific capabilities concerned with gathering and using evidence**
- **scientific attitudes**

Each training session looks at how museum educators can use objects to support the students in developing skills for analysing and evaluating evidence. The objects themselves form an evidence base from which students can be encouraged to make inferences, propose hypotheses and weigh up different ideas or possible explanations. The training will model dialogue approaches for questioning and critiquing claims and proposed explanations.

4. Understanding students' concepts and learning style about science phenomena:

Object-based inquiry can be particularly useful to help students to build bigger ideas from smaller ones and to make connections across subject domains and areas. The training emphasises the importance of getting students actively engaged in investigating their own questions. The idea here is to demonstrate that students are more motivated if they can become absorbed in a study stemming from their own interest and that their understanding will be deeper when they arrive at answers themselves.

5. Relevance of the content to the daily lives of students:

A key focus is on using objects to spark dialogue and debate in current scientific issues.

6. Understanding science as a process not as stable facts. Using up to date information of science and education:

By using real objects as evidence for the inquiry process, emphasis is on the use and analysis of empirical evidence as a means of developing knowledge and understanding. Museums and other informal learning environments have unique access to objects that can be used to demonstrate changes in scientific thinking based on emerging evidence and new data.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

Participants reflect on the difference between engagement, entertainment and learning in relation to existing activities in their institutions. The focus is on using object based learning as means to acquire and develop knowledge in a self-directed learning process. Participants will explore how this model can be used to develop existing activities and resource which better facilitate learning through an inquiry approach.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

In a teacher-as-learner model, the participants take part in object-based inquiries which build on own prior knowledge and deepen understanding as they develop hypothesis and evaluate these based on the evidence in front of them.

9. Assessment: formative (of students' learning) and summative (of their progress):

The process of object-based inquiry learning can be summarised as a process of formative assessment. The approach places the museum educator in a role of facilitator and sessions are student-directed thus freeing the museum educator to observe students as they work and interact with others. Through these observations the teacher is able to determine which students are developing understanding of central concepts or ideas and which students might need further guidance or support.

10. Cooperation among teachers and with experts:

Museum educators wwork with fellow professionals with varying degrees of experience to share and develop their own understanding. The training will aim to equip the participating museum educators with skills to develop CPD best practice for teachers in their own institutions.

4.

School - research centre

Collaborative educational activities

4.1 UniSchooLabS:
Remote access for schools to university science labs

Summary:
The UniSchooLabS best practice links the traditional science lessons with the use of remote and virtual university science laboratories. Students are given the opportunity to work with real scientific infrastructures and eScience applications and engage in interesting and fascinating activities that allow them to witness how real scientific work is done. Within the framework of this best practice a catalogue of available labs and accompanying activities have been developed that allow students to interact and experiment with scientific instruments and learn about science through minds-on and hands-on activities.

Aims:
- To introduce to students the concept of scientific inquiry. Students conduct science experiments following the inquiry-based teaching approach. They are asked to document every step of their inquiries and produce scientifically accurate results.
- To facilitate the implementation of a set of good practices that allow the effective use of remote and virtual labs. Teachers and students are provided with a set of good practices that are connected to the school curriculum and guide them to use the labs as efficiently as possibly. Thus, the interaction and the experimentation with the labs are done according to sets of already tested guidelines that ensure the effective use of the labs.
- To provide opportunities for interaction between schools and universities. Through the use of the remote and virtual university science laboratories of the UniSchooLabS practice, students and teachers are given the opportunity to interact with the creators of the labs and respective scientists collaborate with them, and learn first hand how scientists work.

Main activities:
Teachers are provided with all the necessary tools that allow them to perform activities with their class that are connected to the school curriculum using remote and virtual labs. The UniSchooLabS toolkit offers to the teaching community a catalogue of available labs and respective guidelines that teachers may deploy in order to carry out their activities. Teachers act only as facilitators; they prepare the conduction of the experimentations by using existing activities or they may design their own, tailored to the exact need of their class. Students are the main actors of all the activities as they are given the tools to perform the activities on their own and document the whole procedure through the UniSchooLabS notebook that is available in every activity. Teachers may also collaborate with the lab owners in order to produce new and effective activities, while they are also given the opportunity to interact with other teachers within the UniSchooLabS teachers' community.

4.1 UniSchooLabS:
Remote access for schools to university science labs



Narrative:

The UniSchooLabS practice aims to transform the current science teaching practices by introducing hands-on and minds-on activities that are realised through the use of remote and virtual university science labs. The use of remote and virtual labs gives the opportunity to every teacher to perform scientific experiments with their students. Thus, even students in schools where science labs are not available have the opportunity to conduct experiments and learn by doing through their computers.

Teachers may implement their activities by using labs from a list of available labs that cover numerous subjects of physics and chemistry and teachers may choose from these labs in order to realize their activities. Each lab is accompanied by good practices that help teachers integrate the use of the labs in their everyday lessons. The good practices are activities that have already been used in different contexts and they have already proven their efficacy. They all follow the inquiry-based teaching approach where students have the leading role and teachers merely facilitate the procedure. The tool that has been developed allows the teachers to provide their students with all the necessary supporting materials and basic guidelines while students may write down their ideas and record the experimental procedure and outcomes in a digital notebook that each activity is provided with.

Moreover, teachers are given the tools to create their own activities involving any of the available labs. Certain guides are offered so as to help teachers design effective inquiry-based activities. The involved inquiry-based activities include a preparatory phase that allows students to identify the problem at hand, make their predictions and design their investigation plans and experiments. The second part of the exercise is the experimental procedure where students are asked to use one of the labs and conduct an experiment that is related to the problem at hand. Using the UniSchooLabS notebook, students may work on their own or in groups, document the procedure and upload their results in the UniSchooLabS toolkit. Thus, the entire class' work is at the disposal of the teachers as it is properly organized and stored along with the activity in an easily accessible and easy to use environment. All activities are finished with a last part where students are asked to assess their results, come up with conclusions and scientifically correct explanations and compare their explanations with their initial predictions.

The educational methodology that is followed within the UniSchooLabS best practice is in accordance with the recommendations of the High Level Group on Science Education (Rocard Report, "Science education now: a Renewed pedagogy for the future of Europe, 2007)

Overall, students work in groups to perform scientific experiments, make observations and collect data within realistic contexts and explore different areas of physics and chemistry. Thus, they acquire new knowledge through hands-on and minds-on activities that are stimulating and engaging.

Finally, teachers are also given the opportunity to interact with other teachers from numerous European countries through the UniSchooLabS on-line community, share their experiences and learn from the experience from others. Moreover, they also have the opportunity to collaborate with the lab owners and developers in order to produce more effective activities.

Example:

Conservation of momentum in particle collisions

In this exercise students learn about the conservation of momentum and how to use vectors through fundamental particle collisions. This exercise deploys a virtual lab that is called HYPATIA which makes use of real scientific data from the ATLAS experiment in CERN. The tracks from thes particles' collisions are displayed in the analysis tool allowing students to study the fundamental particles and their interactions.

End user:
Students of primary and secondary education.

Involved actors:
Primary and secondary education students and teachers, university researchers and teachers.

Location:
In the school class and on the web.
Connection with the curriculum:
Physics, Chemistry.

Languages available:
English, Greek, German, Italian.

Where to find the application or case:
unischoolabs.eun.org/web/unischoolabs

Evaluation parameters:
This educational approach is based on the inquiry-based learning model, which aligns with the recommendations of the High Level Group on Science Education (Rocard, 2007) for the provision of increased opportunities for enhancing motivation and participation.

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	x
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

4.1 UniSchooLabS:

Remote access for schools to university science labs

Mapping best practices with main principles

1. Building interest in natural phenomena and scientific explanations:

The UniSchooLabS approach focuses on building interest in natural phenomena and explanations by allowing students to learn about them through experimentations with virtual and remote labs. The enhancing of students interest in science through hands-on activities is the very heart of this best practice.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

Students are involved in activities that give them the opportunity to learn about science and natural phenomena through hands-on activities. The experimentations are also connected to everyday life, allowing them to witness the connection between their lives and what they learn in school during science lessons. Moreover, by engaging in scientific inquiry activities students develop critical skills and a creative way of thinking which are essential characteristics of any responsible citizen.

3. Develop multiple goals:

- **understanding big ideas in science including ideas of science, and ideas about science**
- **scientific capabilities concerned with gathering and using evidence**
- **scientific attitudes**

The UnischoolLabs approach focuses on helping students understand the interconnection between different natural phenomena and the principles behind them by actively studying these phenomena and principles through virtual experimentations. Thus it builds on facilitating students in understanding the big ideas in science. At the core of each activity is the use of remote and virtual labs. Students also learn about scientific inquiry which basically consists of observing, gathering data and process them in order to produce results. Hence, by promoting virtual experiments and connecting them with everyday science lessons, the UniSchooLabS best practice basically helps students understand how scientists work and adopt scientific attitudes.

4. Understanding students' concepts and learning style about science phenomena:

The UniSchooLabS activities are solely student-centered. With the use of the each activities' notebook students have the freedom to act at will and document their experiments and present their findings based on their own point of view. Following the inquiry-based approach, the activities promote active collaboration and allow students to work in their own fashion and approach each problem based on their experiences and current knowledge.

5. Relevance of the content to the daily lives of students:

The toolkit's activities cover contemporary subjects of modern physics like astronomy and particle physics of which students often hear about new achievements in these fields in their everyday life. Moreover, the toolkit also involves activities that concern everyday habits and phenomena like motion, issues that concern public health like the electromagnetic radiation or radioactivity. Moreover, certain activities especially in the field of electronics help students learn about instruments that are very common in everyday life and they are also used in numerous professions.

6. Understanding science as a process not as stable facts. Using up-to-date information of science and education:

Following the inquiry-based teaching approach students do not participate in the learning process just as spectators who accumulate facts and knowledge but they are the main actors of every activity. They perform experiments on their own and the acquire knowledge about science by doing science. Thus, through inquiry, they have the opportunity to understand the very nature of science and understand that it is not a stable concept but an evolving set of big ideas that are interconnected and play a key role to our lives and the world

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

The activities of the UniSchooLabS best practice are carefully designed so as to achieve maximum efficiency as they are based on good practices that are tested repeatedly in different contexts and they have proven their efficiency. Moreover, the IBSE methodology that is followed ensures that the impact on students' cognition is maximised. Students perform activities that are designed to help them perform skillfully and independently, develop their critical skills and think creatively. As they are the leading actors of the learning process they learn to be responsible, respond and participate and to act independently and precisely.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

The core of the UniSchooLabS best practice is to introduce to students the concept of scientific experimentation. Students are asked to participate in learning activities that simulate in detail the experimental procedures followed by real scientists. Students are expected to identify a problem, make specific predictions on the matter, design an investigation plan and make experimentations so as to come up with answers on the subject at hand. They are asked to process and analyse the information and the data they have acquired through their experimentations and finally manage to communicate the explanation they have come to and compare them to their initial predictions.

9. Assessment: formative (of students' learning) and summative (of their progress):

By being engaged in hands-on and minds-on activities, students not only learn efficiently about the subject at hand but they are also getting acquainted with the concept of research. They learn to collect data from different sources and combine them in order to come to conclusions. Thus, the activities realised have a cognitive impact on students and they also help them learn how to learn. Each step of the learning process is documented by the students and thus teachers are able to monitor the process and have a clear idea of students' performance throughout the activity so as to assess the progress of each activity.

10. Cooperation among teachers and with experts:

Teachers work in collaboration with the lab owners and the experts from universities who have developed the respective software of the labs. Thus, they are given the opportunity to design effective lessons plans and activities and exploit the full potential of the labs.

4.2 HYPATIA

Hybrid pupil's analysis tool for interactions in ATLAS

Summary:

HYPATIA is an event analysis tool for data collected by the ATLAS experiment of the LHC at CERN.

Aims:

Its goal is to allow high school students to visualise the complexity of the hadron-hadron interactions through the graphical representation of ATLAS event data and to interact with them in order to study different aspects of the fundamental building blocks of nature.

