The Second European Conference on Primary Science and Technology Education

Science is Primary II

Engaging the new generation

October 15 –17, 2006

Stockholm, Sweden

Proceedings

Abstracts from lectures, poster sessions and reports

Acknowledgements

I would like to mention and thank the key organisations behind this conference.
The European Commission for supporting Scienceduc and the Royal Swedish Academy of Sciences for providing localities and service.
The local organisation committee has worked out the program for the conference with advice and suggestions from the international advisory committee and the Scienceduc coordination. Kerstin Reimstad has served as a coordinator of the organizing committee and more than that she has handled most of the local practical preparations for the conference. The support and help from Pamela Lucas and the central Scienceduc coordination has been crucial all along as was the local support by Karin Bårman and the RSAS staff during the conference.
Above all I would like to thank all the speakers and the participants for making this conference to such a memorable event.

Sven-Olof Holmgren, Chairman of the conference

The coordinators of the conference

Kerstin Reimstad
kerstin.reimstad@linkoping.se
City of Linköping, Sweden

Pamela Lucas
lucas@inrp.fr
La main à la pâte – Ecole Normale Supérieure
1 rue Maurice Arnoux
92120 Montrouge
France

Table of Contents

Preface

Sven-Olof Holmgren
Chairman of the conference
Member of The Royal Swedish Academy of Sciences, Stockholm, Sweden

This year is the 10th anniversary of the start of "La Main à la Pâte in France and next year there will be 10 years since the start of the Swedish NTA program.

Four years ago, on November 23, 2002, Georges Charpak called a meeting at l'Academie des Sciences in Paris. The aim of the meeting was to explore common interests in supporting primary school Science and Technology (S&T) education in European countries. The participants represented Estonia, Hungary, France, Sweden and Portugal. Later on Germany and Italy has joined as observers.

The Paris meeting was the starting point for the work on a common proposal and application to the EU commission for a project called Scienceduc. The application was accepted for a two-year program under FP6 - Science and Society.
The present conference is the last deliverable unit in the Scienceduc project.

By some mysterious coincidence it has been commonly assumed all over the world that Science, as opposed to classical literacy, is too complicated to be taught in primary school. One of the most important recent insights is that this is completely false. In fact the absolute contrary seems to be true. Small children have naturally (by evolution) engraved mental skills to explore the material (natural) world. In many countries now recent national curricula include Science at primary school level. However, in most cases teachers and schools are not well prepared and comfortable with this and need support and training in order to succeed.

With a very practical experiment based approach for primary school S&T education we have seen very enthusiastic response from children, teachers, headmasters, local school authorities and parents. The special didactics used within Scienceduc has evolved in many countries over many decades and have roots as far back as the first part of 20th century when John Dewey had a particularly strong influence among other places also e.g. in Sweden. It goes under different names in different regions but the term "inquiry" that has been coined in the US seems to catch on internationally at the current time. The US National Academies have contributed very effectively to this by initiating many years of dedicated work and important reports in the field of education and learning. The US National Science Resources Center (NSRC) that emanates from these efforts has directly inspired the initiation and development of the Swedish NTA program. Speaking only for Swedish experience but I believe it is also true more generally to say that there is no single item in this program, which has not been tried before in one way or the other. It seems that it is the systemic approach with specially developed in-service teacher training and materiel support organised by the local school authorities that gives the teachers the means and courage to develop there own class room practice in S&T.

Two years ago, on October 15 to16, 2004, a “European Conference on Primary Science and Technology Education” supported by European Union was held in Amsterdam. When planning the present conference we thought it would be a good idea to call it Science is Primary II. Hoping that it might become a start of a recurring event. This might indeed happen since a new EU supported program, Pollen, has started during 2006. Pollen is a three-year program and has 12 European member states and a board meeting of Pollen was held in connection with the present conference.

At the Paris meeting Georges Charpak told us about his bold vision of a large common effort to renovate S&T education in Europe in a similar way as CERN has put Europe back on the centre of the map in its field of basic Science after the devastating war. CERN is a particularly good example of a European cultural initiative that also has become a truly international endeavour in the best sense of the word. Few people know this better that Georges who himself at CERN made crucial contributions to the progress of this whole field of Science and the atmosphere in the lab.

