The Fibonacci Project

DISSEMINATING INQUIRY-BASED SCIENCE AND MATHEMATICS EDUCATION IN EUROPE

Companion Resources For Implementing Inquiry in Science and Mathematics at School

Implementing Inquiry beyond the School

WITH THE SUPPORT OF

EUROPEAN COMMISSION

SEVENTH FRAMEWORK PROGRAMME

Resources for Implementing Inquiry in Science and Mathematics at School

The Fibonacci Project (2010-2013) aimed at a large dissemination of inquiry-based science education and inquiry-based mathematics education throughout the European Union. The project partners created and trialled a common approach to inquiry-based teaching and learning in science and mathematics and a dissemination process involving 12 Reference Centres and 24 Twin Centres throughout Europe which took account of local contexts.

This booklet is part of the *Resources for Implementing Inquiry in Science and in Mathematics at School*. These Resources include two sets of complementary booklets developed during the Fibonacci Project:

1) Background Resources

The *Background Resources* were written by the members of the Fibonacci Scientific Committee. They define the general principles of inquiry-based science education and inquiry-based mathematics education and of their implementation. They include the following booklets:

- 1.1 Learning through Inquiry
- 1.2 Inquiry in Science Education
- 1.3 Inquiry in Mathematics Education

2) Companion Resources

The *Companion Resources* provide practical information, instructional ideas and activities, and assessment tools for the effective implementation of an inquiry-based approach in science and mathematics at school. They are based on the three-year experiences of five groups of Fibonacci partners who focused on different aspects of implementation. The *Companion Resources* summarise the lessons learned in the process and, where relevant, provide a number of recommendations for the different actors concerned with science and mathematics education (teachers, teacher educators, school directives, deciders, policy makers...). They include the following booklets:

- 2.1 Tools for Enhancing Inquiry in Science Education
- 2.2 Implementing Inquiry in Mathematics Education
- 2.3 Setting up, Developing and Expanding a Centre for Science and/or Mathematics Education
- 2.4 Integrating Science Inquiry across the Curriculum
- 2.5 Implementing Inquiry beyond the School

Reference may be made within this booklet to the other *Resource* booklets. All the booklets are available, free of charge, on the Fibonacci website, within the *Resources* section.

Editorial coordinator : Susana Borda Carulla

Fibonacci Scientific Committee : Michèle Artigue, Peter Baptist, Justin Dillon, Wynne Harlen, David Jasmin, Pierre Léna

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Implementing Inquiry beyond the School

Lead Editor: Prof. Hannu Salmi, University of Helsinki, Finland

Co-Editors: Dr. Veera Kallunki, Dr. Arja Kaasinen, University of Helsinki, Finland

Fibonacci Contributors: Andrea Frantz-Pittner, Silvia Grabner, Natur Erlebnis Park, Austria ; Konrad Krainer, University of Klagenfurt, Austria; Liisa Suomela, Sirpa Tani, Reetta Hyvärinen, Noora Pyyry, Pauliina Rautio, Jani Koivula, University of Helsinki, Finland; Louise Hayward and George MacBride, University of Glasgow, Scotland; Petra Skiebe-Corrette, Frei University of Berlin, Germany; Tina Jarvis, University of Leicester, UK; Renata Carvalho, Rosário Oliveira, Carla Pacheco, César Garcia, Luz Figueiredo, Ciência Viva, Portugal; Aki Bergström, Kati Solastie, Suutarila School, Helsinki.

Scientific advisor : Prof. Justin Dillon, King's College London, UK

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Introduction

Hannu Salmi, University of Helsinki

The topic of this booklet, Implementing Inquiry beyond the School, includes the current widening thinking about open learning environments. According to this line of thinking, both schools and all out-of-school settings are environments where learning can take place. In addition to everyday experiences, learning can happen in particular designed spaces such as science centres and natural history museums. Furthermore, there are lots of other organised science-rich activities taking place after the school day. Different science clubs and camps are good examples of this. And, also different media of which the newest are the Internet and its applications, act as parts of the open learning environments.

In this booklet, the goal is to introduce different ways to use these external environments as a part of science education. In many of these examples the aim has also been to create a meaningful combination between the formal and informal settings and to create a continuum of an open learning environment.

Another standpoint of this booklet is the inquiry-based approach of science education that fits closely to the philosophy of the out-of-school settings. However, although the benefits of inquiry-based science education are obvious in activating pupils' thinking in theory, it is challenging to realise these good ideas in practice. Making observations and doing investigations requires skills that have to be taught. In this process, motivation is an essential catalyst and product. To achieve the best results, both the teacher and the student need to be motivated. The examples in this booklet offer positive outcomes and practices of using an inquiry-based approach in open learning environments.

This booklet discusses the implementation of inquiry beyond the school, also from the standpoint of an example of a research-based teacher training. The aim of this discussion is to underpin the idea of a good teacher. Becoming a good teacher requires developing in-training teachers' competence. This can be done by concentrating on teacher training that is based on the latest research on the field. In addition to the in-training teachers' training, this competence-thinking also fits into the in-service training of working teachers. To be a good science teacher requires motivation, basic knowledge about the subject matter and skills to utilise the latest results of science education. Open learning environments, including both formal and informal learning contexts, belong to the present research field of science education. Thus, the contemporary research knowledge about the formal and informal learning contexts, science centre pedagogy, outdoor education, different analysis tools for studying open learning environments, methods to organise and plan effective lesson plans around out-of-school activities and the effectiveness of inquiry-based science education belong to the competence of a good teacher.

Implementing inquiry beyond the school is also a topical issue when creating new national curriculums for schools in Europe. In countries like Estonia and the Netherlands, using out-of-school settings as a part of school teaching is already a natural part of the curriculum. Furthermore, for instance in Scotland, the Curriculum for Excellence explicitly recognises the importance of learning outside of school time and the school environment in all curricular areas. This includes learning organised and jointly planned by the school (e.g. young engineers' clubs, a visit to a science centre or outdoor education centre, a visit to a shipyard), community learning and development, learning planned by other organisations (e.g. youth organisations, sports clubs) and informal learning within the family and community. In Scotland, the four Science Centres, the Royal Botanic Gardens, National Museums of Scotland, the two national parks, Scottish Natural Heritage, Historic Scotland, the National Trust for Scotland, the Scottish National Zoological Park and local authority botanic gardens all offer educational programmes matched to the Curriculum for Excellence sciences and/or technologies.

In addition, in other European countries like Finland the trend of including the out-of-school environments as part of school teaching is also changing. According to the committee of the Ministry of Education and Culture that is pondering the next reform of the national curriculum of Finland, the environment around us is changing so rapidly that it is time to take the new learning possibilities into account when formulating the new curriculum. Especially utilising the new forms of technology such as different interactive, ICT-based and digital learning environments should be considered. This makes it possible to include the out of school learning as a part of school teaching. The ultimate target of this booklet is to search and present new ways to inspire and motivate pupils to learn natural sciences.Qualities, core qualities in particular, are inherent and very difficult to change. Character strengths and virtues such as creativity, courage, kindness, and fairness are examples of such core qualities. In distinguishing between qualities and competencies we could say that qualities come from the inside while competencies come from the outside. The task of pedagogists is to offer these competencies.

Towards the open learning environments

Bridging the gap between formal education and learning in informal contexts

Hannu Salmi, Veera Kallunki, Arja Kaasinen, University of Helsinki

Learning and education can be defined both narrowly and broadly: they can occur either unconsciously or formally. One of the first to present this broader definition was the German philosopher Krieck in 1922, who used the term «unreflektierte Erziehung» (in English "education by chance"). According to him, people also learn unconsciously through work, art, language and culture. The whole relationship between human beings is an educational one. Philosophically, informal education represents the ideas of freedom, in the spirit of Rousseau's tradition as manifested, for example, in the work of A.S. Neill.

Learning in informal contexts has often been regarded as the opposite of formal education. Even the names of the classic books - *Deschooling Society* by Ivan Illich and *The Unschooled Mind* by Howard Gardner have been provocative. These books also contained harsh criticism on schooling, which alienated students from meaningful learning. Moreover, both authors argued that learning from informal sources was effective and motivating. These books have had a great effect on education and educational research.

The terminology of informal education is variable, due to, on the one hand, the slight difficulties caused by differences in school systems and, on the other, some translation problems. One of the main difficulties is that pure learning in informal contexts refuses to be categorised, and the definitions are not needed until it becomes institutionalised. Learning in informal contexts and open learning environments are the latest terminology in the field.

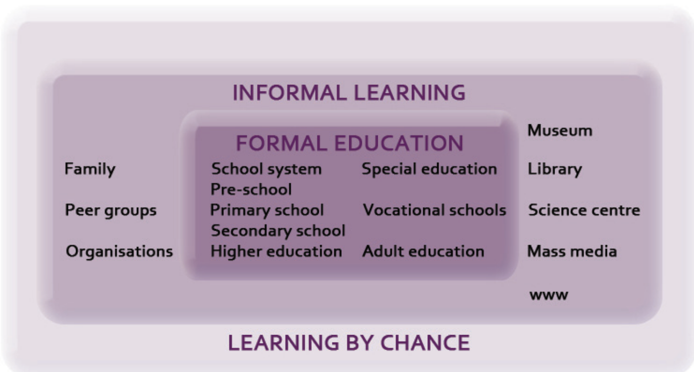


Figure 1 The relationship between the different kinds of education.

The relationship between the different kinds of education is shown in figure 1, which is a combination from several sources. Originally, it was the scheme for educational statistics in the UNESCO report *Learning to Be - The Faure Report* in 1968. It was originally used to show the forms of life-long education.