Main activities:

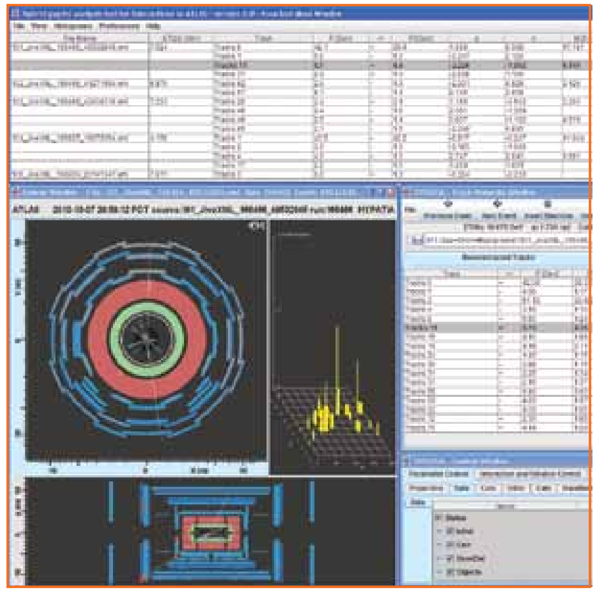
HYPATIA allows the use of events that have been collected by the ATLAS experiment or simulated using the Monte Carlo method.

The user can:

- Select the desired events from dedicated sets of selected event streams
- Browse the events with any order
- Study the particle tracks either through their graphical representation or through the tables
- Select from a variety of detector graphical representations
- Customise the display of information to his / her particular needs
- Combine multiple tracks to infer the existence of short-lived "invisible" particles which decay very fast into a number of secondary particles.
- Collect interesting tracks and plot histograms of their properties.
- Aggregate particles and study the distribution of their mass, momentum, angles, missing energy etc.
- Use the techniques used by physicists in actual research.
- Use HYPATIA to build teaching scenario (lesson plans) which fit to the IBSE.

Narrative:

HYPATIA is based on the ATLANTIS event display. HYPATIA can be used on most modern operating systems such as Windows, Linux, Unix, Solaris, MacOS etc. By using the ATLANTIS graphical representation (canvas) we ensure very accurate and detailed display of the event tracks. Also we ensure that the computing power required will be minimal and so HYPATIA will run on almost any computer regardless of memory or processor speed.The canvas allows even inexperienced users to interact with the events using simple point-and-click functionality. The multiple views of the ATLAS



End user:
HYPATIA can be used by high school children with basic knowledge of the constituents of matter and electromagnetism. In Greece this means 15 -18-year-old students. It can also be used by university students studying physics and also by researchers for event analysis.

Involved actors:
HYPATIA can be used by high school teachers in their classes. Material is available that describes the use of the event display and the scenarios that can be implemented in the classroom, depending on the available time and the level of the students. It is advisable for the teacher to have participated in a training program involving the use of HYPATIA, but this is not necessary.

Connection with the curriculum:
Teaching conservation of momentum, magnetic fields etc.

Languages available:
The material is available in Greek and English.

Where to find the application or case:
The homepage of HYPATIA is: hypatia.phys.uoa.gr
Aditional material and scenarios involving HYPATIA can be downloaded from the LA@CERN portal : www.learningwithatlas-portal.eu

Evaluation parameters:
Questionnaires were distributed to the students who took part to the workshops.The results were described in the Guide for Best Practice of the Learning from ATLAS@CERN program (www.ea.gr/ea/myfiles/File/publications/CERN_GGP.pdf)

Duration:
HYPATIA is a tool that can be used in scenarios with varying length. For example the scenario for teaching conservation of momentum to high-school students takes one hour, and the International Masterclasses take a full day.

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	
8	Competencies related to the area of teaching/learning processes within the domain	
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

4.2 HYPATIA

Hybrid pupil's analysis tool for interactions in ATLAS

Mapping best practices with main principles

PATHWAY

1. Building interest in natural phenomena and scientific explanations:

HYPATIA allows high school and university students to visualise the complexity of the hadron-hadron interactions through the graphical representation of ATLAS event data and interact with them in order to study different aspects of the fundamental building blocks of nature.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

Using Hypatia is a powerful illustration of how an eScience experience can provide rich and meaningful opportunities for people to participate in and learn about science. With the appropriate guidance from the research teams, students can use tools of science as they learned the practices, goals, and habits of mind of the culture of science.

3. Develop multiple goals:

- **understanding big ideas in science including ideas of science, and ideas about science**
- **scientific capabilities concerned with gathering and using evidence**
- **scientific attitudes**

By engaging in scientific activities, students also develop greater facility with the language of scientists; terms like hypothesis, experiment, and control begin to appear naturally in their discussion of what they are learning. They think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science. When a transformation such as this one takes place, young people may begin to think seriously about a career in a research laboratory.

5. Relevance of the content to the daily lives of students:

The HYPATIA learning environment allows students to work through material at their own pace, with different levels of support according to their own preferences. Inevitably, different students will embrace technology to greater or lesser extents and in different ways through the complementary interfaces the system offers.

5. Relevance of the content to daily life of students:

Today much of the ethical and political decision-making involves some understanding of the nature of science, its strengths and limits. To understand the role of science in deliberations about the projected outcomes of the experiments taking place in the LHC, their safety and value -given the immense investment involved- all students, including future scientists need to be critical consumers of scientific knowledge. The proposed practice improves students and teachers ability to engage in such debates, since they not only impart a knowledge of the content, but also a knowledge of how science works, an element which should be an essential component of any school science curriculum.

6. Understanding science as a process not as stable facts. Using up-to-date information of science and education:

The proposed practice introduces students to concepts and ideas of science of a multidisciplinary nature spanning all science disciplines and engineering. As such it safeguards sustained intellectual engagement by the majority of students, while promoting the interest of the few who will choose to pursue careers in science. The students are asked to employ real-problem solving skills, to handle and study situations, and to engage in meaningful and motivating science inquiry activities.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

Through the use of HYPATIA students gain knowledge about the building blocks of matter and the interactions between particles.They also learnhowthescientificresearchprocessworks.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

Students can conduct real event analysis in the same way that researchers are doing.

9. Assessment: formative (of students' learning) and summative (of their progress):

The use of HYPATIA has been evaluated in the framework of the Learning with ATLAS project (*www.learningwithatlas.eu*). The evaluation design and the analysis of the results were made by the research team of the University of Bayreuth and it is presented in the Guide of Good Parctice of the project. The results demonstrate the efficiency of the HYPATIA tool to promote the introduction of IBSE in the school environment.

10. Cooperation among teachers and with experts:

The proposed practice asks for cooperation between teachers and scientists and empowers teachers not only to change their teaching practice and introduce contemporary scientific issues in their lessons, but also to propose and initiate the necessary changes in their schools, to allow for a more seamless introduction of ICT innovations.

4.3 Learning with ATLAS@CERN

Summary:

The portal for Learning with ATLAS@CERN is an e-science application designed for use by students, teachers and even science museum visitors. The aim is to improve science instruction by expanding the resources for teaching and learning in schools, universities and science centers and museums, providing more challenging and authentic learning experiences and lessons.

Aims:

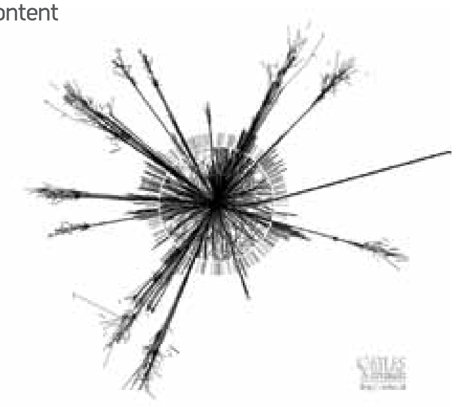
The LA@CERN portal aggregates scenarios and objects that are uploaded by school teachers, university professors, researchers, or any other member of the public. Its aim is to act as a repository where a school teacher can find complete scenarios of simple educational objects that fit the needs of his / her classroom.

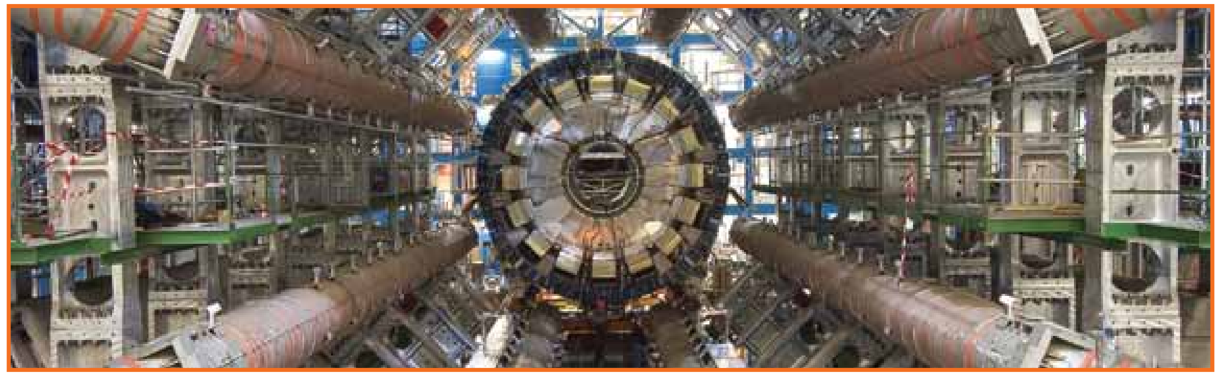
Narrative:

The portal for Learning with ATLAS@CERN is an experimental laboratory for students, teachers and science museum visitors. The Learning with ATLAS@CERN Repository includes educational materials (lesson plans, student projects, videos, animations and high quality images of unique high energy physics phenomena). In the ATLAS@CERN Repository one can search for Educational Content and Learning Missions. By using the provided user interfaces you can find the material you are looking for. You can also browse through the top rated material in each category.

The Learning with ATLAS@CERN Tool-Box will provide you with all the necessary tools to prepare your content for the ATLAS@CERN Repository. It contains links to three interactive event analysis tools (AMELIA, HYPATIA and MINERVA) that allow users to explore the events collected by the ATLAS experiment at CERN in an intuitive way, which is much friendlier than the public through 3D and 2D animations of physical processes in a game like approach. The web pages of the three analysis tools include detailed information on the use of the tools and support materials for teachers and students.

Learning with ATLAS@CERN is trying to build a community of users interested not only in downloading educational material, but also in developing novel material through use or re-use of existing works. To facilitate this need the ATLAS@CERN Portal offers a user-friendly web-based interface for uploading material. In order to upload new Educational Content or Learning Missions it must be first tagged with metadata according to the IEEE LOM standard. This is done by employing the ATLAS-LOM Metadata Authoring Tool. Full access to all the tools uploads and downloading material is given only to registered users.





End user:
End users of the portal are usually school students of the upper two levels who learn from the new material presented by the teachers in their class. However, it can also provide material for visitors of science centers or students of universities.

Involved actors:
Teachers of the last two grades, university professors, educators in general.

Location:
School, university, museums.

Connection with the curriculum:
The connection with the school curriculum varies depending on the specific material downloaded from the portal by the involved actor.

Languages available:
Material is available in English, Greek, Finnish, French, German and Swedish.

Where to find the application or case:
www.learningwithatlas-portal.eu

Evaluation parameters:
With questionnaires/interviews distributed by the WP of the LLP EU project and continuous use of Google analytics.

Duration:
The duration depends on the material selected.

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

4.3 Learning with ATLAS@CERN

Mapping best practices with main principles

PATHWAY

1. Building interest in natural phenomena and scientific explanations:

The Learning with ATLAS@CERN brings the use of "cutting-edge" eScience applications to school students. These applications promote science teaching and learning as a process of inquiry as well as technological thinking as a process of problem-solving. They act as the window onto live scientific experiments and phenomena, ongoing scientific research, and the personalities and stories of working scientists across Europe.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

Using The Learning with ATLAS@CERN resources is a powerful illustration of how an eScience experience can provide rich and meaningful opportunities for people to participate in and learn about science. With the appropriate guidance from the research teams, students can use tools of science as they learned the practices, goals, and habits of mind of the culture of science.