This conference reports very encouraging progress in S&T education in primary school and it is my belief that we start to understand how this can be scaled up in different kinds of national school systems in Europe. This may indeed be a good start in trying to realize Georges Charpak’s bold vision. However, it should also be understood that there are many challenges still to meet such as further critical evaluation and directed research to be fed back into the continuous improvement of means, methods, systemic approach and adaptation to the different national school organisations. Substantially more resources could now be well spent in order to speed up the local development and dissemination in Europe.

The background and the goals

The development of society requires to meet one absolute prerequisite, the intellectual and moral development of Man. From this viewpoint, an early education in Science, inquiry based, should be of great help, not only in order to give children a basis in technical knowledge, but also to aim at international cooperation, research, openness, modesty and civic responsibility, so highly requested in our times.

Science education is broadly defined as the learning process through which young people progressively understand the basis of scientific reasoning, practice/experiment, develop the technical abilities and build-up a detailed knowledge of the natural world, its laws, models as well as the technology to act upon it.

Science education is a challenge for European education systems and the long-term quality of education. Primary school appears of special interest: Numerous studies show that challenging the natural curiosity at an earlier age is essential to develop the proper attitude towards scientific knowledge. In addition, new trends and conceptual views for science teaching have developed in the last decades, based on the importance of investigation. Important progress has been made in various areas such as didactics, hands-on and inquiry learning, cognitive sciences and socio-cultural approaches.

In a number of countries inquiry based science education programs that have been launched in the last decade have already given substantial results but they also require major efforts to be developed towards teacher's training, resource elaboration, and educational research.

Although very successful, inquiry based science education has been limited to a relative small number of schools in Europe. Reasons are the need of proper tools, resources and training.

This conference was organized within the framework of the European Science Education Initiative, Scienceduc- Renovation of science teaching in European primary education with inquiry methods.[1] This is a program financed by the Sixth Framework Programme, European Commission. The conference is also possible thanks to the support and collaboration of both the Royal Swedish Academy of Sciences and the Royal Swedish Academy of Engineering Sciences.

The overall perspectives for the conference were

- Inquiry-based Primary Science
- Research and Development
- The European Perspectives in Primary Science Education

---

[1] SCIENCEDUC, project sponsored by the European Commission and integrated to Nucleuscluster, a European science education initiative.
Links: Nucleus website: http://www.xplora.org

The goals:

- Analyse methods and practices for extending the inquiry based science education programs to new primary schools,
- Enhance the development of high quality methods for evaluation and research in different countries,
- Exchange about and develop teacher training in high quality science teaching for primary schools,
- Promote contacts and networking between teachers, principals, teachers' trainers, science education leaders, program coordinators, researchers, scientists, policy makers and local authorities.
- Enhance exchanges between European and non-European schools on science education projects,

The conference gathered teachers, principles, policy makers, program coordinators, researchers, scientists, teacher trainers, representatives from school administration and mass media.

Overview of primary science education and scientific career perspectives

José Mariano Gago
Minister for Science, Technology and Higher Education, Portugal

Transcription of the video

Good afternoon everyone. I would like firstly to apologize for not being able to be with you this afternoon in Stockholm. I'm unable to travel. In fact I'm recording this, on Saturday, one day in advance, in Lisbon. I cannot travel to Stockholm because we are finalizing the state budget for 2007, to be presented to Parliament next Monday. It's a good budget for Science, I shouldn't complain but as you may imagine I cannot travel this weekend.

First of all, I would like to praise Georges Charpak and Leon Lederman for their commitment to Science education. It is quite uncommon for such distinguished scientists to devote a large fraction of their time, their work and their life to Science education and in particular to primary science education and to experimental science education. I would also like to thank the Swedish Academies of Sciences and Engineering for organising and hosting this meeting.

The reason why I'm here and why I would like to address you is because we have been involved very much in Portugal (and I have been involved personally), with the same problem in trying to overcome the difficulties of experimenting, of networking real science with schools at all levels, and in fact of networking science and the scientists with the general public. Primary education and experimentation in elementary education is a part of that problem.

I think we all face the same difficulty: How to overcome the rhetoric of teaching elementary science? The rhetoric of teaching elementary science gives an enormous amount of time and energy to definitions, in fact to the learning of formal languages, without any proper acquaintance with practice of scientific inquiry, experimenting, controversy, analyzing data, discussion. I think this is one of the main problems of scientific development.