The methods of learning in informal contexts have traditionally been used in, for example, the teaching of biology and geography, science education, museology solutions and art education. The first essential research concerning informal education was clearly related to biology and field education. Some of these results indicated enormous effects on learning from informal sources. Some researchers also hold the strong opinion that informal education should not be studied using only classical quantitative methods. However, it soon became evident that only evidence-based results matter, because there was more than enough imprecise data and results based on anecdotes or every-day-experiences. Such results have since been multiplied in the literature.

Until the 1990s, informal learning solutions were often considered as unreachable ideals, or informal education was used only as a tool for criticising school or school reforms. To advance the public understanding of science, new forms of education were actively sought. Learning does not take place only in the actual world of school, but in the presented world of nature, parks, yards, science centres, gardens, and the media, as well as through the virtual worlds of the internet and social media.

A huge amount of information, especially about modern phenomena, is obtained in a personal way from family, friends and peer groups. Furthermore, the roles of television, libraries, magazines and newspapers are also essential. Visits to museums and science centres have grown during the last decade. Most of these forms of education can be classified as informal, either focused on young people via informal, out-of-school education programmes or as learning occurring totally outside of any educational institutions, for young people or adults. Informal education has often been regarded as the opposite of formal education. Since the 1990s, however, informal education has become a widely accepted and integrated part of school systems. Despite this development, there has been less theoretical or empirical research in the informal sector. Recently, *learning in informal contexts* has become a more accepted part of science education.

Figure 2 contains an artificial dichotomy: novel technologies, such as Augmented Reality (AR), are bringing new options to everyday science learning without the need for school or a physical environment. In this dichotomy, outdoor education is defined and located in the real environment and near the borderline between formal and informal education: when leaving the physical classroom setting, the park, forest, yard, or nature clearly represents everyday informal science learning, whereas when the teacher gives clear educational tasks to students, the educational process immediately resembles school and the curriculum. A fruitful combination would bridge the gap between formal and informal education and use the term open learning environment to describe it.

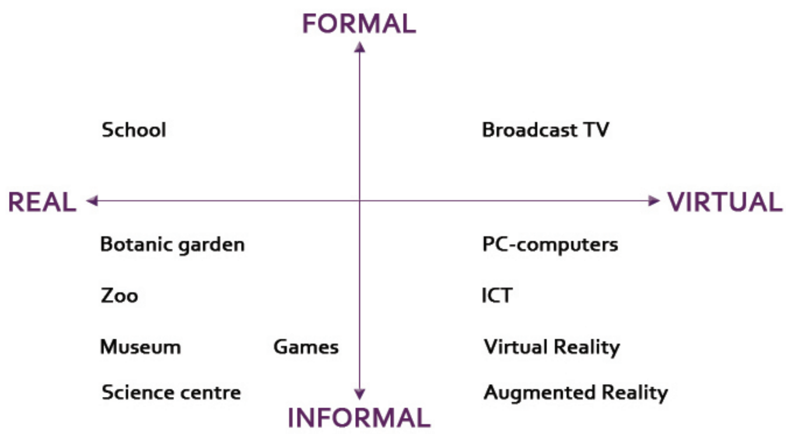


Figure 2 Persistent dichotomies or blurring boundaries? (Hawkey 2002; Salmi 2012)

Out-of-school education is also a term included in school legislation in several countries. Out-of-school education often uses informal education sources for formal education. It forms a pedagogical link between formal and informal education. Outdoor education is one form of out-of-school education.

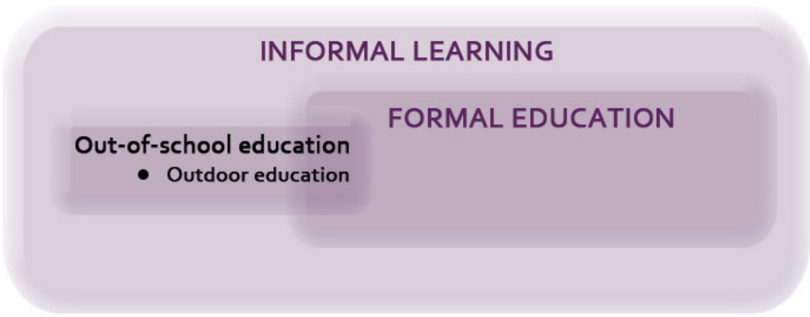


Figure 3 Out-of-school education as a link between informal contexts and formal education.

Does it make us think? Inquiry based learning in science and engineering

Louise Hayward and George MacBride, University of Glasgow

IBSE in Scotland: a case study of attempts to build sustainable change

Over the past decades innovation education has often been marked by a failure to bring about any significant or sustainable change in the experience of learners. This has been the case even for high-profile and well-funded intentions. Experience and research, in Scotland and elsewhere, very clearly suggests that sustainable change requires that policy makers, researchers and practitioners must seek to work and to learn together. These processes require integrity defined as follows: a) educational integrity, b) personal and professional integrity, c) systemic integrity.

Educational integrity

The starting point for any innovation likely to lead to real change is to establish the extent to which there is a need for change. IBSE (inquiry-based science education) is an idea that has been part of the thinking of science communities in Scotland for some time although not part of the practice of every teacher. What then was the educational rationale for change?

Scotland remains above the OECD average in science and is similar to the OECD average in maths. Boys outperform girls in maths and they perform at a similar level in science. Although the impact of socio-economic background on attainment is above the OECD average, data from the Scottish Qualifications Authority (responsible for all upper secondary qualifications) showed that there had been little decline in the number of young people studying STEM (Science, Technology, Engineering and Mathematics) subjects in the upper secondary school.

However, in 2008 the Scottish Government reported on the evidence from a national survey of achievement in science (SSA 2008). This showed, as in previous years, that a significant number of pupils were not achieving the expected levels of knowledge and understanding in science. Perhaps, most interestingly, there were considerable differences between the teachers' reports of their pedagogy and pupils' reports of their classroom experiences. Teachers reported active, inquiry-based learning as part of classroom practice, whereas students reported fairly passive experiences and information on attitudes showed that their interest in science continued to decline.

A survey carried out by the University of Glasgow using the ROSE (Relevance of Science Education) questionnaire in 2006 concluded that young people doubted whether science was on balance beneficial; Their views of learning in science and technology in school were also negative. There was low interest in STEM-based careers. More specifically, surveys confirmed that young people continued at best to be ignorant of engineering or at worst held damaging stereotypes; there was limited (and declining) interest in university engineering courses.

There was then a case to be made for change: 1) for teachers related to the evidence around attitudes to science and depth of understanding; and 2) for policy makers there was the mismatch between the policy aspirations of encouraging young people to go into careers in science and engineering and the current reality.

Personal and Professional Integrity - Engineering the Future (EtF) and the Fibonacci Projects

Having established a rationale for change in a Scottish context, in this section of this paper we describe how in two projects we attempted to design a model for change that would be sustainable. The first project, *Engineering the Future*, was funded by the Engineering and Physical Sciences Research Council to explore ways of building sustainable change in engineering education through:

- engagement and dialogue with politicians and policy makers (local and national);
- research to inform the project design and through the project to check for alignment, engineering research contextualised in schools, and research on pedagogy; and,
- exploring with practitioners the potential for engineering within the secondary school science curriculum (collaboration with teachers, engineers and industrialists).

EtF worked with teachers, educational researchers and university engineers in the collaborative development of inquiry units from S1-S6 (12-17/18) including those for high stakes school qualifications (Higher Physics) and the development of collaborative teaching, using of state of the art university engineering equipment to support research units for school qualifications (Advanced Higher Physics).

Did EtF contribute to differences in policy? The Scottish Government's Science Action Plan became a Science and Engineering Action Plan which recognised that it was essential that Scotland's young people understand the importance of science and engineering. The policy also identified a number of ways in which the outcomes of the Engineering the Future project could be taken forward.

The second project, the Fibonacci project, provided a focus for the Scottish participants to explore with colleagues from across Europe challenging issues around large scale change in inquiry-based science education. Within Scotland, the main task in the context of the Fibonacci project was to explore ways of building sustainable change in engineering education in primary schools. As the University of Glasgow was a TC2, the project was funded mainly by Scottish Government. The task was more complex than the EtF project because primary teachers are often less confident about science and engineering and there are far greater numbers of schools in more dispersed locations.

Working principally with colleagues from Klagenfurt in Austria and Helsinki in Finland, ideas of how to build sustainable networks and how to build sustainable models where schools could experience the excitement of contemporary science beyond the walls of the classroom e.g. through science centres became the focus of discussion. Fibonacci stimulated a think tank of ideas, from how to work with teachers to have them self-assess the quality of their own IBSE practices (Paris) to how to develop a deeper understanding of the practices of being a scientist, e.g. scientific notebooks (Berlin).

The same principles involving research, policy and practice underpinned this project. In particular it was agreed that the university team would work with Education Scotland, the national curriculum development and inspection agency, to develop a framework of exemplification. Examples, developed with teachers (originally teachers with an existing interest in IBSE) and engineers would use real engineering contexts related to key government policy aims (e.g. sustainability, renewable energy and health sciences) and would make links to engineering in Scotland (past, present and future). Resources were explicitly designed on inquiry-based learning principles and explicitly linked to the Scottish curriculum. To promote professional engagement amongst teachers with varying levels of confidence a range of levels of support were provided. The materials were designed to be developed by teachers to suit their own contexts and interests. Central to these materials were open-ended challenges to engage pupils.