3. Develop multiple goals:

- **understanding big ideas in science including ideas of science, and ideas about science**
- **scientific capabilities concerned with gathering and using evidence**
- **scientific attitudes**

By engaging in scientific activities, students also develop greater facility with the language of scientists; terms like hypothesis, experiment, and control begin to appear naturally in their discussion of what they are learning. In these ways, students begin to gain entry into the culture of the scientific community and start to change the way they think about themselves and their relationship to science. When a transformation such as this one takes place, young people may begin to think seriously about a career in a research laboratory.

4. Understanding students' concepts and learning style about science phenomena:

The Learning with ATLAS@CERN learning environment allows students to work through material at their own pace, with different levels of support according to their own preferences. Inevitably, different students will embrace technology to greater or lesser extents and in different ways through the complementary interfaces the system offers.

5. Relevance of the content to the daily lives of students:

Today much of the ethical and political decision-making involves some understanding of the nature of science, its strengths and limits. To understand the role of science in deliberations about the projected outcomes of the experiments taking place in the LHC, their safety and value -given the immense investment involved- all students, need to be critical consumers of scientific knowledge. The proposed practice improves students and teachers ability to engage in such debates, since they not only impart a knowledge of the content, but also a knowledge of "how science works", "an element which should be an essential component of any school science curriculum".

6. Understanding science as a process not as stable facts. Using up-to-date information of science and education:

The proposed practice introduces students to concepts and ideas of science of a multidisciplinary nature spanning all science disciplines and engineering. As such it safeguards sustained intellectual engagement by the majority of students, by asking them to employ real-problem solving skills, to handle and study situations, and to engage in meaningful and motivating science inquiry activities.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

The students will be asked to employ real-problem solving skills. Adopting this approach, the dynamic character of scientific thought will be efficiently assimilated, stimulating and encouraging the creative minds of the participating teenagers. By engaging in scientific activities, students also develop greater facility with the language of scientists (e.g. hypothesis, experiment, and control). In these ways, students begin to gain entry into the culture of the scientific community and start to change the way they think about themselves and their relationship to science.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

The activities that are supported by the portal are expected to trigger students' scientific adventure and incorporate the 'wow' factor (i.e. wonder) in the learning of science. The use of the portal explicitly develops such science-related occupational aspirations, by demystifying the work of the researcher, making it familiar and tangible for younger students. On the other hand, the use of such eScience applications in school will also help to authenticate curriculum work, as students can see first-hand the relevance and application of the science learnt in the classroom, in the real world.

9. Assessment: formative (of students' learning) and summative (of their progress)

The evaluation design and the analysis of the results from the use of the portal were made by the research team of the University of Bayreuth and it is presented in the Guide of Good Parctice of the project. The results demonstrate the efficiency of the scenarios that are available through the portal to promote the introduction of IBSE in the school environment. Furthermore, the data demonstrate a significant change on teachers behavior toward a "teacher as a designer of the educational activities" that is one of the most crucial characteristics of an IB approach in science education.

10. Cooperation among teachers and with experts:

The use of the Learning with ATLAS@CERN portal expands opportunities for teachers' professional development, including occasions to interact with working scientists, e-masterclasses, science contests, workshops and training seminars. The teachers who will participate in the project will become curriculum developers themselves, validating thus the proposed approach and methods. According to the National Science Education Standards "the challenge of professional development for teachers of science is to create optimal collaborative learning situations in which the best sources of expertise are linked with the experiences and current needs of the teachers".

4.4 International masterclasses

Summary:

The "International Particle Physics Masterclasses" provide an opportunity for high-school students to be "scientists for a day". We, as scientists, aim to generate an interest in nuclear and particle physics among high-school students and their teachers.

Aims:

The goal is to familiarise the students with the work being done at CERN and the LHC in particular. The researchers explain the basics of particle physics and why it is important. They also demonstrate the fundamentals of particle detector operation and explain the way particles interact with them and leave a characteristic signature according to their different types.

Main activities:

Lectures by experts about particle physics, CERN, the LHC and detectors, followed by discussion and Q&A sessions, introduction to software tools, video conferencing with other schools and quizzes.

Narrative:

The selected high school students of the last two years go to their nearby University or Research center. The morning lectures start with an introduction to the Standard Model of particle physics and an explanation of why it is important to modern physics, in general. The following lectures explain the work being done today at CERN and the LHC. The audience is told about the experiments that are conducted there and the results that the research hopes to get from them, and In particular the ATLAS experiment. Then there is a Q&A session with the students where they can ask questions, get clarifications on the issues discussed and explain their own views on physics in general. After lunch, there is an introduction to the HYPATIA event display that will be used in the laboratory exercises. The students and teachers are told how to identify the different particle tracks in the detectors. They are told why we can't see certain particles (like the Z boson) and how we can infer their existence from their decay to other tracks. In the first exercises, the students learn to distinguish between electrons and muons. In the second exercise the students make use of the invariant mass technique to account for short-lived particles, like the Z boson, whose decay products (electron-positron or muon-antimuon) are measured. Z particle decays are mixed with background events from other physical processes and the students have to tell them apart. The exercises use real LHC collision events recorded by the ATLAS experiment. In each event, electrons or muons are identified through their characteristic behavior, and their energy and momentum are added to form the energy E and momentum p of the parent decaying particle, which can then be used (with the usual E-p equation) to find the decaying particle's invariant mass. The latter is then recorded. If the pair of particles really stems from Z particle decay, the resulting invariant mass distribution will feature a peak around the corresponding mass. The participants determine this distribution by making a histogram of the masses of Z particles they discover. After the laboratory exercise is finished, the students and their teachers gather in a classroom where there is a discussion about their results. They also have the opportunity to discuss their results with students from other countries and the moderator team at CERN through video conference. Through that connection they can compare their results and determine who came closer to the expected result. Finally, there is a quiz which includes questions about the subjects that have been discussed throughout the day, with the best team getting a prize from CERN. Currently, the masterclasses run in about 25 countries in a 3-week interval in March of each year, with 130 Universities and about 8,000 students participating.

End user - involved actors:
The physics masterclasses are suitable for 17 -19-year-old high-school students, and there are separate ones for teachers as well.

Location:
The masterclasses are held at universities and research centers in large cities.

Connection with the curriculum:
The masterclasses have an indirect link with the school curriculum in the areas of electromagnetism, atomic and subatomic structure and basic physics.

Languages available:
The material is available in various languages. Currently English, Greek, German, Portuguese, French, Czech, Finish, Hungarian, Israeli, Italian, Dutch, Norwegian, Polish, Serbian, Swedish, Slovakian, Spanish, and South African.

Where to find the application or case:
The main website is
physicsmasterclasses.org/neu/index.php

Evaluation parameters:
Questionnaires to the students are distributed every few years and evaluated by the organisers (Technical Un. of Dresden). A recent evaluation can be found in: Physics Education 42 (2007) 636-644.

Duration:
The Masterclasses take up an entire day. The lectures are held in the morning and the laboratory exercises in the afternoon.

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	
7	Competencies related to self-reflection and meta-cognition	
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	

4.4 International masterclasses

1. Building interest in natural phenomena and scientific explanations:

The masterclasses teach the students the basics about particle physics. They explain the interactions between the different particles and demonstrate the results in the laboratory exercises.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

After the morning lectures there is a Q&A session covering topics such as the importance of science and the ties of scientific research and everyday life.

3. Develop multiple goals:

- understanding big ideas in science including ideas of science, and ideas about science
- scientific capabilities concerned with gathering and using evidence
- scientific attitudes

The masterclasses revolve around the central theory of particle physics, the Standard Model. They explain its importance and, through the laboratory exercise, demonstrate the scientific research process in this field.

4. Understanding students' concepts and learning style about science phenomena:

The students are given the opportunity to ask questions and voice their opinion on both the Masterclass sessions and the subject matter being discussed. For example, they often make suggestions about how this material could be covered within the school physics lessons.

5. Understanding science as a process not as stable facts. Using up to date information of science and education:

The laboratory exercise gives the students the opportunity to engage in "real" scientific research using the same methodology and data that real researchers use in their work.

6. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

The masterclasses give the students both theoretical knowledge about particle physics in general and practical hands-on experience on how scientific research is done.

7. Doing science: experimenting, analysing, interpreting, redefining explanations:

The students analyse real data that are recorded at CERN.

8. Cooperation among teachers and with experts:

Teachers participate in parallel sessions with similar activities. They also discuss didactic matters with the university teachers, such as the integration of the material covered in the masterclasses into the school curriculum.
These sessions are not mandatory and they are held only by the institutions that choose to do.

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4.5 Building a cloud chamber

Summary:

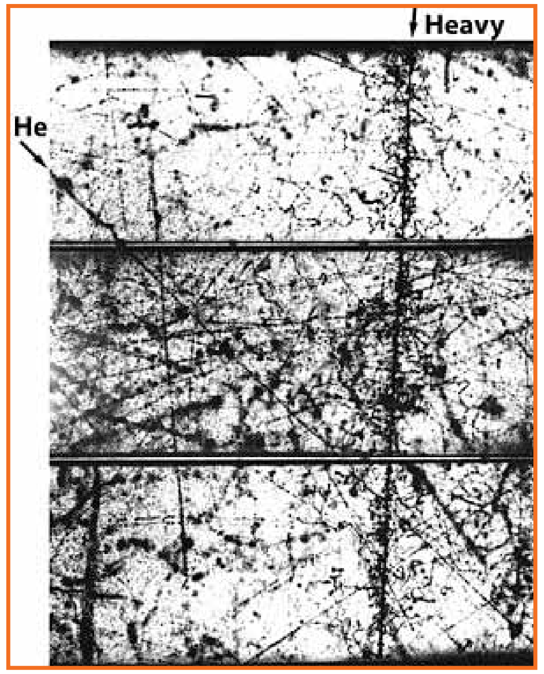
Building a Cloud Chamber is a hands-on evidence-based experimental activity embedded in CERN's High School Teacher Programmes. Structured around the IBSE methodology, the ultimate aim of this activity is to raise student interest in the world of particle physics and its applications to fields that influence students' everyday life and well-being. It is designed to enable students to gain inquiry knowledge and skills through observation, collection and interpretation of experimental data, and reflection on experimental outcomes.

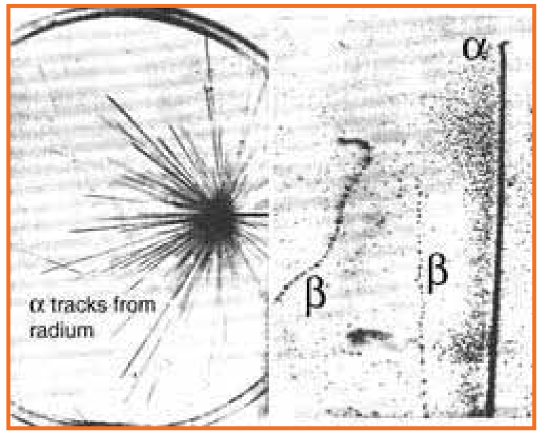
Aims:

Building a Cloud Chamber, at a general level, aims to serve as a springboard for exploring different ideas about particle physics based on a multidisciplinary approach. "What is matter made of?", "What does a particle mean?", "How can I visualise particles?", "What types of particle detectors have been developed and currently used by scientists at big-science laboratories like CERN?", "Are there particle detectors developed for purposes other than basic research?" are some of the questions which this evidence-based activity is aimed to address in a playful, interactive and hands-on fashion towards generating and sustaining student interest in modern physics and science.

Main activities:

The Building a Cloud Chamber activity may commence with a discussion initiated by the teacher on the natural phenomenon of cosmic rays and their detection, particle physics, CERN and the LHC, and a brief history of particle detectors' evolution from Wilson's original cloud chamber to the large detectors presently used at CERN's LHC. This is followed by a step-by-step construction of cloud chambers by the students themselves who are divided into small groups and whose work is guided and facilitated by the teacher or other involved actors. Observations of cosmic particle tracks are then conducted by each group. This is followed by students reflecting on the construction of their cloud chambers, on their observations of cosmic particle tracks, their considerations of alternative explanations. The activity may conclude with a discussion on various technological applications of particle physics detectors to everyday life.