Years ago, I remember Unesco having analyzed the basic school curricula all over the world trying to compare science and mathematics curricula in more than a hundred countries. It's amazing to discover that nowadays, the proportion of time devoted to science and mathematics in general, all over the world, is more or less the same in elementary school, on paper of course. The subjects that are considered in biology, physics, chemistry, geology, etc, are more or less the same, at primary, secondary, or upper secondary education; they are not very different in all the countries. So, the program of those who were supporting science as something that should be part of the general culture of the population, that program already promoted in the 19° century, is on paper and has been realized. However, what documents do not say is what is behind these names: When you say physics - 4 hours a week for 11 years old students, what does that mean in different countries of the world, in different schools and even in the same country? In some schools it means 2 hours in the laboratory and 2 hours in groups trying to analyze results and using books and other sources of information to understand what is going on. But in other countries, very frequently, it corresponds to something completely different: it means 2 hours during which students keep silent and listen to a teacher repeating what's in the textbook and if you read the textbook, it is about definitions, definitions of force, definitions of speed, whatever, and then the examination is about repeating the definitions. Science should be more creative. The fighting against this is extremely difficult especially in undeveloped countries. But even in developed countries, in many areas, it is extremely difficult, but it should be done not only for the sake of science. I think it has to do with using science and mathematics as a tool for social exclusion in schools. Why for exclusion? Because nowadays students in schools come from a variety of social backgrounds and those who do not come from higher classes, from parents who have been educated, those students that have enormous difficulties in keeping quiet, in following the proper rules of the formal languages with elementary mathematics or the natural language, they are of course excluded by such a rhetoric. On the other hand, those who just accept that they must do it because later on that is important for their future (because their parents keep saying it), they become cynical about science: "Well, we do that and then we'll just go on". Most of them will not discover what science is about, that science is about inquiry, about understanding and that the interaction between human mind and matter or society, requires organized action, informed action, then the analysis of the data, of what you have observed and registered, etc …

Science education should be a socialization process, as sociologists say, to scientific practice, to what the scientists and those using science in their professions do. But of course, to do it in a limited space, in the isolation of the school is extremely difficult. And it's more difficult if the teachers themselves do not have the proper understanding and the proper background in science. Most of them have never been in a lab, or they have never seen or discussed with a real scientist or engineer. So science education as a socialization process is an important aim. We must aim at that and to do it will require more than what is going on in the classroom. That is one of the reasons why we tend to emphasize the problem of the networking of schools with society in general, the networking of the scientists, of those working in real science, with the general public because that means the students, the teachers and also the families. Of course, there are many paths, not only experimenting. History for instance, is a path to socialize the students to science, to understand how an idea came into life, how an interpretation was found to be in the past untrue, the idea about what is our relation with the discovery of truth. However to understand what you say when you speak about that, you must have at least some first hand understanding and first hand knowledge about practical work, about experimental work, about what you are seeing, what you are really talking about.

We have tried in the last 10 years in Portugal to do it on a comprehensive way. Such is our contribution to this problem. What we have developed in Portugal is a movement now supported by a national agency for the promotion of scientific and technological culture, which is an independent agency nowadays. In fact, it has been recognized by sociologists as a kind of social movement involving the scientists, the public, many science teachers and many other professionals including engineers.

How this movement evolved? It evolved from many different areas: First in school, trying to promote experimental sciences in schools. Traditionally in many schools in Portugal, democratization of the school was accompanied not by an increase in practical work and experimental work but by a decrease of it and by a raise in rhetorics in teaching science. We tried to fight that. We did it through project work and creating in schools all over the country a system which is a kind of double funding as you have for research in universities. From the science budget we now devote about 5% of the science budget to popularisation of science and promotion of scientific culture. That includes promoting experimental sciences in primary and secondary schools.

Project work is the initiative of teachers themselves and sometimes teachers from different disciplines from the same schools, from different schools or scientists and teachers, which of course is very frequent. Projects are presented for making better experimental science education.