Systemic integrity and sustainable change

There is a further design task necessary for a country that desires to change the practices in all of its schools: how to build from the engagement of a small number of schools to every teacher in every school. A pebble in a pond sends out ever increasing circles that are identical. Large-scale transformational change needs similar processes – an identification of what matters in the early stages of a process of change accompanied by a strategy to involve ever-increasing numbers of people. What matters in change is the same for the first person involved as for the last. This is the journey that Scotland is now undertaking, supported by the thinking and the practices of the Fibonacci partners.

Part of the Scottish Government's commitment to taking forward the work of *Engineering the Future* included the creation of a portal (STEM Central) to support teachers and included materials to support teaching developed in collaboration with teachers. The Glasgow University team offered a structure for the development of this on-line resource supported by people in a range of roles across Scotland.

Five strands of engagement were agreed:

- building capacity through enabling people to learn from one another where teachers work together, and teachers and engineers work together;
- engaging learners in a deeper understandings of engineering i.e. what it is and why does it matter;

- extending opportunities for learners to investigate Scotland's past, present and future in world leading engineering research and development;
- challenging and supporting learners to experience and understand the inter-relationships between their current learning and real world engineering; and,
- developing learners' understanding of and attitudes to careers in engineering.

The STEM portal makes resources available to teachers or provides a shared space for teachers to develop resources. However, this is only one step. A network of support involving local education authorities, science centres, STEM ambassadors, and University staff will work with teachers to promote better quality experiences in inquiry based approaches for learners.

This active professional role for teachers is becoming embedded in ideas of the professionalism of teachers, e.g. in professional standards, in employment contracts and in curriculum policy. The government in Science and Engineering 21 had made a strategic commitment to developing STEM education in the context of promoting engineering and science as key components of the economy.

Curricular statements argued that active learning is likely to be more engaging and therefore recognised more explicitly investigative and research skills. There is a focus on applications of science as they are more likely to generate interest. This is reflected in STEM curricular guidance and in the promotion of interdisciplinary learning. It is also recognised in the National Qualifications taken in the upper secondary school in the forms of a Researching Unit in each science qualification and of the Interdisciplinary Project in the group award of the Science Baccalaureate. This is reflected also in the advice and exemplification on assessment provided by Education Scotland through the National Assessment Resource.

The model of curriculum development where researchers, policy makers and practitioners are part of the development is a crucial aspect of sustainable change. As such, IBSE-pedagogy has tomust be part of what it is to be a science, engineering, mathematics or technology teacher. If a school inspector visits a school, s/he must look for IBSE practices. Each player in the system has a part to play. Like the back of an old-fashioned watch, all the cogs have to turn for the watch to work. If one of the cogs does not turn, the watch will stop. It is our task to ensure that all the cogs turn.

Examples of implementation of outdoor education

Outdoor education

Arja Kaasinen, Liisa Suomela, University of Helsinki

Outdoor education is understood and implemented as education that includes environmental education, biology and geography. For example, in biology there are plenty of themes that would be easier to understand and learn in nature. Outdoor education is an educational method that is widely used all over the world, although the concept of outdoor education has many meanings. In some countries it is very close or almost a synonym for environmental education. Emphasising the role of experience and emotion has connected it with adventure education and camping. In Finland, outdoor education is part of the school curriculum and it is taught during school time. The Finnish national core curriculum states that, "The contents of, and approaches used in environmental and natural studies are chosen… [in such a way] that studies can also be done as fieldwork".

The role of outdoor education has been only a fragmentary part of biology education, where the formal classroom setting has dominated the teaching. Limited connections to nature during childhood may influence the children and their environmental behaviour. The environment, outdoor space, and children's age, as well as the curriculum and teachers' views influence how outdoor learning and teaching should be carried out. Outdoor education is not a new innovation, but recently new approaches have started enriching it. For example, technological developments (mobile phones, social media, e-tagging) offer new opportunities for organising outdoor education. However, the content has to stay focused.

Outdoor education includes educational themes especially from biology and geographical education, but it is often also integrated into many other school subjects. Biology is a natural science, where living organisms play the main role. Outdoor education can help students learn and understand biology, but in addition to the basic role outdoor education plays in cognitive learning, it also has affective and motoric aspects. Rickinson et al.'s (2004) meta-analysis examined more than 150 research reports related to outdoor education between 1993 and 2003. As a summary, they conclude that there is abundant evidence of the effectiveness of outdoor education. Outdoor education has been found to be more effective in developing cognitive skills than classroom education. Touching, feeling, smelling or interacting in some other way with wildlife is an effective way of learning.

Outdoor education can stimulate students on the emotional level to understand on the environments around them. Fieldwork has been shown to motivate students. Motivation helps students to not only learn, but also to remember and recall the content of biology. It is often forgotten that teachers' motivation and confidence in teaching science subjects are also important. Experiences lead to emotions, motivation and meaningful learning. Outdoor education has been shown to be one of the most beneficial ways of learning.

One of the main benefits of outdoor education and fieldwork is that they guide and encourage pupils to do observations. Observing is not self-evident; it is a skill that needs to be learned. We all need perception skills in our everyday life and these skills need to be practised consciously. Well-prepared and executed outdoor activities are very useful in improving not only perception, but also other cognitive skills, such as memory, classifying, recognition and naming skills. It is also a very good way of raising environmental awareness of pupils, because many researchers have documented the concern of young people's diminishing relationships and awareness of nature.

Environmental problems such as the loss of habitats and biodiversity, climate change and all the other environmental challenges will have to be faced by everyone today and in the future. Without understanding how nature, ecosystems and the organisms inside it function and how people are influencing them, it is very difficult to realise how we can prevent environmental problems and how important it is to live in a sustainable way. Many times, understanding has a connection with motivation. Without going out, seeing, feeling, smelling and touching the real natural environment, it is impossible to wake up to the deep connection between people and nature.

Evidence of outdoor education in biology in Finland

Arja Kaasinen, Liisa Suomela, University of Helsinki

The popularity of outdoor education has been growing in different types of educational systems. In addition to the long tradition of teaching biology via field education, the rise in the importance of environmental questions globally among the attitudes of young people in particular has also added to the value of outdoor education. In addition, the trend of utilising open learning environments and informal learning sources in education in all its forms has a clear link to outdoor education, which clearly bridges the gap between formal education and informal learning.

Educational programme

Outdoor education is included in the basic course of biology didactics in the Department of Teacher Education at the University of Helsinki. This is the students' first course of biology and the only outdoor education course. The course includes both lectures and workshops. In the first lecture students have an exercise where they have to think the basics of the didactics of biology through some teaching subject, like how to motivate pupils to learn about plants. After the lecture they participate in workshops about humans and health, laboratory exercises focusing on biology, species recognition and outdoor education and fieldwork.

Figure 4 The Fibonacci-project team in the Nuuksio Nature Park forests in Finland.

During the outdoor education workshop students go outside for three hours. Outdoor education includes lots of practical exercises. Exercises have been chosen to stimulate ideas, and to encourage and motivate students to teach biology outside the classroom. One hour is used for doing activities in the forest and for the rest of the time students do exercises with water, insects and plants.

During the course, students work in groups. Activities that are trained are suitable for children aged 6 – 12, but can also be applied to younger or older children. The main philosophy behind the course is an inquiry-based learning method, where pupils can make observations on their own, seek and find, learn, inspire and become familiar with the feelings of success. They are given the tools to see the biodiversity and to understand it. Real plants, butterflies or spiders are always better than a picture from a school book!

The outdoor education biology course has been studied using the New Educational Model & Paradigm (NEMP) analysis tool. The statistical analysis of the data gave clear evidence of *three main factors*: 1) the independent characteristic role of outdoor education, 2) changes in learning environments, and 3) the innovative approach behind the successful administration of outdoor education. There was also a statistically significant difference related to age and work experience in relation to the items *Outdoor education as provider of feedback* and *Outdoor education as tool*. It seems that the longer experience of classroom work the teacher has, the higher extend she applies and appreciates the outdoor education solutions.

Field visit in Portuguese woodlands

Rosário Oliveira, Renata Carvalho, Carla Pacheco, César Garcia, Luz Figueiredo,
Ciência Viva, Portugal

The project, *A Woodland near You* has been running in Portugal for three years, and has involved more than 100 groups from primary and secondary schools in the study of local woodland ecosystems under the coordination of Ciência Viva and the support of an expert from the National Museum of Natural History. The support offered to schools included worksheets to guided field trips, advice on the choice of woodlands, help in the identification of species and workshops focusing on woodland biodiversity. Groups in the project were also helped by local science centres, environmental groups and authorities (e.g. fire fighter departments).

Ciência Viva decided to integrate this project in Fibonacci as it promotes inquiry-based activities carried out in out-of-school environments and it has had an impact in the school and local communities. The work of all the groups has been organised into a book published recently. The online version is available on the project website: http://www.cienciaviva.pt/bosque.

Students got involved in a broad variety of activities which created situations for problem solving, experimentation and observations. During field trips pupils collected biological materials (leaves, seeds, fungi, lichens), taking into consideration the preservation of species. Learning to read a map of the region and to working with the coordinates on Google Earth are examples of skills children developed.

Preparing the field trips involved creating curiosity in the pupils and getting them familiar with the tools so they could make observations, identify plants and animals and collect specimens. The field trips were followed by further observations and activities in class that helped pupils understand the material gathered. Realising the relationship between climate and other variables with regard to the patterns of the distribution of species and the identification of climate indicators were other issues pupils learnt about.

Teachers reported that the project activities carried out outside of the classroom were highly motivating and helped children learn about the different issues related to the natural ecosystems, namely the importance of woodlands for air quality, provision of food, medicines, and the geo- and biodiversity of woodlands for the prevention of erosion. The project activities opened up opportunities for engaging pupils in autonomous activities that promote initiative and collective decision-making e.g. the definition of strategies to disseminate information about the ecosystem in the local community. In the following sections, activities carried out in two primary schools are described.