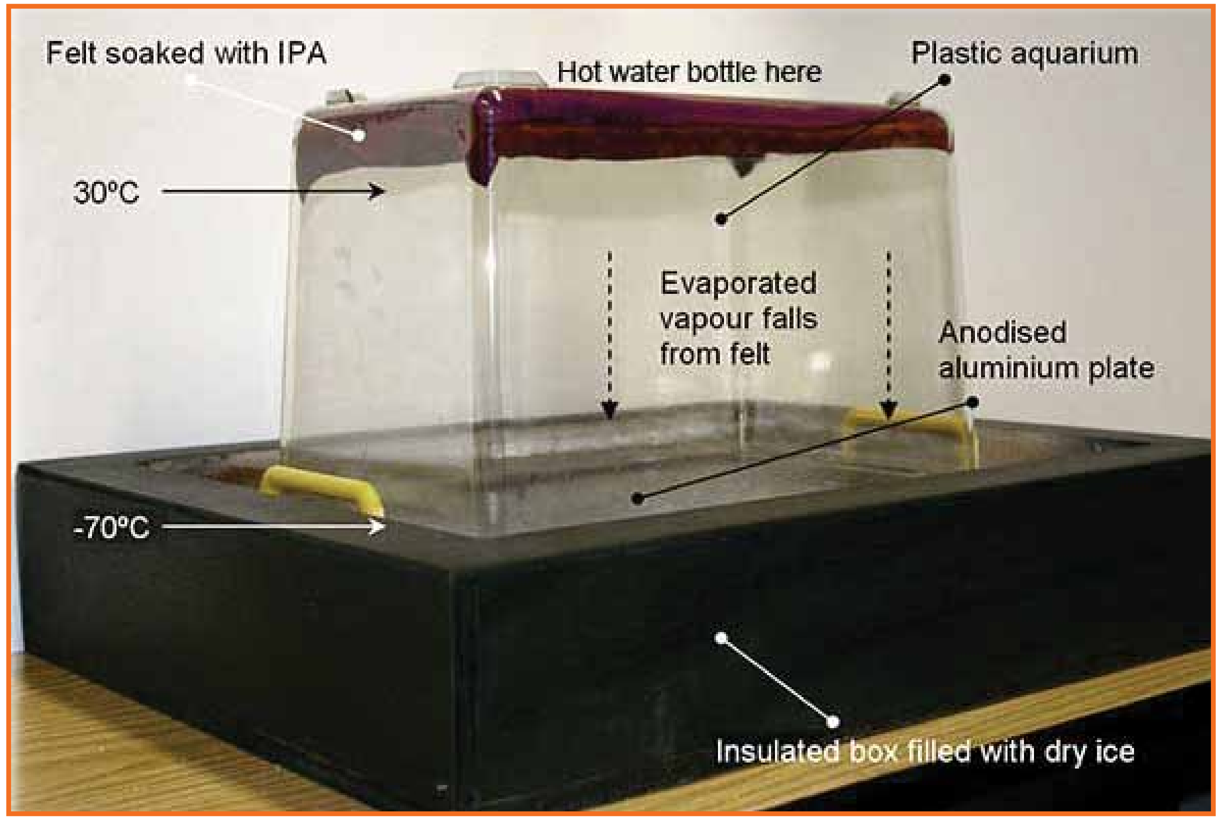




Narrative:

The scientific effort at CERN and other particle physics laboratories to study the fundamental forces and building blocks of nature by reconstructing the conditions under which the Universe was created can be far from straightforward for students to grasp and understand. The Building a Cloud Chamber activity affords students a rich learning experience in the history, theory and practice of particle physics research by simulating the pioneering work of Nobel Prize-winning scientists through the use of common scientific principles and techniques whereby they become able to visualise "invisible" charged particle tracks and understand how charged particles interact with matter. This hands-on experimental activity incorporates a strong student-centred, inquiry-based and collaborative focus and can serve a variety of learning objectives leading to an increased appreciation of and interest in how science works, what scientific research means and what its value to society is.

For the activity to achieve its intended educational potential, teachers or other involved actors such as tutors or trainers act as facilitators and thus need to be confident communicators, able to draw on a multidisciplinary approach to raise student interest in modern science and to instil a feeling of mystery and discovery potential. The Build a Cloud Chamber workshop, which forms an integral part of CERN's High School Teacher Programmes, places physics teachers from all over the world in the shoes of their students by offering them a first-hand experience with this experimental activity by which they can develop ideas and learning pathways in order to maintain and extend student interest in modern physics and science.



4.5 Building a cloud chamber

PATHWAY

The underlying logic of this workshop is based not on instructing teachers in adopting a single best approach to implementing the activity in their school laboratory but rather on demonstrating narratives of student engagement in science inquiry processes by immersing them in how big ideas in science are born, what it takes for scientists to test them and how interconnected scientific research, technological innovations and everyday life are.
The Build a Cloud Chamber workshop shows inquiry learning in action and offers teachers the flexibility to further customise the activity to respect the educational needs of their students, to match the science curriculum requirements and to adapt the experiment in new contexts. Using examples from the history of science, the evolution of the scientific enterprise and the relevance of big-science research to students' everyday life is a common thread inherent in this practice. Promoting curiosity and a feeling of discovery potential in students and at the same time enabling them to gain additional inquiry skills such as observation, data collection, interpretation and communication is also at the core of this practice. Health and safety considerations associated with the experimental work of scientists are also important learning aspects for students.

End user:
Secondary school students ages 13 to 17 years old.

Involved actors:
Secondary school students, teachers and other actors (e.g. tutors, trainers, university students etc.). It is advisable that for the teachers (or other involved actors) to have participated in a Building a Cloud Chamber workshop.

Location:
The activity is best conducted in the school laboratory.

Connection with the curriculum:
Teaching electromagnetism, radioactivity, particle physics, astronomy, science and technology, etc.

Where to find the application or case:
http://teachers.web.cern.ch/teachers/document/cloud-final.pdf

Evaluation parameters:
The activity has been evaluated by the participants of CERN's High School Teacher Programmes as part of the internal questionnaire survey given to teachers upon the completion of their training.

Duration:
The duration of the activity is a minimum of 2 didactic hours but it can be customised according to students' age and prior knowledge of physics. An average workshop for teachers usually lasts 1.5 hours.

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	
7	Competencies related to self-reflection and meta-cognition	
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	x
11	Competencies in the use of ICTs	
12	Competencies in the knowledge, planning and use of curricular materials	x

4.5 Building a cloud chamber

Mapping best practices with main principles

1. Building Interest in natural science phenomena and explanations

Build a Cloud Chamber allows students to visualise, observe and interpret the phenomenon of cosmic rays and how charged particles interact with matter.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

Cloud chambers were used several decades ago in the first experiments to detect particles. Since then they have evolved into huge electronic particle detectors like the ones used by the LHC experiments at CERN. With the appropriate guidance of the teacher, students can develop better understanding of the dynamic interplay between scientific inquiry, technological innovation and social change.

3. Develop multiple goals:

- **understanding big ideas in science including ideas of science, and ideas about science**
- **scientific capabilities concerned with gathering and using evidence**
- **scientific attitudes**

With references to Nobel prize winning stories from the history of physics and science, students construct meaning in big science and how it works in practice. Engaging in a hands-on experimental activity, such as Build a Cloud Chamber, students develop inquiry skills of observation and appreciate the importance of evidence-based science for explaining natural phenomena. Describing their investigations in scientific language by using the terms hypothesis, methodology, findings and results, students are enabled to adopt scientific attitudes such as curiosity and objectivity in the collection and interpretation of experimental data.

4. Understanding students' concepts and learning style about science phenomena:

Build a Cloud Chamber is a student-centred science learning activity in which students are encouraged not only to build upon existing ideas to explore more complex natural phenomena but also to communicate their experimental observations and its implications based on their own experiences and point of view.

5. Relevance of the content to the daily lives of students:

Looking through a century of scientific progress in the field of particle physics, this activity offers students a rich opportunity to connect the diffusion of scientific ideas and discoveries with technical and technological applications to various issues of everyday life, especially the ones concerning medical applications of particle physics for diagnosis and treatment of diseases. Further, this activity helps students learn about recent developments in scientific data acquisition, processing and transfer for high energy physics experiments (e.g. WWW, GRID), and the ways in which these developments affect decisively their capacity to access and use information in their daily lives.

6. Understanding science as a process not as stable facts. Using up-to-date information of science and education:

Throughout this inquiry-based experimental activity, students are the main actors who build their knowledge of and skills in science by learning-by-doing. Thus, following the five phases of inquiry-based learning, students develop understanding of science as a systematic and on-going process that follows common scientific principles and employs scientific methodology as means of reaching scientific evidence to explain natural phenomena.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

The Build a Cloud Chamber activity promotes student curiosity and discovery potential without compromising important aspects of the scientific research process, such as health and safety parameters, individual responsibility and group collaboration based on shared interests and goals. Students thus begin to internalise the general ethos of the scientific community and to change the way they think about their role in and relationship to science.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

The Build a Cloud Chamber activity immerses students into the world of scientific discovery and wonder. Further, by learning the processes, tools and their underlying scientific principles in visualising "invisible" particle tracks, students are able not only to demystify the work of the researcher but also to build confidence in their science problem-solving skills.

9. Cooperation among teachers and with experts:

The Build a Cloud Chamber activity is the outcome of collaboration between the community of physics teachers participating in CERN's High School Teacher Programmes, CERN's Education research staff and CERN scientists. Acting as a springboard for exploring different ideas about particle physics, teachers are also given the opportunity to adapt and refine the activity and to co-develop further lesson plans and activities according to the particular needs of their students.

4.6 Quantum spin-off: how inquiry can lead to entrepreneurship

Students of last stage of secondary school in the research centre for nano-electronics IMEC

Summary:

Quantum Spin-Off opens the world of modern physics to secondary school students. It shows the applications of Quantum Physics and gives them a taste of entrepreneurship for the high-tech sector. The high school students are brought into contact with a world-leading research institution in nano-electronics (IMEC *www.imec.be*) and with large and small high tech companies like IBM-Skillteam, Xenics, SkyScan and Lumoza. The pupils first develop some basic understanding of quantum physics and its applications by inquiry-based methods. Later on, they work on a specific valorisation idea in close collaboration with the researchers of the participating companies and institutions. In the second phase of the project, the pupils start to think of a product as an application of the modern science they learned. Eventually, they develop a business plan for their own spin-off company with the support of real businessmen.

Aims:

Quantum Spin-Off gives secondary school students the chance to understand the link between the insights of modern physics and the opportunities in high-tech enterprising. Quantum Spin-Off aims to (a) bring pupils into contact with research in quantum physics, nanoscience and nanotechnology (b) provide opportunities to do inquiry (c) show pupils how an innovative idea at a fundamental scientific level can lead to an application, a product and eventually to a business.

Under the guidance of researchers and businesspersons, the pupils learn in an inquiry-based manner to develop a technical application based on research results and to convert this into a business plan.

Main activities:

- Throught inquiry, pupils learn the basic concepts of Quantum Physics. The learning stations are delivered via the web to the participating schools.
- At the Quantum Spin-up day at IMEC, they meet the researchers. The pupils immerse themselves in quantum physics and its applications such as LED's, flash memory, infrared cameras and medical imaging. The participating high-tech companies show how basic research and patents can lead to fascinating applications.
- Research Day at the university: After a few weeks the pupils meet their researcher again. They attend a talk about nanophysics, they go into the nanolab and start talking more deeply about their nano-patent with their researcher.
- Research Day in Spin-Off Company: Every class visits a spin-off company with their researcher. The development of a product is at stake and the design of a technical plan is initiated. Businesspeople give insight on how to develop a good product.
- Spin-Off Day in IBM Forum in Brussels: Presentation of the valorisation results and awarding the Quantum Spin-Off prizes.