Second, we made efforts in trying to network scientists and schools, not only in primary education but with a large emphasis in primary education. Networking scientists in schools means that many scientists devoted time in schools to help science teachers, to interact with the media, to go directly to the schools. We try to promote a culture of proximity, of human proximity, of media proximity, of real interaction, developing projects on special areas like genetics, meteorology and others. You combine the use of your hands, the analysis and organisation of collected data, the share of knowledge among schools and with scientists themselves.
Considering the net of schools and of research labs, a large fraction of schools and a large fraction of all research labs in Portugal are involved now in the same network and they interact through projects (large projects and small projects).
Another note about this net is the science centres. We have at the same time developed a network of science centres, now a dozen across the country. They are of importance for this process. They are natural places for interactions between schools, scientists and general public.
Third, we feel that the direct relation outside the school, between scientists and the general public and that includes of course the students but also their families, is very important. We tried to do it in these 10 years during summer time (June, July, August and September) and it was easy because many scientists are available and because many people are on vacation. Now we have very large projects of direct interaction in the areas in which it is easy to combine practical observation with human contact: Astronomy, geology, biology, etc…across the country.
I have met some families with their children that organize their vacations in order to go to different places where these interactions and contacts occur.
One of the points I would like to emphasize is that we have tried to address this problem, the specific problem of which science in primary education is a part, through a comprehensive movement involving schools, labs, science centres and the media. We feel, through its results, in particular the raise in the choices by young students to go to scientific and engineering carriers through this decade. This is a good way to do it, trying to combine the interest, the willingness to learn by many people of different social classes and cultural backgrounds, with the generosity of scientists.
This is my last point: all of this requires an enormous generosity by scientists themselves. Not only the very famous scientists but a large fraction of the scientific community: from the young post-doctorate students to the top leaders of laboratories, those that the public is used to see on television and those that no one knows.
All this in Portugal has been possible because about 300 – 400 scientists every year devote a large fraction of their leisure time to this type of human and direct interaction with schools and with the general public.

This is our contribution. I'm afraid, I would like very much to listen to your reactions, but this apparently is not be possible.

Ciência Viva is the name of the program in Portugal. You will find it in the web (www.cienciaviva.pt). We'll be delighted to get reactions from you.

Thank you very much.

Defining, Teaching and Assessing Inquiry: Looking Back, Looking Ahead

Norman G. Lederman
Illinois Institute of Technology,Chicago, USA

One of the most prevalent themes in international science education reform documents is the emphasis on scientific inquiry. This emphasis is not new. It has been a recurrent focus of concern for at least 50 years, arguably 100 years, in the U.S. Moreover, inquiry has had similar long-term support in numerous other countries. The stress on scientific inquiry is broad-based and concerns how science should/could be taught as well as what students are expected to know and what they can do. Although scientific inquiry has long been a focus in curriculum and instructional reforms, there is almost universal dissatisfaction with the level of inquiry-oriented instruction, students' understanding of inquiry and their ability to perform in this area. Interestingly, the ever-increasing dissatisfaction of policy makers, administrators, and the general public concerning the attention to inquiry in science classrooms is only surpassed by classroom teachers' lament about the quality of the curriculum materials and instructional support available. This presentation will focus on defining the construct and describing its implications for the teaching and learning of inquiry.

Science can be viewed as consisting of a body of knowledge, methods and a way of knowing. Although the three are intimately related in any discussion of science, the "methods" of science typically refer to scientific inquiry (i.e., how scientists develop the body of knowledge). Two years ago, the National Science Teachers Association (a U.S.-based organization of teachers and science educators – the largest organization of its kind in the world, with over 50,000 members) provided a formalized definition of how it perceived classroom-based scientific inquiry. The conception was largely based on U.S. National Science Education Standards and emphasized scientific inquiry as having three perspectives: a teaching approach, skills and procedures students should be able to perform, and knowledge about how scientists develop knowledge. In the history of how scientific inquiry has been viewed in K-12 classrooms, the specifications concerning what students should KNOW ABOUT inquiry constitute a new perspective. Delineations of what constitutes inquiry teaching and what students should be ABLE TO DO have been provided in numerous other documents. Nevertheless, there is still considerable disappointment with the quality of the aspects of inquiry present in science classrooms.

Although there are varying definitions of scientific inquiry around the world, there is almost universal agreement that scientific inquiry is a desirable component of K-12 science teaching and learning. Consequently, how scientific inquiry can be taught is of great concern. Unfortunately, the inquiry-based curriculum materials that have been available for several decades tend to focus almost exclusively on the DOING of inquiry as opposed to knowledge ABOUT inquiry. Hence, various research-based approaches to teaching inquiry will be provided. Examples of how the various aspects of inquiry can be introduced into science classrooms will be discussed along with research results regarding the teaching and learning of inquiry. In addition, techniques for the successful modification of existing materials and approaches will be provided.