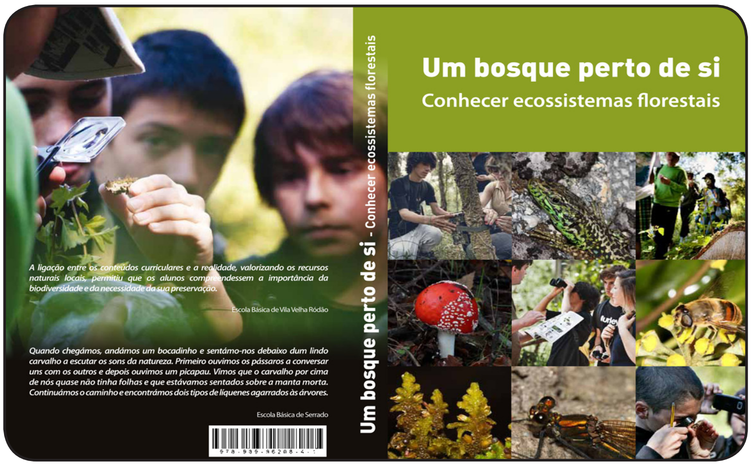


Figure 5 Web-based activities and information collected by schools in the project.

Studying a montado ecosystem

A primary school group from a rural area (Gloria school, Estremoz) studied a rich ecosystem typical of the region: the *montado*.

Becoming familiar with the trees found in montados, cork oaks (*Quercus suber*), was one of the tasks pupils got involved with during their field trip. In order to find out which animals live in the ecosystem, the children made observations in tree trunks, in the soil and in the banks of a small stream. By observing and touching the bark of oaks the children started wondering about the characteristics of cork. The children were invited to observe mosses on trees and to find out the reason why they were just found on a specific side of each tree trunk (a compass was used as a support).

“How do mosses survive?” was an initial question that was used to involve the children in discussion. During the field trip, in order to help answer the question, small bits of moss were collected so they could be observed in class. Looking for specific lichens that function as bio-indicators in order to come to conclusions about the quality of air in the montado was another activity. Trying to find out where and why water was to be found in the montado was another challenge the children faced.

Back in school, pupils were challenged to check their predictions, namely the cork’s isolation capacities (sound and temperature) and resistance to fire. In order to come to conclusions, experiments were set up and carried out. Information from all groups was shared, and specimens collected during the field trip were observed. Using guidebooks and with the help of an expert, the children classified and organised specimens into previously labelled envelopes. These specimens then became part of the school collection that was made available for the school community.

An expert in the traditional uses of plants helped the children with the identification of the specimen. An expert from the Estremoz science centre gave support to the school teacher in the planning of activities and the preparation of the school trip.

Figure 6 A field trip to the woodland near the school.

Field visits to Serra da Boa Viagem

In spring time a class from a school in the centre of the country (Buarcos, Figueira da Foz) went on a field trip to Serra da Boa Viagem with a double mission: to perform observations of the ecosystem and transplant the small oak (carrasco, *Quercus coccifera*) that had grown in the classroom from an acorn from a previous visit to the woodland.

On their arrival, the group observed the changes that had occurred in the woodland after their visit in the autumn. New leaves and flowers were to be seen, whereas fruits in the trees and plants no longer existed. Insects were seen pollinating flowers from plants the children were already familiar with: *Crataegus monogyna*; *Smilax aspera*, *Rubia peregrina* and *Rubus spp*.

Two plants took the children's attention: *Allium roseum*, whose leaves the children realised had a pleasant smell, but the roots of which smelt like garlic and *Dipsacus sativus*, whose common name (cardo penteador) comes from its function in ancient times - to card wool.

The children were invited to sit under an oak tree (*Quercus robur*), be silent, shut their eyes and listen to the sounds of the wind and the birds singing. The whole group turned around when Alexandre shouted he had seen a squirrel; but the animal had escaped. However, a gnawed cone found on the ground proved he was right. This was the starting point for doing observations of animal marks in the ecosystem.

The group chose a site to plant their oak. Pedro and Ana, with the help of the teacher, dug a hole for the seedling. When holding it, the children noticed that a little bit of the acorn was still to be seen in the root. A sign was put next to the plant for easy identification on future observations and would allow children to realise the slow growth of trees.

In the weeks that followed the visit, with the help from experts from the community, a miniature woodland was recreated in class and put next to the terrarium previously built with materials collected in the group's first visit.

The sounds recorded in the woodland during the field visits in different seasons were later used to create a multimedia narrative, the Orchestra.

Figure 7 Observing plants in the Spring time.

Cities as urban open learning environment for young people

Sirpa Tani, Reetta Hyvärinen, Noora Pyyry, Pauliina Rautio, University of Helsinki

The importance of different learning environments – formal, informal and non-formal – have been recognised widely in the studies of education. Virtual learning environments have been included as integral parts of institutionalised education in schools, and, at the same time, more attention has been paid to different physical environments outside of school (such as museums and science centres). This trend is important because of its potential to 'open' school doors to the surrounding society.

In geography curricula, students' everyday environments, their environmental experiences and own observations have traditionally been important especially in the early years of education. Hence, the idea of expanding educational contexts to the daily spaces where life is situated is not a new phenomenon for geography teachers and teacher educators. However, these ideas are relatively new in the studies of educational sciences. In recent years, a 'spatial turn' in education has been witnessed.

Today cities are environments where learning often takes place, because the majority of the world's population lives in urban areas. This means that urban environments are the closest and most familiar spaces also for young people. Everyday life happens in these urban settings and young people thus construct their identities in relation to their environments.

Figure 8 Challenge: inclined plane.

These issues are explored in the project "Dwelling with the City" where children's and young people's ways of living with their environments are studied especially from the perspectives of housing and living, and as potential for new pedagogies of place. The objective of the project is to produce in-depth understanding of the ways in which young people grow co-existing with their everyday life environments. The cities as sites of research are Oulu, Helsinki and San Francisco. More often than not questions about living and housing are approached from adults' perspectives: their views on ideal housing environments, aesthetic values and needs guide decision-making in planning processes. At the same time, children's and young people's opinions are easily neglected.

There has also been relatively little research on young people and their experiences of 'home' and belonging. As the actual home is often a place where children and young people are subject to direct control by their parents, they attempt to carve out space for themselves by playing and hanging out in their residential neighbourhoods. Research in the project "Dwelling with the City" produces new knowledge of the ways by which children and young people dwell with their living environments and negotiate the spatial limitations of their everyday lives. Children and young people are approached as competent, creative users and legitimate residents of their living environments. By paying attention to the multifaceted meanings that are attached to urban spaces by the young residents, new aspects for open learning environments can be reached.
http://dwellingwiththecity.wordpress.com/.

Figure 9 Cities as open learning environments for young people in Finland: Half pipe.

Examples of implementation of science-centre pedagogy

Science centre pedagogy

Hannu Salmi, Arja Kaasinen, Veera Kallunki, University of Helsinki

"Science education is not only a question of advancing technology or of demands for a scientifically qualified workforce, but is also a question of social goals. The aim is not solely to produce more scientists and technologists; it is also to produce 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." (Coombs 1985)

The role of learning in informal contexts is increasing in modern societies. This phenomenon is closely related to the growing impact of science and technology on our everyday lives. Lifelong learning needs new practical forms.

A science centre is a learning laboratory in two senses. First of all, it is a place where visitors can learn scientific ideas by themselves using interactive exhibit units. Secondly, it is a place where informal education can be studied in an open learning environment.

In the USA, the background to the expansion of modern science centres in the 1960s was the Sputnik phenomenon. The crisis in national confidence that resulted from the successful launch of Sputnik had a knock-on effect on all education in the USA. The attitude towards the study and teaching of science dramatically changed. The educational system in the USA was totally reformed.

The San Francisco Exploratorium opened in 1968. In the 1970s and 1980s there was a period when nearly identical exhibitions were built by science centres just by copying exhibit units and whole exhibitions from other science centres. The main source for this was the 'Exploratorium Cookbooks', which were to a large extent published for this purpose. Many new institutes still utilise this concept for their main content, which says much about the international nature of science and science centres. However, the staff of science centres adapt their national and local features with their own ideas when choosing the content, design and programme ideas.

Frank Oppenheimer has been quoted as the creator of the science centre pedagogy. His criticism of the passive pedagogy of science education derives implicitly from John Dewey's ideas (1938) expressed in his thesis 'learning by doing'. The same approach can be seen in contemporary developments in science centre pedagogy: The famous hands on principle articulated by

Oppenheimer is a corner stone of the principle of interaction in modern science centres. What Dewey and modern science centre pedagogy share is the accent on motivation, free will and the learner's own activity that is stimulated but not forced.

The growth of science centres since the 1990s is closely related to the developments of the information society. Communicating science to the public via different media is not only a matter of giving sufficient support for scientific research and academic education in society, but is also a process of giving citizens their basic democratic rights in relation to scientific information.

The continuing world-wide trend is for a broadening of the subject range of science centres and an increasingly interdisciplinary approach to exhibition themes. One non-trivial problem that has been raised in the discussion of the role of science centres and universities is related to the meaning of the word 'science'. In English, science generally means the natural and physical sciences and is often limited to physics, chemistry and biology. However, in German, Swedish or Finnish, the words 'Wissenschaft', 'vetenskap' and 'tiede' include the humanities, history, psychology, social science and linguistics. The modern science centre must be able to present phenomena related to all academic research. Accordingly, the content of the leading science centres in Europe has been planned in an interdisciplinary way. The content of exhibitions is supported by a broad spectrum of temporary exhibition themes. Also the recent PISA (Programme for International Student Assessment) results are showing the importance of this relation and interaction between science and society.