Students talking with their researcher in IMEC

4.6 Quantum spin-off: how inquiry can lead to entrepreneurship

Narrative:

Quantum Spin-Off gives secondary school students the chance to understand the link between the insights of modern physics and the opportunities in high-tech enterprising. By bringing school pupils in contact with real researchers and entrepreneurs in the high-tech sector, Quantum Spin-Off brings real Science and Entrepreneurship into the classroom. The students get a threefold task to perform on a very inquiry-based manner:

a. Investigate the concepts of modern quantum field theory. They are provided with inquiry-based learning material to perform this task.

b. Investigate a patent describing an application of quantum and nanoscience. They interact with a real scientist in order to understand what the patents means.

c. Think of a product based on a real patent and develop a technical plan for it. Develop a business plan for a spin-off company that is going to develop, produce and sell this product.

The project is planned in several steps:

1. Spin-up day at IMEC
   At the beginning of the school year the Spin-up day is organised at IMEC in Leuven, where the students immerse themselves in quantum physics and its applications such as LEDs, flash memory, infrared cameras and medical imaging. The participating high-tech companies show how basic research and patents can lead to fascinating applications. The students meet the researchers with whom they are going to collaborate for the rest of the project and start thinking about a possible application of a truly existing high-tech patent.
2. Spin-off valorisation process
   For several weeks the students work as in a high-tech company. They will contact the supervisors of the participating high-tech companies or research groups and create a technical and a business plan. There are at least three working days in the company and / or research institution where representatives of the class can discuss the detailed plans. Also contacts via email and phone are possible. The economy and science teachers coach their students during this process.

3. Spin-off day
   Eventually the groups of students present their technical and business plans to a jury. The jury of experts of the participating companies and research groups honours the best projects with a Quantum Spin-Off prize.

End user - involved actors:
Interested pupils of the third stage of secondary education (upper secondary level) and their teachers.

Location:
The project uses a combination of locations: school, university, research labs, companies and also the web.

Connection with the curriculum:
The project connects to official learning goals as:
- Learning by inquiry
- Learn modern physics

Learn to enterprise

Languages available:
Dutch

Where to find the application or case:
The project website is:
www.vakdidactiek.be/spinoff
Evaluation parameters:
Quantum Spin-Off is evaluated in a threefold way:
- By the participating students: by means of a questionnaire aiming at student's motivation and learning gains.
- By the teachers of the participating schools: by means of the questionnaires provided by the EUN, aiming at teacher's professional development on inquiry-based Teaching Methods. In addition to this formal evaluation, a half way intervision meeting is held with the teachers to discuss the course of the project.
- By the researchers: by means of the appreciation they give to the work presented by the pupils (both on the research days as their final rewarding on the final spin-off day). In addition to this two intervision meetings are held with the researchers during the course of the year.

Duration:
The duration of the case for the pupils is one school year.
September 2011: introduction
October 2011: Spin-up day
November 2011 – April 2012
Valorisation process with 3 research days
May 2012: Spin-off day
Quantum Spin-Off will be repeated in the school year 2012-2013

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	x
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

4.6 Quantum spin-off: how inquiry can lead to entrepreneurship

Mapping best practices with main principles

1. Building interest in natural phenomena and scientific explanations:

Quantum physics is an enormously fascinating and intriguing branch of physics, which is present in our everyday life with many applications but unfortunately not covered at all in Flemish schools. The understanding of the basic ideas of quantum physics, of its history and of its everyday life applications achieved by the pupils with this project has a great potential to boost their interest for science.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

The average citizen believes quantum physics is some crazy scientist's thing that has nothing to do with real life. The same average citizen has a dvd player, a laser pointer, tiny size electronics and might need a CT or MRI scan sometime. This project aims at increasing awareness of the connection between fundamental science and long term benefits for the society in the new generation of citizens.

3. Develop multiple goals:

- understanding big ideas in science including ideas of science, and ideas about science
- scientific capabilities concerned with gathering and using evidence
- scientific attitudes

Direct contact between pupils and real researchers in a real research environment (university, research labs and high-tech spin-offs), gives the pupils a feel of what real science is and who does science, helping eradicate misconceptions about science and scientists. The fact that pupils have to contribute with their own ideas to go from science to product stimulates them to think of science as deeply connected to the society.

4. Understanding students' concepts and learning style about science phenomena:

The pedagogical method of inquiry applied throughout the project gives opportunities for learners of different learning styles. In fact, the learners are more or less considered as real co-researchers, working together with a real researcher from the university, from a research lab or from a high-tech company. The work in research labs and in companies brings pupils out of their normal place and role. The pupils are made responsible for the valorisation project and for their own business plan.

5. Relevance of the content to the daily lives of students:

Modern pupils are technological pupils who often ask themselves no question about all the technology they use and more generally about what happens around them. With this project the pupils see what is behind many of the finished products and techniques they use everyday. This can open the door to a new way of experiencing reality where there is more space for curiosity and questions and where less is given for granted.

6. Understanding science as a process not as stable facts. Using up to date information of science and education:

Our inquiry-based learning stations on quantum physics let the pupil understand its history and conceptual development. It is important for pupils to understand that the validity of the classical physics they have studied in the standard program at school is limited to a certain scale of physical phenomena and that physics in general evolves in such a way that new, more fundamental theories generalise (and so include) older ones.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

These activities are out-of-the-ordinary for the pupils and meant for gaining knowledge. Visiting research labs, interacting with real scientists, seeing experiments of quantum physics in action, working in teams to try to understand a scientific patent and try to make a product out of it, making a business plan: all of this is a full immersion in the science and technology world where pupils play an active role.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

Our learning stations about quantum physics contain many questions. We let the pupil analyse the results of experiments and their implications to give his/her own interpretation and draw at the end his/her own conclusions. We guide the pupil step by step through beautiful derivations by asking small questions. The pupil goes through the derivation himself/herself and understands the logical importance of every step.

9. Assessment: formative (of students' learning) and summative (of their progress):

Formative:

- Over contacts with their researchers
- Over a forum on the website

10. Cooperation among teachers and with experts:

Many groups from different schools, and therefore many science teachers, participate together in the project. They get the opportunity to learn more about quantum physics and its applications and to interact with each other and with the researchers who support them. A forum is organised on the project website where questions from pupils and teachers can be answered by the researchers.

4.7 Chemistry networking science and technology

Summary:

Hands-on experiments in small groups, assisted by research personnel, usually located in research labs are the centre of activity. Besides, introduction to related research fields and everyday implications are given. Usually, a product is produced, which may be carried home by the students.

Aims:

Cognitive: to get to know examples of chemistry affecting everyday life. **Motoric:** carrying out experiments on secondary school level with research equipment schools often cannot afford. **Affective:** to experience how important chemical research is for the needs of modern technology and to develop an attitude towards probable working as a chemist.

Main activities:

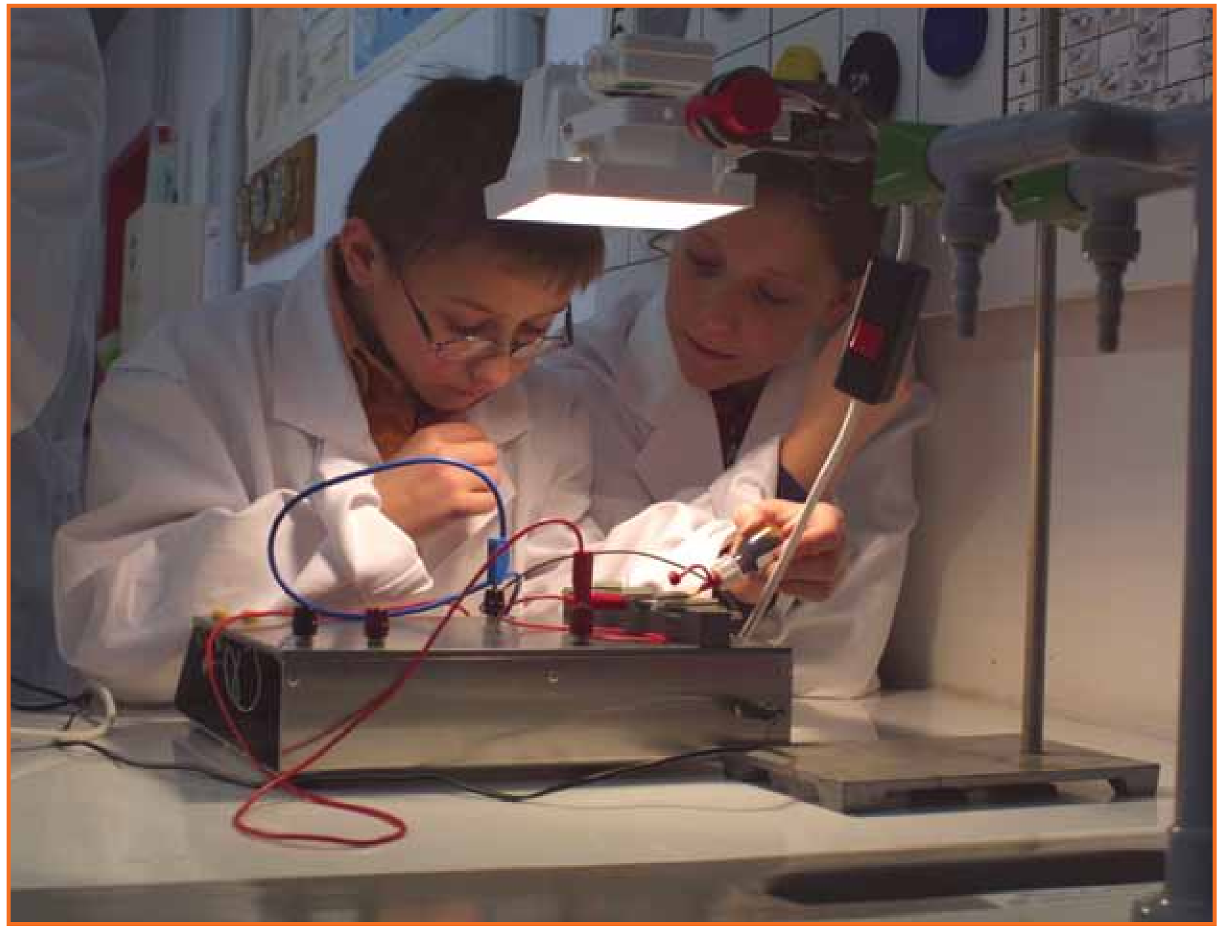
Example case no. 4: Modern Polymers: A. writing with light. Pupils manufacture a copper copy of a black and white graphic (a logo or comic character) by the aid of a photoresist, transparent master, uv light, developing and etching chemicals. The product may be used as window decoration. B. power from light. Pupils manufacture a Grätzel cell from coated window glass, white wall paint and mallow tea (amongst others). Three in a serial circuit may power up an electronic device.

Narrative:

The activity is designed for an average form size of 30-34 pupils. On arrival the form is divided into two groups of equal size. Group 1 is performing activity A

4.7 Chemistry networking science and technology

only, group 2 activity B.
a. Pupils work in pairs. They prepared in school a transparent master copy of e.g. their school logo or a comic character, place it on top of a photoresist coated copper plate (usually used for manufacturing circuit boards), expose it to uv light, develop in sodium hydroxide solution, wash and etch with a peroxide solution, wash again. The copper layer had been etched away at places exposed to the uv light. The positive image is from copper, adjacent areas show the supporting substrate (glass fiber reinforced plastic or pertinax). The product may be used as a window decoration (substrate being transparent), keyring or neck pendant, and so on. The technical process is a model for the manufacturing of integrated circuits from monocrystalline silicon, where photoresists, uv light exposure and chemical etching is also used at a scale some 100 times smaller.
b. Pupils work in pairs. They learned previously in school about the principles of photosynthesis. In the university lab they manufacture a dye cell of the Grätzel type from TCO coated insulation window glass, white wall paint (containing titanium(IV) oxide), mallow tea (red sensibilisation dye), iodine electrolyte solution and carbon black from a candle. This cell provides a voltage of about 400 mV and some 100 microamperes per square centimeter. Working requires concentration and exact following of the experiment guidance. The low-level experiment stops here after measuring the voltage as a dimension of quality. At the higher level, grade 10-12 pupils perform serial and parallel circuits of 2-4 cells and determine (at constant light) the characteristics of voltage and current. They may also use a serial circuit for powering up an electronic device. Everybody may carry his cell home. The basic principle of a dye cell is about the same like photosynthesis. Pupils may discover similarities on the macroscopic (grade 5-9) or submicroscopic (from grade 10-12) level.