Scienceduc: Status reports from seven ongoing national EU initiatives-perspectives on inquiry and curriculum

Renovation of science teaching in European primary education with inquiry-type methods – Status report: France

Pamela Lucas
La main à la pâte, Ecole normale supérieure, Montrouge, France
Scienceduc coordinator

1-Introduction

SCIENCEDUC was a project focused on the development of science teaching in European primary education with inquiry-based methods and sponsored by the European Commission. It aimed at dissemination of the best inquiry-based methods, techniques and practices in science teaching at primary schools through the establishment of a European network in 5 countries: Estonia, France, Hungary, Portugal and Sweden. Some actions were extended to 2 additional countries: Germany and Italy.
Scienceduc actions were carried out within the framework of the formal education system, at different levels, with respect to teacher training, dissemination of good practices and methods, online collaborative projects and evaluation. Here we will provide a general view of projects with a special focus on French actions in Scienceduc and on inquiry based science education in France.

2- Project Outcomes:

2.1- Teacher training:

European summer school for primary Science trainers, Erice, Italy July 9 - 14, 2005

Forty-eight participants from 18 different nationalities attended the summer school.
Common bases for hands-on teaching and teacher training at primary and kindergarten levels were defined, exchanges of good teaching practices were carried out and recommendations provided for the organization of quality in-service training at the European level. Proceedings online at: *http://www.xplora.org/ww/en/pub/xplora/nucleus_home/scienceduc/workpackages.htm* and *http://scienceduc.cienciaviva.pt/teachertraining/*

2.2- Dissemination of good practices and methods

Fourteen national conferences were organized during 2005 and 2006 in Scienceduc countries. They reached close to 1000 teachers, researchers, scientists or ministry representatives locally involved in science education. Reports online at:
http://www.xplora.org/ww/en/pub/xplora/nucleus_home/scienceduc/national_conferences.htm
and http://scienceduc.cienciaviva.pt/dissemination/
In France, the Saint Etienne conference provided an opportunity to discuss links between science and mathematics. Specificity of the inquiry process in mathematics and mathematics within the science inquiry process were tackled during the conference. This was also a way to promote and support educational centres of excellence, with reference to pedagogical practices in France.

2.3- Online collaborative project

European Discoveries (*www.mapmonde.org/europe)* is an online trans-disciplinarily project about science and history in Portuguese, Italian and French and recently in English. Through this project, pupils from 8 to 14 years were invited: to carry out documentary research into one of the 12 major scientific discoveries or inventions, to reproduce the experiment in their classroom using locally available material and to report their research online in an individual or collective multimedia notebook.

2.4- Evaluation

A report and a database about inquiry effects at primary school were completed, first in partner countries, then open worldwide. In France, evaluation references are scarce, especially for primary school. The very few ones existing couldn't be compared because of the variety of protocols and objectives of the studies. A report and the database will be available at: *http://www.xplora.org/xplora/sciencedu*c and *http://scienceduc.cienciaviva.pt/evaluation/*.

2.5- Scienceduc conclusions and perspectives

This project allowed us to contribute to European objectives: "Europe should become a worldwide reference of quality education" and to the improvement of the understanding and practice of science and technology by European society. Our actions were devoted to promoting contacts between education actors and scientists. Scienceduc was a modest project by comparison to the huge task of renovating elementary science education in Europe, however it constituted the first step for Pollen, a more ambitious project that aims to stimulate and support science teaching and learning in primary schools (see Raynald Belay's contribution)

3- Inquiry-based science education in France

In France, inquiry science teaching also means transdisciplinarity, citizenship and communication skills development. The experiment book is considered a very important tool for improving children's written skills.

In 1995, it was stated that less than 5% of French pupils followed science lessons at school. To solve this problem, La main à la pâte was launched in 1997. It was an initiative of Georges Charpak, joined by Pierre Léna and Yves Quéré. They received the unanimous support of the Académie des Sciences to promote inquiry-based science education in France. A pilot experience started and formed the basis of the launching of the plan of renovating science teaching in 2000. In 2002, science standards were published recommending science inquiry instruction.