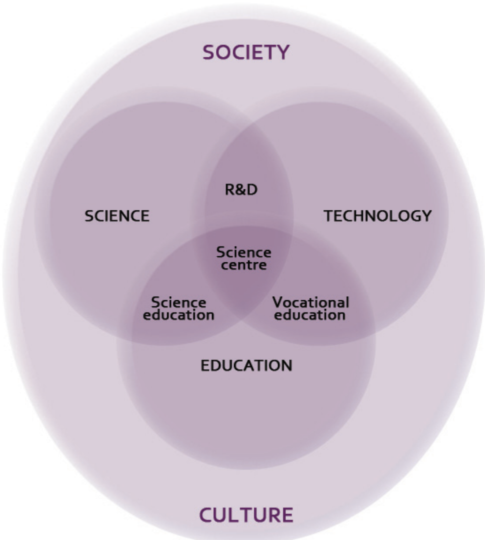


Figure 10 Education, Science and Technology in the context of Society & Culture (Salmi 1993).

Figure 10 presents the positions of a science centre in its relation to science, technology and education, and can be well used in order to explain and express the main goals of the European Commission Science & Society programme, and the way in which these objectives are met through the cooperation between science centres, teacher education and school authorities. Science education is presented in Figure 10 at the point where science and education overlap. Science and technology meet in the area of research and development (R&D), within which academic research is used to develop industrial methods. Vocational education is at the intersection of technology and education.

In the same figure, the science centre is located where science, technology and education meet. According to this description, a science centre features all of these three fields. Any exhibition, event or educational activity like the mobile science exhibition, combine these three elements and adapt them to the nature of the specific content.

Positive attitudes toward science and technology and the motivation for science education are created at a young age both in the field of cognitive learning, but also in the more affective sides of education. Also the European Commission's *Rocard Report* has underlined the importance of this phenomenon. This report and other presentations describe the situation mostly in the pre-schools, primary and secondary schools while we also see the trends around formal education. The role of learning in informal contexts is increasing in modern societies – meaning the countries which are developing their societies by investing and creating opportunities for research, innovations, and education.

The phenomenon is closely related to the growing impact of science and technology in our everyday lives: Lifelong learning needs new practical forms and formal education can learn something from the informal, open learning environments found in science centres.

Informal science laboratories for pre-service teachers and pupils to learn together in Germany

Petra Skiebe-Corrette, Frei University of Berlin

Informal science laboratories are out-of-school laboratories where school students perform experiments themselves. They were founded in response to the declining number of students electing to study the "hard" sciences such as chemistry, physics and mathematics. The first of these laboratories was founded in the beginning of the 90s; Today there are about 120 within Germany.

The aim of these laboratories is to increase children's interest in science by providing hands-on activities in an authentic environment thus giving a realistic and modern view of science. Most of these laboratories are located at universities and research institutions, but they can also be found in science centres, museums or industry.

Most informal science laboratories invite school children to perform hands-on experiments for a couple of hours or a day, but some also offer courses that last a couple of days. The topics of the experiments in most informal science laboratories concern biology, chemistry or physics, but there are also laboratories that have technical or mathematical topics. These topics can relate to the research of the institute and/or to the school curriculum. The children that visit can be primary or middle school pupils or high school students. Often an informal science laboratory caters to multiple grades, but seldom to all grades. Entire classes are able to visit most of the science laboratories.

In order to learn from each other and to better lobby, local networks of informal science laboratories were formed, as well a national association of informal science laboratories, called LernortLabor - Bundesverband der Schülerlabore e.V. One of the first local networks that was founded is called GenaU (Gemeinsam für naturwissenschaftlich-technischen Unterricht, Together for science and technology education), which includes 16 different informal science laboratories from Berlin and Brandenburg, two of the 16 states in Germany. All three universities in Berlin and many of the large research institutions, including e.g. the DLR (Germany's national research centre for aeronautics and space) and DESY (one of the world's leading accelerator centres) run informal science laboratories.

Many informal science laboratories offer post-service teacher training. Some of the informal science laboratories at universities, like the three at the Freie Universität Berlin, are also used to train pre-service teachers. Within a laboratory, content, pedagogical and pedagogical content knowledge can be acquired.

For example, one group of 29 pre-service primary teachers helped develop a set of experiments concerning honey for use in the informal science laboratory.

In order to gain content knowledge the in-training teachers visited a research institution (Länderinstitut für Bienenkunde Hohen Neuendorf e.V.) that focuses on honeybee research and offers services to beekeepers. If a beekeeper wants to mark a honey e.g. as linden honey, the honey has to meet specific standards. The honey has to pass a sensory analysis: it has to taste, smell, feel and look like linden honey. In addition, 20% of its pollen has to be from linden trees. The honey has to meet other standards, including having a water content below 20%, a conductivity below 0.8 mS/cm and lie in a particular pH range. In the honey institute, the in-training teachers visited the laboratory where these parameters are investigated and talked to experts.

The in-training teachers used their pedagogical content knowledge to design five experiments for primary school pupils that would allow the children to test the following parameters: pH, water content, conductivity, pollen content and sensory experience. The students developed word cards for the sensory station that would help children with language difficulties to find the right vocabulary. They also learned to develop and optimise each experiment, and to overcome obstacles when an experiment did not work.

Figure 11 Primary school pupil analysing honey in NatLab, one of three informal science laboratories of the Freie Universität Berlin.

Pedagogical knowledge was acquired by the in-training teachers through supervising different children from different primary grades and different school districts. This contact led to multiple revisions of the different stations and to reflection by the in-training teachers of their teaching practises and a questioning of their own content knowledge. As seen in this example, informal science laboratories can offer valuable experiences for pre-service teachers, as well as for the pupils that visit the laboratories.

Exploring Science with Fridolin in Austria

Andrea Frantz-Pittner, Silvia Grabner, Naturerlebnispark Graz

The Fridolin programme represents a long-term cooperation between science centres and schools in Austria. The programme includes didactic activities, support and underpinning teachers' continuing professional development (CPD). The programme is based on aspects of interdisciplinarity, process-orientedness and networking. Interdisciplinarity means discovery learning, which seeks to connect with the day-to-day reality of children that cannot be achieved in the narrow framework of the separate subject disciplines alone. The different perspectives of the various disciplines and fields of activity were incorporated in both the creation of the teaching content and materials as well as in the composition of the team. The process-oriented aspect of the Fridolin programme highlights learning as a continuous, "never-totally-completed" process. In addition, the programme regards networking of various actors and institutions as one of the central principles.

Figure 12 Thinking and doing with Fridolin.

Philosophy of Fridolin programme

In a world which is determined by the natural sciences, a basic education in them is an important prerequisite for making reasoned decisions and for participating in the social discourse. Science education means a lot more for the Science Education Centre in Graz than just instructing learners in the facts of natural science or than preparing them for a vocation involving the natural sciences. What is really meant is a philosophy of actively approaching the world, and of passing on the empowerment to participate in society's decision-making processes. We see science education as a synthesis of ways of thinking and doing, conceptual knowledge, values and attitudes as well as fundamental competencies.

For us, a natural science mindset represents the prototype of an effective problem-solving strategy. In this way, science education can make an important contribution to the formation of personality. In this spirit, acquiring evidence-based problem-solving strategies, practice in negotiation processes based on solid argumentation, and reflection on one's own thought processes are consequently at the centre of how our teaching is prepared, shaped and managed, and also of our own strategies for action.

The Fridolin programme represents the realisation of these principles in three fields of activity, each of which is closely connected to the others: a teaching approach, a support system for schools, and a framework for CPD and research.

Teaching approach: Central Elements of the didactic setting

The age-appropriate teaching programmes created in the Science Education Centre "Nature Adventure Park" follow a problem-oriented approach, in a didactic constructivist way. This can be found in constructivist-influenced teaching approaches such as "Anchored Instruction" or "Problem-Based Learning". These are the lines along which the teaching activities in the School Biology Centre aim to support the sub-competencies of scientific literacy. The didactic basis for that is the prevalent understanding of the Inquiry-based Learning of the School Biology Centre: Inquiry-based learning is a way to expand and change one's own concepts through investigative procedures. The basic structure of investigative working used therein (question - systematic application of suitable methods to gain information - reasoned logical conclusions) is a basic model for a problem-solving procedure which can also be transferred to other areas of life.

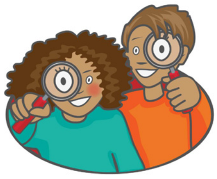
As summary, it is not the individual activity which is characteristic of Inquiry-based Learning, but its integration in a complete problem-solving process. Therefore, the creation of adequate contexts, as well as a structured sequence of coordinated steps toward findings, are of central importance to us.

Exploring Science with Fridolin

The project provides the structural framework for 3–9-years-old children to experience a scientific process of understanding as a form of structured problem-solving and to acquire competencies in the following procedures below. The stimulus for problem-oriented learning processes are adventure stories based on the hand puppet Fridolin, in the course of which challenges arise. These so-called challenges can be met only through structured inquiring. In this way, all the activities and subject matters are given a meaningful context and a higher-level of meaning. The stories are designed in such a way that several paths lead to the goal. Scenery and props support the learners' identification with the narrative scenario. In order to solve the problem, the four most important approaches, which scientists also use to gain insights, are used in a suitable form for children. These are the study of literature, scientific discourse, observation and documentation of phenomena and hypothesis-led experimentation.

Scenery, Staging and Exhibits In accordance with the teaching topic the rooms are designed as an imaginative learning landscape into which single exhibits are integrated. The hand puppet Fridolin enters into a dialogue with the children (optionally supported by minor characters) and introduces into the framework story.