End user:
Children grade 5-12 (two different levels available: 5-9 and 10-12).

Involved actors:
Researchers, teachers, chemistry education developed the case. During activity researchers and teachers are doing the coaching.

Location:
At university lab or very well equipped secondary school labs.

Connection with the curriculum:
Using modern polymers: A. light induced chemical reactions, oxidation, acids, hydrogen peroxide, noble metals, lithography, manufacturing of integrated circuits. B. light induced redox systems, photosynthesis, electric circuit, photoelectric power generation.

Languages available:
German only.

Where to find the application or case:
daten.didaktikchemie.uni-bayreuth.de/cnat/kunststoffe/kunststoffe.htm

Evaluation parameters:
The content of C#NaT runs so well since it comes directly from the users – the teachers and the students – and evolves through this direct communication and reviewing already during its creation to its well-designed end state. Compared to other cases, the content is not constructed by a third party but directly by teachers and students. This best practice has been certified by the internal evaluation of the Bayreuth.

Duration:
2-3 hours net, excluded getting to the university and leaving.

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	
7	Competencies related to self-reflection and meta-cognition	
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	
11	Competencies in the use of ICTs	
12	Competencies in the knowledge, planning and use of curricular materials	

4.7 Chemistry networking science and technology

1. Building interest in natural phenomena and scientific explanations:

A. Curiosity starts when pupils are presented REM pictures of integrated circuits. Watching the scale: structures have dimensions of 1/1000 of the thickness of one human hair. How is it possible to create such structures?

B. Photosynthesis seems like a wonder. If we could imitate the process for current generation our energy problems would be solved. The Grätzel cell does exactly that.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

A. Many industrial processes require etching with acids. Some produce oxygen, others more harmful products that need to be kept in a closed circuit.

B. Science will provide solutions for major problems of mankind: what to do as soon as fossil fuels will be exhausted?

3. Develop multiple goals:

- understanding big ideas in science including ideas of science, and ideas about science
- scientific capabilities concerned with gathering and using evidence
- scientific attitudes

A. Ideas about science and technology: as soon as a principle has been discovered by scientists, engineers start to build devices and optimise for everyday use. Pupils may optimise using different organic dyes (from raspberry, cherry, blueberry etc.)

B. Big Idea: solving the energy problem for mankind. How does a scientist approach the solution? Observe and copy nature, even optimise.

4. Understanding students' concepts and learning style about science phenomena:

The program has been certified by the internal evaluation of the Bayreuth. The education path is inductive: first, learners come to the university lab and do the hands on experiments. Some of the chemistry facts are given at the end of the program the same day, but basic work is done by teachers the following days. Thus we expect a higher motivation for theory than doing it the deductive way.

5. Relevance of the content to the daily lives of students:

A. Integrated circuits work in every electronic device we use in everyday life. They allowed miniaturisation from several kilos to some dozens of grams in about 20 years' time.

B. Prototypes exist for Grätzel cells integrated in school bags to power up cellphone, torch or laptop batteries.

6. Understanding science as a process not as stable facts. Using up to date information of science and education:

Progress in technology provides the same educational profit as "science as a process": integrated circuits get smaller and smaller, transformation of energy gets cleaner and cleaner.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

A. What is the use of learning about acids and bases in school? Understanding technological processes that provide us with everyday equipment.

B. It is not enough to know the functioning principle of photosynthesis. Devices built according to natural archetypes need to be optimised for everyday reliable and safe use as well as low price and longevity.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

Evaluating the quality of their personal Grätzel cell by measuring specific electrical parameters.

10. Cooperation among teachers and with experts:

Cooperation took place in the development process of the program. Teachers communicated their needs for curriculum application, chemistry experts explained their research field and education experts applied a specific organisation form. During a series of three party meetings, some of them with a fourth party, students evaluating the experiments, the program was approximated to completion.

4.8 The "GeneLab"

a gene and biotechnology outreach laboratory

PATHWAY

Summary:

The "GeneLab" is an outreach lab for biotechnology and gene technology within the Centre for Math and Science Education (Z-MNU) under the direction of the Biology Education Department at the University of Bayreuth. As "learning environment laboratory" for secondary school students, pre-service teacher education, and in-service teachers' professional development, it offers experimental modules in the context of gene and biotechnology.

Aims:

Student modules:

Students should gain specific knowledge regarding key questions of molecular biology and basic techniques herein. They should carry out authentic experiments on their own, unavailable at school due to resource as well as time limitations. Additionally, the modules should further other areas of genetic education and combine genetic education with an ethical reflection.

Pre-service teacher education:

Pre-service teachers should develop pedagogical content knowledge (PCK; Shulman, 1986) regarding teaching microbiology, molecular biology, biotechnology, and gene technology. First, as one part of PCK, they should be able to prepare and to carry out experiments within these issues which they should implement later on as future teacher at school. Second, with regard to the student modules, they should exemplary reflect on their PCK of a specific issue which they develop by combining student modules with their teacher education. Additionally, pre-service teachers should also increase their content knowledge as well as parts of pedagogical knowledge.

In-service teachers' professional development (PD): In-service teachers should achieve a higher level of PD by participating both on the student courses, and, especially, on specific lab days with regard to hands-on teaching biotechnology issues at school.

Main activities:

Students: day-long experimental modules.

Pre-service teachers: (a) term-long experimental courses, (b) outreach teacher education module.

In-service teachers: day-long experimental courses.

Narrative:

The "GeneLab" is an outreach lab for biotechnology and gene technology within the Centre for Math and Science Education (Z-MNU) under the direction of the Biology Education Department at the University of Bayreuth. The target groups are secondary school students, pre-service teachers (i.e., university students for biology education, in combination with chemistry or English language education), and biology and chemistry in-service teachers as well as teachers of other subjects like ethics.

Secondary school student courses:

Together with their teachers, classes attend a day-long experimental module in the GeneLab (offered during the term brakes). The students increase their knowledge about key issues in molecular biology and gene technology and apply the basic techniques herein. Since 2003, 4409 students, accompanied by 174 teachers, have attended the programs. In parallel, science education research has provided a consistent evaluation regarding instructional efficiency. Results have been published in international peer-reviewed journals (e.g., Scharfenberg & Bogner, 2010). We offer student modules including authentic experiments. For instance, the module Genetic Fingerprinting (11th grade) includes: the isolation of students' deoxyribonucleic acid from oral mucosa cells; the polymerase chain reaction with a selected human mini-satellite sequence; and agarose gel electrophoresis of the isolated and amplified DNA probes. Additionally, students discuss and value the pre-implantation diagnostics (PID) and its ethic-moral consequences. Within biology education, gene technology is a necessary subject in the current syllabuses for Bavarian secondary schools. All modules conform to these syllabuses.

Pre-service teacher education:

In 2003, the GeneLab started a lab course for biology pre-service teachers regarding experiments which the university students may include in their later science education at school. The future teachers prepare and carry out experiments in microbiology, molecular biology, biotechnology, and gene technology (in total, up to now, 90 university students). Additionally, in the student lab round 2006, the GeneLab started the newly developed teacher education module Learning and Teaching in an Outreach Lab which is combined with the student module Genetic Fingerprinting. The pre-service teacher module consists of six elements. First, the university students complete a half-day seminar about the specific content of the student module as well as about its biology educationally relevant aspects. Second, guided by the university lecturer, they build up the equipment to all work areas for the eight student groups (maximum of 32 students). Third, they participate in three subsequent lab days together with the student groups from the participating schools. During these days they undergo a three-fold change starting from (a) the role of a school student (i.e., they participate in parallel in seven school student groups as eight group at this day and carry out all experiments); (b) on the second experimental day, they tutor two student work groups (tutor role) according to the assignment-assistance model of tutoring (Kersaint et al., 2011); (c) on the third experimental day, they change to the teacher role (i.e., they teach one hands-on phase to the students, in the other ones: tutoring). A final reflection seminar wraps up the module. Accompanying explorative research has shown some effects on pre-service teachers' PCK.

References

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Shulman, L., (1986): Those who understand: Knowledge growth in teaching. Educational Researcher, 15 (2), 4-14.

BME (2011). Education in Bavaria.
www.km. bayern.de/education-in-bavaria.html.

4.8 The "GeneLab"
a gene and biotechnology outreach laboratory

Methods of learning/trainin:
Pre-service teachers: evidence-based PCK development; in-service teachers: evidence-based PD development.

End user:
Pre-service and in-service teachers for biology education at two different stratification levels: the Gymnasium as a "university-preparatory secondary school" (highest level; up to the 12th grade); and the Realschule as a "professionally oriented secondary school", where students may receive the "intermediate secondary school-leaving certificate" (intermediate level, up to the 10th grade; Bavarian Ministry of Education [BME], 2011, p. 1).

Involved actors:
Science education researchers with biology and chemistry teaching experiences for years at school.

Location:
Outreach laboratory at the University of Bayreuth.

Languages available:
German.

Evaluation parameters:
Student modules: Since the program started, science education research in parallel has evaluated the modules regarding instructional efficiency of scientific learning. Results have been published in international peer-reviewed journals (e.g., Scharfenberg & Bogner, 2010).
Pre-service teacher education: (a) summative evaluation by the Faculty of Biology, Chemistry, and Geosciences; (b) explorative evaluation since the outreach teacher education module started.
In-service teacher PD: summative evaluation by the Ministerialbeauftragter in Oberfranken on behalf of the BME.

Klautke, S: A category-based video-analysis of students' activities in an out-of-school hands-on gene technology lesson., International Journal of Science Education, 30(4), 451-467 (2008).

Klautke, S: Learning in a gene technology lab with educational focus: Results of a teaching unit with authentic experiments., Biochemistry and Molecular Biology Education, 35(1), 28-39 (2007).

Klautke, S: The suitability of external control-groups for empirical control purposes: a autionary story in science education research, Electronic Journal of Science Education, 11(1), 22-36 (2006).

Scharfenberg, F-J; Bogner, FX: A new two-step approach for hands-on teaching of gene technology: Effects on students' activities during experimentation in an outreach gene technology lab., Research in Science Education, 41(4), 505-523 (2011).

Scharfenberg, F-J: Experimenteller Biologieunterricht zu Aspekten der Gentechnik im Lernort Labor: empirische Untersuchung zu Akzeptanz, Wissenserwerb und Interesse (am Beispiel des Demonstrationslabors Bio-Gentechnik der Universität Bayreuth mit Schülern aus dem Biologie-Leistungskurs des Gymnasiums), (2005).

Duration:
Student modules: day-long; pre-service teacher modules: (a) term-long experimental courses, (b) outreach teacher education module: six days; in-service teachers: day-long.

Optimum number of participants:
Pre-service teachers: twelve; in-service teachers: twenty.

Additional information or resources:
www.bayceer.uni-bayreuth.de/didaktik-bio/de/forschung/proj/detail.php?id_obj=23987;

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	x
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

4.8 The “GeneLab”

a gene and biotechnology outreach laboratory

Mapping best practices with main principles

1. Building interest in natural phenomena and scientific explanations:

Evaluation research (Scharfenberg, 2005) has shown that the lab day furthers the students’ emotional component of interest (Krapp et al., 1992; i.e., measured as affective rating of acceptance) which is based primarily on the hands-on activities. However, the lab day did not further the epistemic component of interest.

Scharfenberg, F.-J. (2005): Dissertation, University of Bayreuth (Online published: opus.ub.uni-bayreuth.de/volltexte/2005/176.
Krapp, A., Hidi, S. & Renninger, K. A. (1992): Interest, Learning and Development. In: Renninger, K. A., Hidi, S. & Krapp, A. (Hrsg.): The Role of Interest in Learning and Development (3-26). Hillsdale, NJ, Hove, London: Lawrence Erlbaum Associates Publishers.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

Nature of science: Within the Genetic Fingerprinting, module students and pre-service teachers are confronted with key concepts describing the nature of science, for instance, the concept tentativeness: parts of DNA which ten years ago have been assigned as junk DNA are now coupled with regulatory functions. In this case, a conserved regulatory element within an intron is associated with the brown/blue eye color in humans (Eiberg et al., 2008).