3.1- Positive effects of inquiry education

Different reports, drawn up by Ministry of Education inspectors, recorded several positive effects of inquiry teaching both on knowledge and on attitudes:

At the knowledge level, there is improvement of basic scientific knowledge as well as the general culture of pupils. Language skills (both oral and written) are also improved, particularly in foreign children. At the reasoning level, pupils are better able to reinvest knowledge in fields other than science and a unifying effect of scientific activities was also evidenced in multicultural contexts.

Concerning attitudes, the main effect observed was mutual respect among pupils. They also seem more engaged in thinking. Low achievers gained in confidence and were also more positively perceived by other students. As for teachers, their positive changes in attitudes towards science were experienced as a pedagogical renewal.

Today, we can say that there is better science teaching in France: 30-40% of French pupils have science lessons (1/4 of those follow science lessons according to the French standards and 1% benefit from the best inquiry science teaching, particularly in areas covered by the Pilot centres, with regard to inquiry pedagogical practices in France). Science lessons represent 1h 40m of the weekly schedule, and the number of training sessions in science for teachers is increasing.

3.2- Factors for implementing inquiry successfully

Several factors were identified: Training and coaching have played a determining role in dissemination. Availability of self-training tools as those proposed online at La main à la pâte website (which counts on 200,000 hits/ month) was also of importance. Collective actions at the school level were needed to make teachers' actions more dynamic. Concerning engagements, long-term ones were required. At least two years of continuous work on the inquiry process were needed to evidence the first results on pupils. Of course, local education and political authorities' support was also required for local creation of resource centres, new positions for "leaders in science" (for teacher coaching), the organization of science training for teachers and scientific events for pupils. The Ministry of Education's support and engagement were needed to introduce changes at the school level.

3.3 - Inquiry perspectives in France

Since September 2006, La main à la pâte is running a pilot experience in order to extend Inquiry science teaching to French middle School.

A better feed-back about La main à la pâte actions carried out since 10 years now is required as well as the identification of factors of development to be stressed to enhance the dissemination. In this purpose, during 2007, we will participate to the implementation of scientific skills and knowledge evaluation to be carried out by the Ministry of Education on pupils of 11 years old.

We will also implement in collaboration with the Colombian program "Pequeños científicos", the evaluation of teachers' practices on the French Pilots centres and we will continue to participate to IAP working group of evaluation of IBSE programs. Within Pollen framework we will carry out evaluations of students and teachers' attitudes as well as the community participation. Then, the efforts of generalization will be pursued.

Perspectives on inquiry-based learning and national curriculum in Estonia

Toomas Tenno, Karin Hellat
University of Tartu, Estonia

A new paradigm of learning and teaching that constitutes a fundamental concept in directed inquiry learning programs for primary school and kindergarten requires a major change in school practice. The present project, Scienceduc, is aimed at implementing the main goals of inquiry-based learning at school – learning with understanding that will lead to the formation of such higher-order cognitive skills as problem solving, critical and systemic thinking, question asking, creativity and social adaptation. In his paper, Uri Zoller (Zoller, 2002) stated basic principles of introducing new paradigms at school in the following way: "We have to go:

- from algorithmic lower-order cognitive skills (LOCS) of teaching to higher-order cognitive skills (HOCS) of learning;

- from doing justice to the disciplines to doing justice to the learner's ability to take an interdisciplinary (or cross-disciplinary) approach;
- from assessment of passive knowledge to assessment of HOCS;
- from focusing on "what graduates should know" to "what graduates should be able to do"."

A reformed national curriculum for basic and high school education in Estonia was implemented in the schools in January 2002. The general objectives of the curriculum and main goals of the science curriculum in this regulation are presented in a very modern way. Fulfilling the requirements of this curriculum will guarantee development of higher order cognitive skills in students at school. The problem is that teaching methods at school do not support implementation of hands-on inquiry in science studies because teacher training and available materials for teachers (study books, workbooks and content of studies) are not suited to the new concept of inquiry-based method and support an old-fashioned style of teaching. The explicative and interpretive method is still generally used at schools. It is not easy for teachers to identify the path towards a new paradigm of learning and teaching that gives students the best opportunities to acquire experimental skills for making their own discoveries and to develop scientific attitudes and habits. At present, inquiry-based learning has not yet been introduced into the everyday science program in the schools.