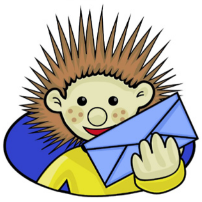
Fridolin's Clever Book In Fridolin's clever book there are texts and pictures. There are also tiny messages in the book which can only be deciphered with a magnifying glass, plus scrambled pictures, secret writing and similar "disguises" for the texts. These pieces of information help in solving the problem.



Observing and Trying out The children get to know tools and ways of working which support directed perception. But also the - playful and not yet systematized - trying out serve the purpose of opening up a topic area and have an important role to play in the process of insight.

Fridolin's Experiment In a ritualized sequence the children are given support in voicing suppositions, identifying modifiable and stable factors, documenting results and drawing conclusions from them.

Conference of Experts For the children the presentation of their own suppositions and opinions, the describing of observations and insights, the reasoning about conclusions as well as the confrontation with other points of view are important elements of inquiry learning.



Letters from Fridolin An exchange of letters between the School Biology Centre and the individual classes makes it possible to continue beyond the direct contact and thereby to provide new challenges as stimuli for inquiry-discovery-based learning processes in classroom work.

The Support-System

The basic structure of *Fridolin's Nature Stories* can be repeated in a wide variety of forms and contexts, for example as a giant research adventure in the school biology centre, or as a teaching visit by the Science-Centre Team, as classroom work with challenge boxes, as support for the regular lessons held by the teachers, or as an excursion to other school-external settings, for instance to local businesses.

Depending on the needs of the teachers, support at different levels of intensity is combined with the activities above. This ranges from a completely planned and held teaching unit in school, to the simple provision of materials, or possibly also to the provision of a telephone hotline for subject-specific or organisational questions.

An essential aspect of all this is that several "Fridolin" activities can be joined together into one stringent process by means of the connecting function of the framework story. Thus, "Fridolin" continues the combination of visit, pre- and post-visit activities and offers the opportunity of entering into a circular process of Science Centre visits and formal educational activities, in the course of which the level of independent activity of the teachers can be increased.

Continuing Professional Development (CPD) and Research

An effective contribution to the sustainable implementation of inquiry-based science education (IBSE) can only be achieved by science centre activities if the support offered is accompanied by CPD measures. Consequently, the relationship is not viewed as one between "service provider" and "consumer", but rather that everyone involved see themselves as a learning community in which the on-going development of teaching can occur through reflection on practical experiences. To achieve that, structured opportunities are required in which meetings are held and space for reflection and creative potential develops.

- Workshops are held for the teachers participating in the Fridolin programme, on three levels. Firstly, the teachers get to know the existing materials and approaches, then they adapt these for their own teaching purposes, and finally they develop their own teaching ideas.
- The "Science Breakfast" creates an attractive setting for the inter-institutional exchange of ideas. The teachers, the didactic specialists from the Science Centre, pedagogues and natural scientists discuss together topics of and approaches to Science Education.
- The inclusion of teachers in Action Research processes strengthens their competence in reflecting on their practices, and enables the individual organisation of IBSE activities which are oriented towards the needs of all involved. Through the inter-connected processes of teaching development, teaching activities, and evaluation in the sense of an action research process, discovery learning can successfully be adapted to the needs of the children and their teachers.

The challenge is to develop appropriate investigative tools, which are suited to the language and developmental level of very young children. Investigative designs which pick up on the elements of narrative teaching settings and use these to provide data have proved successful in this respect. Examples would be Puppet Discussions, interactive mind maps, or "vignette" (mini-scenarios) research using toy figures.

External Environments of the School and Motivation: A Case Study at the UK National Space Centre

Tina Jarvis, University of Leicester

Importance of considering attitudes to science

Science centres can generate a sense of wonder, interest, enthusiasm, motivation, and eagerness to learn, which can be neglected in traditional formal school science. Further results show that the negative attitudes may contribute to the reduced uptake of science and the shortage of scientists. Attitudes not only influence views of science and aspirations for future careers, but they can also influence attainment. Children with a more positive attitude toward science show increased attention to classroom instruction and participate more in science activities. The correlation between attitude to science and achievement appears stronger for girls, indicating that a positive attitude is more necessary for girls to enable them to achieve high scores.

Research at the National Space Centre, UK

Research undertaken at Leicester University investigated attitude changes of 300 children, aged 10 or 11 years, from four schools, who visited the Challenger Centre and general exhibits at the UK National Space Centre in 2002 (Jarvis & Pell 2005). The Challenger Centre is a two-hour experience for a class in two groups. Each group takes a shift in mission control and on a space station. The main challenge is communication about on-board science investigations as well as coping with life-threatening problems. The pupils also visited the main exhibition area where there are full-sized rockets, satellites, and other space capsules in themed galleries, which cover the following: how astronauts travel to and live in space; the planets; exploring the universe; as well as methods and reasons for orbiting the Earth, such as monitoring weather and ozone levels.

Attitudes toward science and space were explored by examining responses to five different attitude scales based on instruments developed over several years. These were administered before, immediately after, and 2 months and 4–5 months after a visit to the main exhibition area and Challenger Centre. Observations during the visits, interviews with teachers and a sample of children were carried out.

Figure 13 National Space Centre.

Pupils' greater interest in space and the value of science in society

Before the visit girls were more anxious than boys. Immediately afterward, children showed more interest in space and a moderate increase in their views about the value of science in society. Nearly 20% of the pupils showed an increased desire to become scientists in the future. These children also showed a positive advantage over the other children with regard to science enthusiasm and space interest. Two months later, they continued to be more positive about becoming future scientists, but only the girls' scores were still significantly high. This indicates that the experience was particularly valuable for girls.

Positive and negative effect of teachers' attitudes, preparation and follow up

Most children found the Challenger experience positive where a careful structure was given by the experienced staff of the National Space Centre. However, their experience was more variable in the exhibition area. Teachers' personal interest and preparation regarding the general exhibition area had a significant long-term effect on children's attitudes.

The teachers of the classes with the highest attitude scores throughout the project prepared the visit thoroughly along the lines suggested by the National Space Centre. Children had been told what to expect beforehand. The children were clear that their visit was primarily a learning experience and a range of follow-up work was carried out. The class with the highest attitude scores had also been given tightly focused and manageable tasks for the exhibition area. While it was clear that preparation and follow-up work is important, the right type of preparation was essential, as one teacher's excessive tasks may have had a negative effect on her children.

The teachers' personal interest was important. One teacher was personally inspired by the visit. He said, 'I was really impressed, really really interested.' The children enjoyed their visit, but he admitted that on a future occasion, he would make sure the children were prepared more effectively so that they did not treat the Space Centre as a 'theme park'. Although he had not done any preparation, his follow-up work was more thorough. His enthusiasm for and enjoyment of the visit was clearly evident to the children. This seems to have helped promote and establish the children's attitude gain, unlike with his colleague who clearly did not enjoy science. This latter teacher said she personally did not like the exhibits and that science did not interest her. She did not do any preparation with the pupils and provided very limited follow-up. These pupils' attitudes to science went down after their visit and continued to decline throughout the year. Several research results do also indicate that pupils' attitudes tend to mirror that of the teacher.

Maximising pupils' positive attitudes

Teachers who were most successful in promoting their pupils' attitudes did the following:

- visited the science museum beforehand and participated in related in-service;
- shared the purpose of the visit with the children before the visit;
- made it clear to their children that the visit was a learning experience, not only a recreational day out;
- explained the structure of the day and the environment to the children before the visit to reduce anxieties about being lost or not knowing what to do;
- enabled children to practise skills that were necessary to optimise their involvement in any practical work;
- provided tasks to be carried out at the science centre that were manageable for both children and helpers;
- had a limited number of open-ended tasks at the science centre that required observation, discussion, and deduction rather than a lot of written recording of factual information;
- advised helpers that they should give practical help with hands-on activities, act as partners for children in activities, read labels for the children, and discuss exhibits;
- did follow-up work in the classroom;
- sent parents information about the day to help them talk about the visit with their children; and,
- reviewed and recalled the visit and ideas experienced in the science museum later in the academic year when studying related new science topics.

It is important to recognise that visits to science centres can have negative outcomes. It is not enough just to take pupils on a trip. Teacher training institutions and science museums need to consider how to enthuse teachers' personal interest in science museum exhibits, because it is clear that, although it is essential to provide pedagogical advice and support, teachers also need to be inspired and enthused themselves.

Pre-lesson – Visit – Post-study: learning repeated in Finland

Hannu Salmi, Veera Kallunki, Arja Kaasinen, University of Helsinki

Every autumn in Finland 120 in-training teachers participate in the two-day course Integrative Science Education Course at the Finnish Science Centre Heureka. The course highlights the role of learning in informal contexts uses the Pre-visit – Visit – Post-visit –model as a pedagogical approach. The three-step model is a research-based pedagogical tool for teachers to be utilised, for example, in pursuance of planning science centre or natural museum visits. The course integrates different natural sciences in a way that promotes an active learning process and intrinsic

The three-step model is based on the 5E learning cycle that was first used as an inquiry lesson planning model in the Science Curriculum Improvement Study (SCIS) programme, a K-6 science programme in the early 1970s. The phases of the 5E model – engagement, exploration, explanation, elaboration and evaluation - highlight the main aspects of inquiry-based science education. The phase of engagement means getting to know the topic. In the phase of exploration, different ideas of pupils are explored through hands-on activities. Explanation is an advanced phase giving explanations and clarifying understanding. In the next phase, elaboration, the topic is deepened by applying the learnt concepts to new fields. The last phase involves an evaluation: both self-reflection and the teacher's evaluation take place.