Science in society: Within the Genetic Fingerprinting, module students and pre-service teachers discuss the role of science in society. In this case, they discuss and value the pre-implantation diagnostics (PID) and its ethic-moral consequences. PID is of particular relevance in Germany due to the current changes in the law.

Bell, R. (2009): National Geographic, online: www.ngsp.com/Portals/0/downloads/SCL22-0449A_AM_Bell.pdf, available 9th Nov. 2011.
Eiberg, H., et al. (2008): Human Genetics, 123 (2), 177-187.
Deutscher Bundestag (2011): www.bundestag.de/dokumente/textarchiv/2011/35036974_kw27_de_pid/index.html.

4. Understanding students’ concepts and learning style about science phenomena:

Pre-service teachers have different opportunities to understand students’ concepts with regard to the subject being taught and to get information about students’ learning style: (1) In the first module component, the half-day seminar about the specific content of the student module as well as about its biology education relevant aspects, pre-service teachers discuss the results of the conceptual change research with regard to gene technology (e.g., Franke & Bogner, 2011). (2) In the role of the tutor (second and third day participating the student module), pre-service teachers are confronted both with the current concepts their tutees (two work groups, i.e., eight students) hold and with different learning styles of the work group members.

Franke, G., & Bogner, F.X. (2011): The Journal of Educational Research, 104 (1), 1-14.

6. Understanding science as a process not as stable facts. Using up-to-date information of science and education:

The experiments conducted do not always reach the results expected by the teachers. One of the most important learning tools in this course is the ‘error’ if treated in an adequate way. The error is addressed and analysed by tutors and participants not only so that teachers can reflect on what did not work, but also in order to develop awareness of science as a continuing process.

Bell, R. (2009): National Geographic, online: www.ngsp.com/Portals/0/downloads/SCL22-0449A_AM_Bell.pdf.
Skoglund, P., & Jakobsson, M. (2011): PNAS, online first: www.pnas.org/content/early/2011/10/24/1108181108.full.pdf.
Scharfenberg, F.-J., & Bogner, F.X. (2011): Research in Science Education, online first: www.springerlink.com/content/t33034537x3u315j/fulltext.pdf.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

The students’ experiments are embedded in a framework of minds-on hands-on units, consisting of a / theoretical minds-on phase (during which the teacher introduces the theoretical background of each experiment) as well as an associated experimental hands-on phase. Before they begin, the teacher introduces the students to the work area during an initial pre-lab phase. At the end comes a final interpretation phase and discussion of the actual results. All experiments are authentic, representing the ‘ordinary day-to-day actions of the community of the practitioners’. The pre-service teachers have the chance to develop their PCK by working with new student groups on the three subsequent days. The tutor role provides the chance to counter against the self-experienced difficulties during the hands-on phases. Finally, their role allows teacher to include their own experiences from the two previous days into an instructional strategy of their own. Moreover, university students also increase other elements of PCK in their first seminar (e.g. knowledge about the current syllabuses). Independently, they also increase their content knowledge as well as parts of pedagogical knowledge (e.g., regarding cooperative learning).

Hodson D. (1998). Teaching and Learning Science. Towards a Personalized Approach. Philadelphia, Open University Press.
Chinn, C., & Malhotra, B. (2002). Science Education, 86, 175-218

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

Both the students and the pre-service teachers take part in their specific module in order to do science, including experimenting, analysing, interpreting, and redefining explanations. The students attend an experimental lab day. The pre-service teachers do science both in the role of the school student (1st lab day) and in the role of the tutor (2nd and 3rd lab day of their module); for details, see narrative.

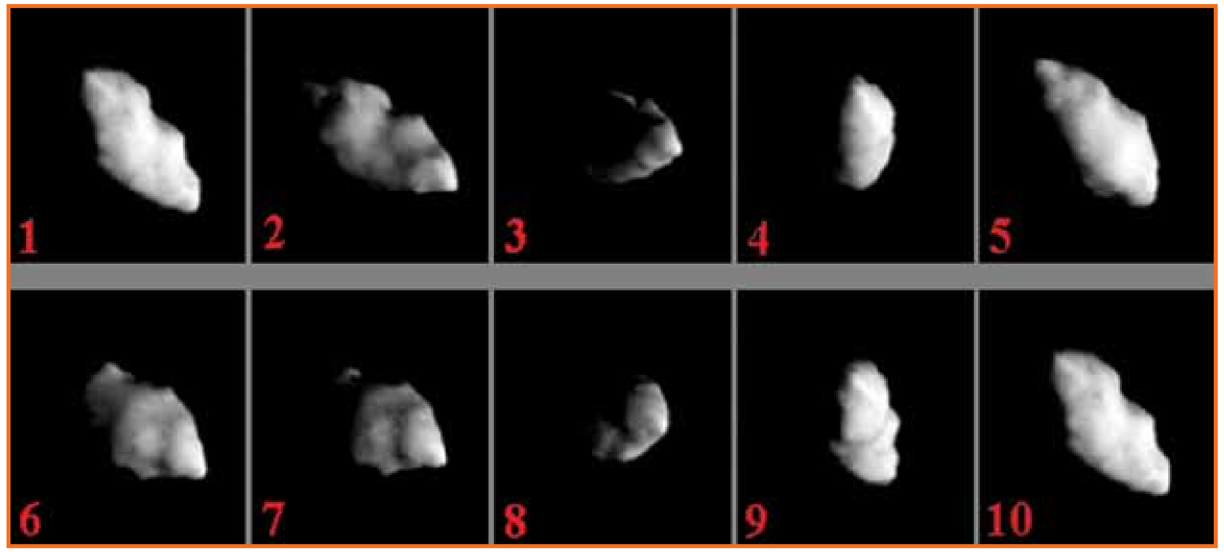
9. Assessment: formative (of students’ learning) and summative (of their progress):

Since the start of the program both modules are being evaluated. Student modules: In total, we have published eight papers in peer-reviewed journals and two doctorate theses up to now (2005 to 2011). Pre-service teacher modules: In parallel to implementing the module into teacher education, we started an explorative evaluation. First results have shown effects on pre-service teachers’ PCK. For instance, pre-service teachers differently assessed students’ learning difficulties before and after the teacher education module.

10. Cooperation among teachers and with experts:

The GeneLab courses for in-service teachers’ PD bring together teachers from different schools in the area around Bayreuth. Due to the complexity of some new experimental approaches, cooperation between the teachers may arise. Independently, they come in contact with science education researchers at UBT, and, content-dependently, with UBT experts in different fields of biology and/or chemistry research.

4.9 COSMOS



Summary - aims:

"COSMOS" is an experimental laboratory for students and teachers, aiming to improve science instruction by expanding the resources for teaching and learning in schools and universities, providing more challenging and authentic learning experiences that are mainly connected to astronomy. The COSMOS repository currently contains more than 100,000 educational materials (photos, videos, animations, exercises, graphs, links) and structured learning activities. It offers to users a series of tools and a set of templates that facilitate teachers in creating effective inquiry learning activities. The COSMOS repository is frequently used by a community of 3,000 active registered teachers..

Main activities:

The main activities included are the following:

- Promote the use of astronomy in teaching science subjects.
- Engage teachers in designing inquiry based activities based on given templates.
- Help teachers get acquainted with the use of digital resources and help them integrate them in their every day teaching
- Promotion of the inquiry-based approach through training workshops and presentation of good practices.

Narrative:

The content of the COSMOS repository contains a large pool of high quality educational activities that mainly focus on astronomy and follow the IBSE approach. Teachers are given a plethora of digital materials that can help them design fascinating and exciting astronomy activities for their students and use them for teaching several subjects in science. The approach followed in the activities of the COSMOS repository is basically student centered and is in accordance with the recommendations of the High Level Group on Science Education (Rocard report). The proposed activities offer a unique opportunity to users, to control robotic telescopes and use real scientific data in order to perform their own research. Through these activities students may learn about different principles and the connections between phenomena not only in astronomy but in other fields as well.

The activities in the COSMOS repository cover all levels of primary and secondary education and are also apt for higher education as well. They connect in-class teaching with extracurricular activities and they are also suitable for families and lifelong learners. The content of COSMOS covers several subjects of physics.

End user:
Teachers and students of primary and secondary education, astronomers, amateur astronomers, lifelong learners.

Involved actors:
Students, teachers, researchers, informal learning web visitors, astronomers, amateur astronomers, stakeholders in education.

Location:
Schools, observatories, and on the web.

Connection with the curriculum:
Natural Sciences - astronomy.

Languages available:
English – Greek – German – French – Finnish – Swedish – Turkish - Bulgarian.

Where to find the application or case:
www.cosmosportal.eu

Evaluation parameters:
Analysis the COSMOS Portal usage data of the portal over a 36 month time-period, dealing with number of contributors and the amount of content uploaded, number of visitors and visitor loyalty. The results of the quantitative analysis are presented in: S. Sotiriou, F. X. Bogner, G. Neofotistos (2011). Quantitative analysis of the usage of the COSMOS Science education portal. J. Sci. Ed. (20) 333-346.

Duration:
One complete educational activity requires approximately 3 didactic hours.

Additional information or resources:
www.ea.gr/ep/cosmos

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	x
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	x
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	x
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

4.9 COSMOS

1. Building interest in natural phenomena and scientific explanations:

The COSMOS best practice offers a wide range of educational activities that aim to facilitate teachers in teaching several science phenomena through astronomy. Through these activities students are offered the opportunity to engage in playful activities that help them understand natural phenomena through the process of scientific data and the use of scientific instruments like image process tools and network of robotic telescopes.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

The COSMOS activities are designed based on the inquiry approach. Students may interact with astronomers and get a first hand idea of their work. Furthermore, just like scientists do, they are asked to make predictions on a given subject, which they test through their inquiry and thus produce result of their own.
As numerous activities are also designed for non-formal education, adult learners and families also have the opportunity to engage in these activities and learn about the role of science in society and scientific inquiry.

3. Develop multiple goals:

- understanding big ideas in science including ideas of science, and ideas about science
- scientific capabilities concerned with gathering and using evidence
- scientific attitudes

The COSMOS repository offers the unique opportunity to teachers to introduce several topics of physics and of natural sciences in general through astronomy. Thus by witnessing the interconnection between different fields of science students realize the bigger picture behind single phenomena. Moreover, by using the tools offered in the repository, students learn to gather evidence and process real scientific data and thus develop an understanding of scientific inquiry and scientific attitudes.

4. Understanding students' concepts and learning style about science phenomena:

The COSMOS repository offers a blended approach that mixes different learning contexts and learning methods. By making their own predictions and designing their own inquiries, students learn to use their imagination and act independently and creatively. Thus they develop their problem-solving skills and critical thinking.

5. Relevance of the content to the daily lives of students:

The COSMOS activities concern contemporary astronomy subjects that students often hear about in their every day life. Hence, students witness a clear connection between what they learn at school and contemporary achievements and discoveries in science.

6. Understanding science as a process not as stable facts. Using up to date information of science and education:

Astronomy activities allow students to learn using real scientific instruments and process the latest astronomy images. Through these activities they may witness the evolution of different phenomena (like solar activity for example) and hence understand that an inquiry on a subject is not a stand-alone project but an ongoing process that may be carried out in several episodes or constitute the ground work of future inquiries.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

The COSMOS activities are built based on an inquiry approach. Thus students are required to make use of their past knowledge and build on it in order to acquire new knowledge using their observations. The inquiries students perform do not focus on mere observation of phenomena but on their in-depth investigation through the use of respective tools and software. Through their investigation of different phenomena students do not simply engage in entertaining activities, they learn to act skilfully and independently and learn by doing.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

The cornerstone of every COSMOS activity is to help students learn by doing. The COSMOS repository offers a full set of tools that students use within different contexts and perform several activities that help them do real scientific research. Students may retrieve data from the repository or use robotic telescopes to gather their own data and process them using image analysis tools. The structure of the COSMOS activities guide the students so as to exploit their findings to their full extend and produce scientifically sound explanations and conclusions.

9. Assessment: formative (of students' learning) and summative (of their progress):

The COSMOS repository offers a series of game-based applications which include quizzes and may help teachers to assess the performance of their students. As all COSMOS activities include a 'making predictions' part and a 'reflection' part, based on the students answers, teachers may also have an idea of the activity's impact on students' knowledge.