The subject plan in the Estonian science curriculum, which serves as a matrix for study books and materials for science teaching, is quite general and lists several terms and concepts. The subject plan does not provide strong recommendations concerning the content of studies at the primary level. The list of terms includes "solids, liquids, weather, plants, animals, senses, comparison, measurement, organisms and their habitats" etc., which allows authors of teaching and learning materials to develop these materials in different ways. In Estonia, the working group for the project "Scienceduc" supported the development of teacher guides and other teaching materials based on the hands-on inquiry method. First, three years ago, inquiry materials for kindergarten and primary level were adapted from the STC program (USA).

The directed inquiry curriculum based on the new paradigm will be designed on the basis of hierarchic principles of knowledge and skills that are important from the point of view of learning with understanding. Studying must develop students' scientific thinking and problem-solving skills. Students must also practice their writing and verbal communication when using the inquiry method in science. New materials were first implemented in the schools and kindergarten in Pärnu, Tartu and Türi. Teachers who used the new method were very fond of it and provided valuable feedback. Prepared materials were revised and teacher training was more strongly oriented towards the initiative of working teachers to get more useful recommendations for the next steps of development of the new kits and teacher's guides.

Today, we must demonstrate the effectiveness of the inquiry-based learning method as compared to the traditional algorithmic method still in use in the schools. To that end, we have started a comparative research program to measure students' emotional and mental development at the primary level using psychological tests. Due to the low interest of our educationalists and lack of resources, this study was only performed in a very small community (two parallel streams in one school). The test results were published in a medical journal and showed differences in students' development when an inquiry method was used at school. At the same time, we also received feedback from our trial that showed better student development. We need a broader and more systemic approach to teaching and learning using inquiry, otherwise this new approach will not result in permanent growth in students' development. Many educationalists of today are certain that the results of traditional teaching are satisfactory and that the algorithmic style of teaching must not be changed. The aim of the Scienceduc project was to provide evidence that hands-on inquiry-based learning will help to

achieve expected results in students' development of higher-order cognitive skills, thus fulfilling at the same time the goals defined in the Estonian national curriculum.
Practical implementation of the hands-on inquiry method in the Estonian schools requires more attention to teacher training efficiency. We believe that teachers should be taught the same way they are expected to teach at school. More attention should be paid to developing the expertise of involved teachers. Also preparation of new themes and teaching guides with kits is important to implementation of inquiry-based teaching. In Estonia, the kit preparation center is located in Tartu.
Estonia has had a good experience of the Scienceduc project, which has supported and disseminated the hands-on inquiry approach in primary science. On the basis of the prepared materials, it will be possible to facilitate inquiry-based science in the seed city of Tartu.

References:
Zoller, U. (2002) Environmental Chemistry, Education for a Sustainable World, Environmental Science and Research, Special Issue 3, p.19

Status report: Germany

Petra Skiebe-Corrette
The Freie Universität, Berlin, Germany

The Freie Universität Berlin represented Germany as one of two associate partners within the EU-Project SciencEduc. As an associate partner, the major aims of the Freie Universität Berlin within this project were dissemination and teacher training as a tool of the dissemination. Therefore, Germany was present at the "International School of Science Teaching: European Summer School for Primary Science Teachers". Dr. Petra Skiebe-Corrette gave a lecture on the "Impact of informal science laboratories on primary science education in Germany". Germany also organized a national conference (27.-28.9.2005) called "Science is primary" in cooperation with the Berlin-Brandenburg Academy of Sciences and Humanities. During the first day of the conference, best practice models from four different countries (France, Sweden, USA, Germany) were presented. In order to involve the federally organised school system in Germany, two representatives from different federal states (Berlin and Brandenburg) were also present, reporting on the status of science teaching in their primary schools. On the second day of the conference, a workshop for teachers was held on the topic "Floating and sinking". An additional workshop for teachers was held in January (18.1.2006) in cooperation with the Swedish "Science and Technology for All" program, which sent the teacher trainer Jan Engquist. The topics of this workshop were "Chemical tests" and "Motion and design". The teaching materials are part of the program "Science and Technology for Children" developed by the National Science Resources Center associated with the American National Academies and the Smithonian Institution. 42 primary teachers from 28 schools were present. Of those 28 schools, 21 applied to take part in Pollen, the follow-up EU program.
As a result of SciencEduc, the Freie Universität Berlin now cooperates with Berlin-Brandenburg Academy of Sciences and Humanities in a project concerning primary science education. In addition, the Freie Universität Berlin is one of the three partners in a contract