The three-step model activates learning during the science centre visit, because both the pre-visit and post-visit phases deepen the topic. The model takes into account, for instance, the following aspects of learning: orientation, motivation, focusing and preconceptions about a topic to be learned. Engagement takes place in the pre-visit phase, whereas exploration, explanation and elaboration belong to the visit phase, and evaluation is performed in the post-visit phase. In the table below, the exemplary details of using the three-step model in the Integrative Science Education Course at the Finnish Science Centre Heureka are presented.

Laboratory workshops mean taking part in workshops of the open laboratory and children's laboratory in the role of a learner. The aim is to give in-training teachers possibilities to familiarise themselves with the role of a visiting pupil by carrying out the following activities: doing experiments, cooperative learning, and learning by doing. In this way in-training teachers notice how these kinds of hands-on activities increase motivation. These workshops follow the typical structure of laboratory workshops including also the phase of giving explanations of the observed phenomena.

During the science theatre shows, "Why doesn't the cow fly?" and "Gas World", the structure of the workshops includes the typical pre-visit and visit phases of the three-step model. In the role of a learner, in-training teachers' curiosity is provoked, they are asked questions about current affairs and they propose preliminary explanations or hypotheses. Finally, they can propose simple investigations of the topics. After that, in the visit phase, in-training teachers carry out observations, and in the final discussion the host of the show gives explanations based on evidence, and also other possible explanations are together considered.

The final part of the two-day course is familiarising with the Heureka Classics exhibitions that include all phases of the model. For an example of this, see the lesson plan that is downloaded to the OSR portal. It is called Heureka Classics - Science and Fun: http://www.osrportal.eu/connect.php?m=thenewviewer&nid=95849.

Pre-Visit Stage

As an introduction the teacher education takes place in the University, other institute, on a special course, or through remote ICT-learning.

- The subject matter of the exhibitions is part of the professional and personal development for all the teachers.
- Use of ICT as a cost-effective pre-lecture for *the orientation for the visit* itself, and *the focus of the visit* to the Centre.
- Pre-tasks for the visit stage.

Visit Stage

Training takes place in science centre open learning settings (workshops, demonstrations, experiments, laboratories, planetarium, exhibitions, out-door settings, etc.).

- The main impact for the visit to the science centre is *intrinsic motivation and learning by doing.*
- As supplementing impact for the visit to the science centre the teachers mention a) the exhibitions content as an entity and b) having an opportunity to utilise varying learning methods.
- The teachers impact of the visit to the science centre is well-organised especially in relation to their school rhythm, and the visit to the single exhibit unit (like laboratory).
- The co-operative learning nature as an impact of the visit to the science centre is found important by the teachers.

Post-Visit Stage

Utilising the hands-on methods learned in the science centre back at school in teaching as well as bringing ideas for pupils and studentsimpact for the subject matter, the most important for the teachers is "learning by doing".

- Impact for the subject matter, the most important for the teachers is "learning by doing".
- Impact of the opportunity to apply a method "to make observations".
- Impact of Laboratory, Demonstrations, and Planetarium as specified by IBSE personal & professional learning sources.
- Impact of the entity: Pre-lecture + Visit + Post-lecture, back added-value for their work (while the teachers invest a lot of their – especially mental – resources for the process!).

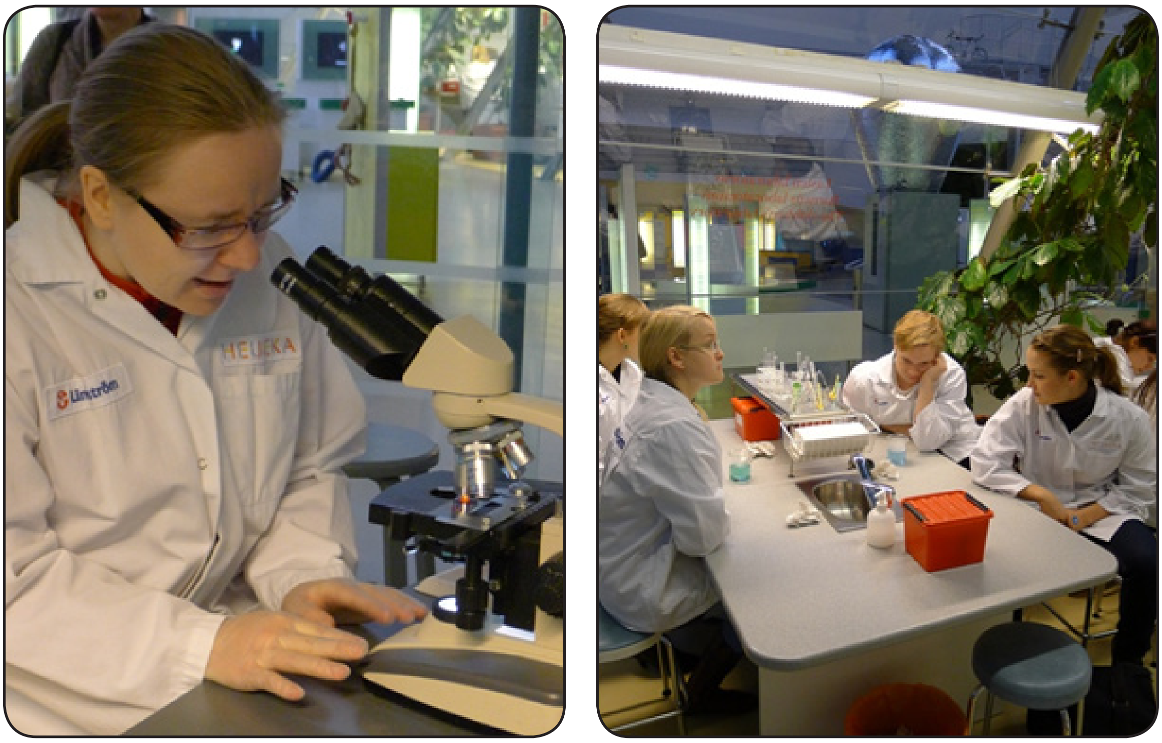


Figure 14 Integrative Science Education Courses for in-training teachers at Heureka include lots of possibilities for experimenting in workshops.

School visit to Heureka Science Centre using the three-step model

One of the schools participating in the Fibonacci project was Suutarila Lower Comprehensive School. The school is situated on the outskirts of Helsinki, a half hour drive from the city centre. The school was founded in 1982. Suutarila Lower Comprehensive School is a fairly big primary school in Helsinki having about 380 pupils and about 30 teachers and other staff. Despite the large number of pupils our school has a cosy and pleasant atmosphere. Classes 1-6 from from the school participated to the Fibonacci project through pupil visits to the Heureka Science Centre and by taking part in the project training sessions. In the following example, pupil visits to the Heureka Science Centre using the three-step model as a pedagogical tool are described (http://www.fibonacci-project.eu/).

Dinosaurs in Science Park Galilei

Pre-Visit

Before the science centre visit the 4th graders (10-year-olds), made their own mind maps of dinosaurs. In addition to written concepts and sentences these maps also included the pupils' drawings about the topic. In this phase Heureka's webpage about dinosaurs was also introduced to the pupils and some pre-visit tasks were performed.

Figure 15 Left: An artist's impression about an asteroid collision to the Earth (Figure: Wikipedia), right: Meteorite collision in the school experiment (Figure: Ari Bergström).

Visit

In the science centre the pupils familiarised themselves with the exhibitions. In particular, they were motivated by the self-directed experimenting such as searching for fossils of dinosaurs in the sand.

Figure 16 The mass extinction of Triceratops: Left: 1 second before the collision, middle: 1 mill second before the collision, right: asteroid collision causing devastation (Figure: Ari Bergström).

Post-visit

The dinosaur exhibition was discussed at school after the visit. In particular, pupils were interested in the mass extinction of dinosaurs. Every pupil made a new mind map of dinosaurs. There were also discussions about geological eras and meteorite collisions. Following this, the entire class made an experiment about the meteorite collision. The teacher dropped three stones of different sizes into a bowl of sand where there were also toy dinosaurs. The stones simulated the meteorites. The meteorite collision experiments were videotaped. The different phases of the collisions are portrayed in the following figures.

Using ICT to apply three-step model in European context

Veera Kallunki, Hannu Salmi, Arja Kaasinen, Jani Koivula, University of Helsinki

The three-step model has also been utilised in different ICT-based teaching environments. In this chapter, applying educational portals and augmented reality with the three-step model are introduced.

The Open Science Resource (OSR) is a portal that enables access to the digital collections in European science centres and museums, to follow educational pathways connecting objects tagged with semantic metadata and to enrich the contents provided with social tags of your own choice. The portal includes numerous educational materials such as images of exhibits and scientific instruments, animations, videos, lesson plans, student projects and educational pathways with guidelines for interactive museum visit experiences. http://www.osrportal.eu/

The pedagogical model used in planning the lesson plans is the three-visit model. Teachers can either use the lesson plans in their own teaching, or to design new lesson plans and upload them to the portal. The software of the OSR portal guides a teacher to use the three-step model in the planning, so the lesson plans get a pedagogically meaningful content for the science centres or museums.