10. Cooperation among teachers and with experts:

Teachers may cooperate with the astronomers and the stuff of observatories in order to perform their activities. Based on the indications of astronomers and the stuff of observatories teachers also have the opportunity to design new effective activities.

4.10 Asteroid hunters

PATHWAY

Summary:

Asteroid Hunter presents an example for the application of IT in the training on physics and astronomy. With the help of the program ASTROMETRICA can be found moving objects – asteroids images obtained with different telescopes. This astronomical program is used to measure the equatorial coordinates of a newfound and already known asteroids.

Aims:

The BP Asteroid Hunters is aimed at:

- Providing opportunity for students to explore the asteroid movements – small bodies in the Solar system.
- Students raise hypotheses for the detected objects and their belonging to the Group of the Main Belt or the group of the dangerous Near-Earth asteroids and check their hypotheses.
- Stimulation of the artistic skills of the students to create a model of the asteroid orbit, which equatorial coordinates they have calculated.
- To make cross-curricular relations between mathematics, physics, chemistry, history (its discovery and former observations) of the asteroid which is the object of their research.

Main activities:

Students are introduced to the basic elements of the celestial sphere, the equatorial coordinate system, with the help of the astronomical program ASTROMETRICA.

Using example astronomical images they are trained to detect asteroids in the background of the fixed stars. They use appropriate star catalogues to find the stars for comparison, to determine the equatorial coordinates of moving objects - new and already discovered asteroids. Based on these calculations, as well as information from astronomical databases, students determine the ephemeris, asteroids' orbit elements, its type (silica, metal or carbon), information about its discovery and previous observations. Based on their calculations and the found scientific information, students create a model of the asteroid object of their research.

Narrative:

BP Asteroid Hunter can be applied in the following scenario:

1. The teacher leads the students to explore some basic elements of the celestial sphere (zenith, nadir, north and south pole, celestial equator, meridian star ecliptic) and the equatorial coordinate system.
2. With the help of a discussion students classify the celestial objects on the basis of their visibility in the different time of the year. The teacher emphasize on the division between unfading and those that are rising and setting objects and are seen in during the different seasons. Students learn methods to determine the equatorial coordinates using star charts and learn to rely on an asteroid ephemeris (a table of data on the spatial position of the asteroid in the solar system for a certain period of time).
3. Students give examples of unfading and rising stars and determine their equatorial coordinates.
4. The question "How to detect moving in Solar system near earth objects?" is asked and discussed. (Phase 1)
5. In the process of formulating the idea for detecting a rapidly moving objects in the background of the fixed stars, the teacher demonstrates this using the computer program ASTROMETRICA.
6. For 15 minutes the teacher shows the students how the computer program for detecting fast moving objects in the Solar system works.
7. Students work the sample images of selected parts of the sky in which there are asteroids with the help of the computer program ASTROMETRICA. (Phase 2)
8. Students explore and analyze the measured equatorial coordinates with their classmates. (Phase 3)
9. Students comment how the accuracy of the measurement which they made depends on the accuracy of the calculated equatorial coordinates. (Phase 4)
10. Summarize the conclusions from the carried out work. (Phase 4)
11. A task is given for homework – to find information in the astronomical database about the ephemeris, orbit elements and information, type of the asteroid and its discoverer. This will be presented in the form of mini scientific conference (an interactive method of teaching - role play) and will be evaluated by the whole

4.10 Asteroid hunters

class. (Phase 5)

12. During the next lesson the results of the students' presentations and their credibility are commented. (Phase 6)
13. It is recognized how the astronomical program ASTROMETRICA helped us to understand the dynamics of the asteroids, the scientific information of the astronomical databases helped us to create a model of the asteroid and to understand it's movement in the Solar system and if this asteroid threatens to collide with the Earth.(Phase 7)

In accordance with the Blooms' taxonomy the aims of the given approach are the following:

Cognitive domain

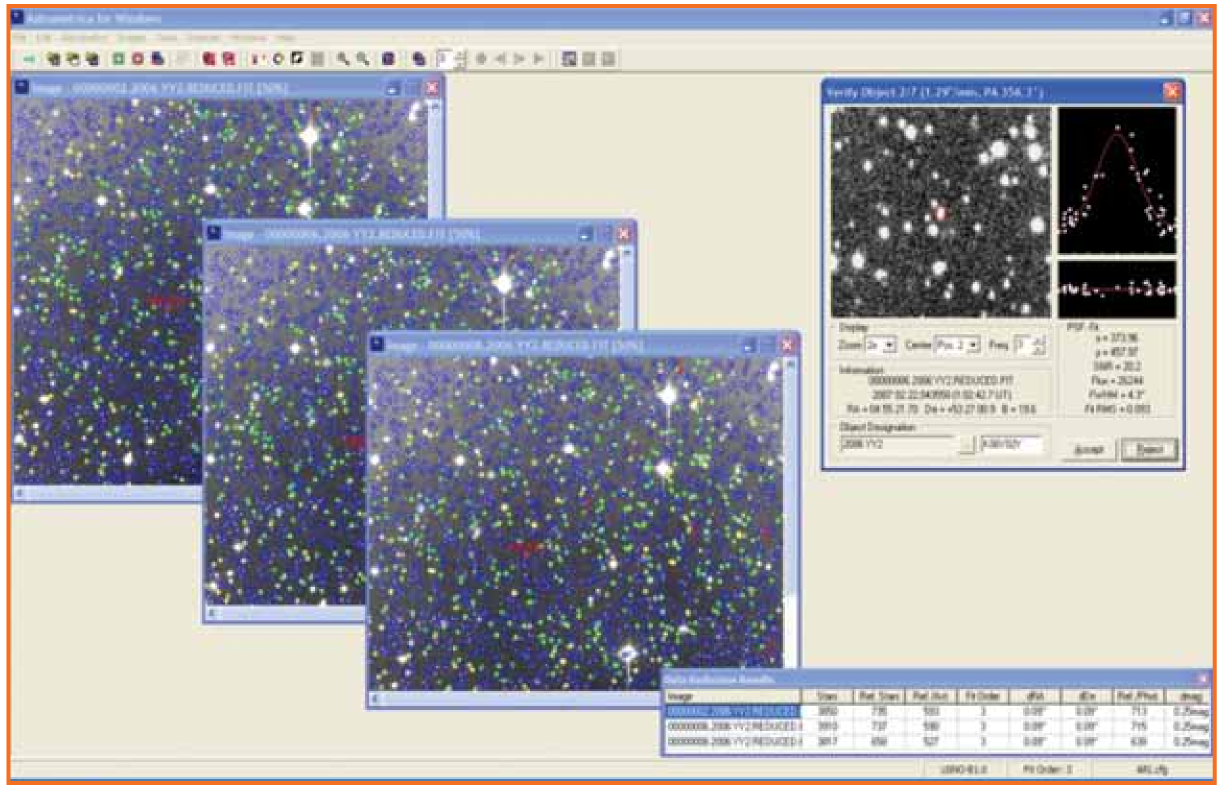
- Knowledge – Students acquire knowledge about the dynamics and the nature of the asteroids.
- Comprehension and evaluation – Students think critically and creatively and develop their observational skills. They have to determine the equatorial results by themselves and to develop skills for very precise measurements of the object of astronomical image. .
- Analysis - Students develop their analytical skills. On the basis of the calculated equatorial coordinates, the orbit elements and the object movement students have to define whether the asteroid belong to the group of the near and dangerous asteroids.
- Synthesis and application – Students create models of the asteroids, found by them in the astronomical images

Affective domain

Students receive a real appreciation for their findings. Students have the opportunity to apply knowledge in physics, astronomy, chemistry and history in the creation of a model of the asteroid which presents the dynamics and nature as well as the process of finding the object.

Psychomotor domain

Students are introduced to software that is applicable to other subjects. Students are encouraged to share their models and have fun with the possibilities of the product.



Methods of learning supported:
Inquiry-based Teaching methods

End user:
Students grade 10-11 (age 16-17)

Involved actors:
Researchers, teachers, Student-astronomers.

Location:
Asteroid Hunter can be used not only in school but in extracurricular activities such as (workshops, project learning, astronomical and school clubs) as well as self study.

Connection with the curriculum:
Physics and Astronomy, Mathematics, IT, Chemistry, History

Languages available:
The ideas about using Asteroid hunters in physics and astronomy lessons are available in Bulgarian and English.

Where to find the application or case:
http://iasc.hsutx.edu/index_files/Page389.htm- software and support files

Evaluation parameters:
BP Asteroid Hunter is applied with a great success for a year mainly in the mathematical and language high-schools in Bulgaria. A survey was made with teachers in physics and astronomy in relation to the usage of ASTROMETRICA in their practice. The application of this product is very well accepted especially from teachers in physics and mathematics.

Duration:
This example is for 2 teaching hours and about 2 hours independent homework.

Additional information or resources:
http://www.astro.bas.bg/AIJ/issues/n17/VRadeva.pdf
Radeva, V., Ibruamov, S., Trackinh and discovering asteroids, Bulgarian Astronomical Journal, Volume 17,2011, 142-151p
Радева, В., Българският принос в откриятията и наблюденията на астероиди, Наука, 1, 2012, 42-43.

Teachers' competencies

1	Competencies related to subject matter/content knowledge	x
2	Competencies related to the nature of science including inquiry knowledge and skills	x
3	Competencies in framing a discipline in a multidisciplinary scenario	x
4	Competencies in knowledge of contemporary science	
5	Competencies in mastering and implementing a variety of instructional strategies	x
6	Competencies in sustaining autonomous life-long learning	
7	Competencies related to self-reflection and meta-cognition	x
8	Competencies related to the area of teaching/learning processes within the domain	x
9	Competencies in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students	x
10	Competencies addressing students' common sense knowledge and learning difficulties	x
11	Competencies in the use of ICTs	x
12	Competencies in the knowledge, planning and use of curricular materials	x

4.10 Asteroid hunters

Mapping best practices with main principles

1. Building interest in natural phenomena and scientific explanations:

The usage of a professional software in the lessons on physics and astronomy helps students to see more clearly the link between astronomy and mathematics, both applied together to solve a real problem and to motivate them for self-work.

2. Building up informed citizens: Students understanding the nature of Science & Science in society:

Students learn and model asteroids-small bodies of the Solar System with the help of astronomy, mathematics and IT.

3. Develop multiple goals:

- Students explore the asteroids – bodies of the Solar System though exploring the surrounding world.
- Students raise a hypothesis and to experiment.
- Stimulation of the artistic skills of the students.
- Make cross-curricular relations.

4. Understanding students' concepts and learning style about science phenomena:

Students have the opportunity through ASTROMETRICA software to design real models of real objects' movement and to explore their nature.

5. Relevance of the content to the daily lives of students:

The proposed BP is directly linked to the real world and as an additional motivation is the opportunity to find a new object in the Solar System and to participate in international programs for prevention of the Earth from collision with a dangerously close asteroids.

6. Understanding science as a process not as stable facts. Using up to date information of science and education:

During their work with Asteroid Hunters students realize the facts that in the real world asteroids very rare collide with the Earth but they acquire skills to find them and create models with the available instruments and the acquired skills how to use them.

7. Activities for gaining knowledge, not for entertainment, nor for simple imitation of results:

In the given practice students are introduced with a new software which if they are willing can learn, they can analyse asteroids' dynamics and nature, make conclusions and construct models.

8. Doing science: experimenting, analysing, interpreting, redefining explanations:

The lesson of the BP Asteroid Hunters can be designed on the basis of the 7 phase model of an open IBSE scenario. Students pass through all levels of the experiment – from developing scientific questions through raising and checking of the hypotheses to the reflection on the implemented activities.

9. Assessment: formative (of students' learning) and summative (of their progress):

In the given BP the assessment has an entertaining nature because it is conducted in the form of a mini-scientific conference and the assessment of the students' projects is done by the students themselves.

10. Cooperation among teachers and with experts:

BP Asteroid Hunter is designed for the classed in physics and astronomy but in case of necessity there is a possibility for joined work with the IT teacher.

5.

References

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