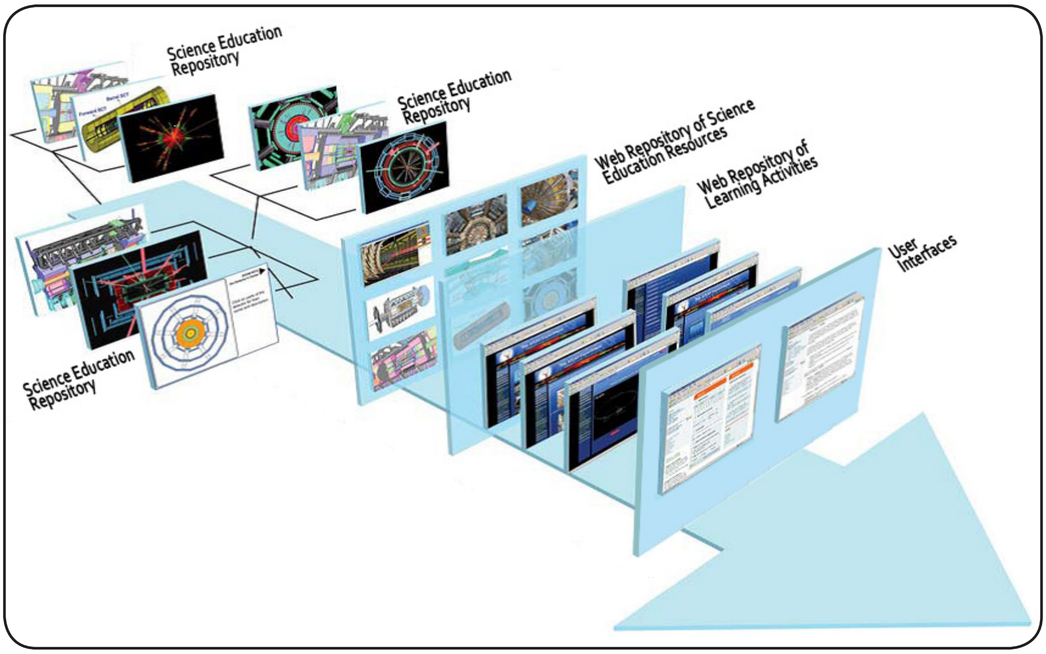


Figure 17 Combination of different ICT-based learning sources for pre – visit – post –materials.

Augmented reality generally means a modern computer-assisted learning environment that combines the observed real world phenomena with graphically added information or images; even spatially positioned sounds can be used. The meaning of augmented information is to enrich the original phenomenon by information that is useful in many kinds of revolutionary applications in education, including the study of architecture, art, anatomy, languages, decoration, or any other subject in which a graphic, simulation or 3D model could improve comprehension.

Technically, the virtual information produced by computer is merged with video streamed from a webcam that is recording the real world phenomena. The result is similar to virtual reality, but uses real-world images in real time. In short, augmented reality supplements real world perception and interaction allowing the user to see a real environment augmented with computer-generated 3-D information.

Basically, it has been shown that virtual learning environments promote better learning results. However, in the case of learning natural sciences either real learning itself or a combination of real and virtual environments is preferred. In addition, augmented reality could help both gifted learners and those with low motivation, as well as pupils with special educational needs, to gain from the use of augmented reality.

In the Science Centre To Go project a new application for utilising augmented reality in teaching and learning natural sciences was designed. As a design artefact a special pedagogical suitcase of miniature exhibits of a science centre was planned. The miniature exhibits that operate with ordinary hardware enable learners to experiment whenever and wherever they please. http://www.sctg.eu/

Example of using three-step model: Wing dynamics - Why does an aeroplane fly?

The three-step model has been used for instance in planning lesson plans by utilising the Science Centre To Go project's pedagogical suitcase. Wing dynamics is one of five miniature exhibits which can be demonstrated by the equipment of the suitcase. The demonstrations using this augmented reality software are performed in the visit phase of the lesson plan. The aim of the wing dynamics lesson plan is to teach pupils to understand how an aeroplane flies in different stages i.e. take-off, flight and landing.

The post-visit phase gives the possibility to communicate explanations and deepen understanding. Pupils present a report based on their findings of their investigations with the Mini Wing Miniature Exhibit and the whole pathway.

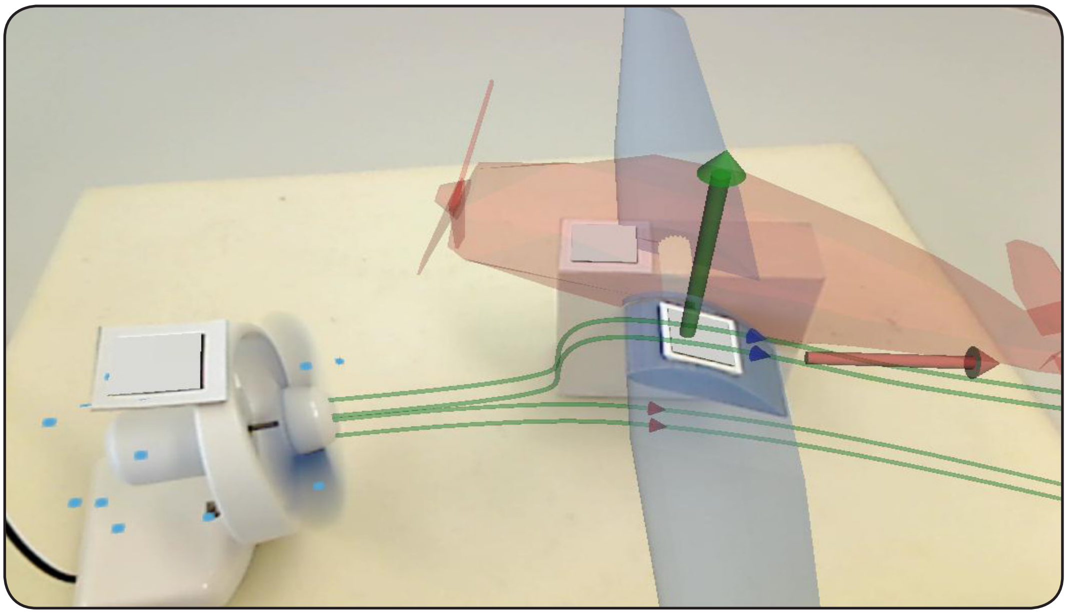


Figure 18 During the Wing dynamics lessons the students make a short study of aero dynamics using Science Center To Go Mini Wing exhibit. The demonstration of the experiment is based on advanced visualization techniques. Investigating the flight of an airplane by the augmented reality software corresponds to the visit phase to the science centre.

Conclusions

The topic of this booklet, Implementing Inquiry beyond the School, highlights the widening of the traditional learning environments of science education in the direction of informal contexts, and using these environments as places of inquiry-based science education. This new open learning thinking brings together both formal and informal contexts as an aim to form new meaningful learning environments. This booklet introduces good practices about connecting learning in classrooms with learning outside the school. Examples of science centres, planetariums, space exhibitions, open laboratories and nature field education share the same out-of-school pedagogy principles.

As it appears from the examples described, meaningful learning requires careful planning: the content should be to generate motivation towards the topic to be learned. Learning should be arranged pedagogically in a meaningful way, taking into account both the learner's age, pre-knowledge and skills, and planning a logical structure of lesson plans. Especially, when learning in open learning environments, it is important to make sure that there exists a continuum of learning. As described in many examples of this booklet, having pre- and post-lessons at school in pursuance of outdoor education or science centre visits, makes achieving long-lasting learning results a sure thing. So, using, for example, the three-step model in planning and realising teaching is useful.

Implementing inquiry is an important part of any science learning. As it is described in the context of the Fridolin programme, inquiry-based learning is a way to expand and change one's own concepts through investigative procedures that include phases of questioning, applying systematic application of suitable methods to gain information, and making reasoned logical conclusions. However, making observations is a skill to be learned. In training this skill, it is essential that pupils have possibilities to do hands-on experimenting, which has been shown to activate thinking. Hands-on and brains-on learning and inquiry-based science education are effective teaching approaches to be utilised in open learning environments.

According to recent research (Salmi, Kaasinen & Suomela 2012), there are encouraging signs that through careful planning of learning in science centres and outdoor education contexts both the learning of cognitive knowledge and motivational results are improved. Furthermore, this encourages a move toward innovative learning where each external environment of a school plays an independent and characteristic role in learning.

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Interesting websites

Science Center to Go	http://www.sctg.eu/
Open Science Resources	http://www.osrportal.eu/
Pathway	http://www.pathway-project.eu/
Natural Europe	http://www.natural-europe.eu/
Um bosque perto de si	http://www.cienciaviva.pt/bosque
Fridolin auf Touren	http://www.naturerlebnispark.at/
Näkyvä	http://www.nakyva.fi/
Heureka	http://www.heureka.fi/portal/englanti/
Dwelling with the City	http://dwellingwiththecity.wordpress.com/

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Credits

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To advance public engagement of science, new forms of education are actively being sought. Although informal learning has often been regarded as the opposite of formal education, a huge amount of knowledge and skills are obtained in a personal way from several open learning environments. Out-of-school education programmes are clearly bridging the gap between formal education and informal learning by renewing the educational systems.

The objective is to utilise the key elements of curricula in different countries to teach the scientific research process based on learning in science centres and teaching at school. Pedagogical hands-on methods, originally developed in science centres and out-door education contexts have now been adopted, converted and moved into formal education via effective teacher education and professional development.

Teachers are the key players in the renewal of any education. This booklet offers the evidence-based practices related to informal learning environments in Europe. The focus is not only on cognitive learning, but on the wider scope of the public understanding of science.

Contact details

Fondation *La main à la pâte*
1 rue Maurice Arnoux
92120 Montrouge - FRANCE
+33 (0) 1 58 07 65 97
Fibonacci@fondation-lamap.org

Contact details

Hannu Salmi
University of Helsinki
Unit of Science Centre Pedagogy
+358 (0) 9 1912 9757
hannu.salmi@helsinki.fi

WWW.FIBONACCI-PROJECT.EU