concerning the German translation of the La main à la pâte website. The other two partners are the French Academy of Sciences together with the Berlin-Brandenburg Academy of Sciences and Humanities. The Freie Universität Berlin also works together with the Swedish Academy of Sciences and their “Science and Technology for All” program. The “Science and Technology for All” program has sent teacher trainers and will help to adapt American school materials to the German culture due to their experience in adapting the same materials to the Swedish culture. In addition, the Freie Universität Berlin also has a contract with the American company Carolina Biological Supply company which has granted the Freie Universität Berlin the right to translate the materials from the American “Science and Technology for Children” program. Good contacts are also present to the National Science Resources Center, which is responsible for the development of these materials.
As mentioned above, as a result of the workshops on inquiry-based science education, it was easy to recruit the schools for the EU program Pollen. These workshops also fostered a program run by the Freie Universität Berlin, in which technology topics are introduced to primary schools. The first topic introduced to the primary schools is “Motion and Design”, which was taught as part of the second dissemination workshop. This project is funded by the TSB Technology Foundation Berlin. Both SciencEduc and the follow-up program Pollen have improved contacts to the Ministry of Education in Berlin. Based on these contacts, the ministry has extended the delegation of a teacher to the Freie Universität Berlin to work in the informal science laboratory NatLab, which represents the Freie Universität Berlin in both EU programs. NatLab was selected by the Robert Bosch Foundation to receive a national award given to initiatives which support science education in school by connecting scientists, teachers and school students. The international connections brought about though SciencEduc and Pollen were mentioned in the statement written by Robert Bosch Foundation explaining their choice of NatLab for this award.
The organising committee of “Science is primary II” has asked each ScienEduc member to answer the following questions:
Perspectives on inquiry and curriculum: How does inquiry fit your national curriculum?
Germany is a federation of 16 states including three cities, each of which has its own responsibility for school education. Therefore Germany does not have a national curriculum. In 2005, Berlin implemented a number of major changes in its curriculum. In primary school, science is taught as part of the subject “Sachunterricht” in the grades 1 to 4, which includes topics concerning both science and social sciences. The curriculum for “Sachunterricht” has been reworked and since 2005 includes an increased number of topics concerning science and technology. In the grades 5 and 6, the new subject “science” has been implemented, which is taught four hours a week.
What are the challenges involved in the practical implementation?
The changes of the curriculum and the new subject “science” are difficult for the schools to implement. The majority of primary school teachers did not study a science subject and are therefore afraid to teach it, especially topics concerning physics and chemistry. Also, due to the fact that the curriculum is new, most schools are not properly equipped. Therefore the primary teachers of Berlin need teacher training and teaching materials that allow the teaching of inquiry-based science in an ordinary classroom.
What characteristics of inquiry are most important and why are these traits important?
The major task is to get teachers excited about teaching science and to provide them with high quality materials to make inquiry-based science possible in their classrooms. It is only through these teachers that we can reach our goal to bring the excitement of inquiry-based science to German school children.

Status report: Hungary

Zsuzsanna Gajdóczky & Bernadett Kkohegyi,
Apor Vilmos Catholic college- VAC, Hungary

1. How does inquiry fit into your national curriculum?
In Hungary, our National Curriculum contains specific material for the various fields of science and for different age groups. Scienceduc fits well into this guideline. In theory, there is no problem with children's knowledge of living things and surrounding nature. But reality is totally different from the ideal.

2. What characteristics of inquiry are most important and why are they important?
We have no reliable data as to when the process started. The fact is, that in surveys from the middle of the 80s, the popularity of the natural sciences (physics, chemistry, biology, geography and mathematics) significantly decreased. Among girls in the secondary schools, physics was 11th and chemistry 12th on their list of favourite subjects. And the situation has not changed significantly since that time.
Some of these girls will become nursery and primary school teachers. They usually do not perform experiments in secondary schools, or even afterwards. They do not see any hands-on methods, so for them the sciences are just boring and time-consuming. They have no experience of scientific observations or discoveries. This lack of motivation in teachers greatly influences children's later interest in science. And these under-motivated children will become the teachers of the next generation.
The challenge involves overcoming this indifference. Our teachers have to participate in continuing professional education, and a great variety of temes are offered on equal terms. That is why we must suggest attractive programs. How shall we make our training the one they choose to come to?

3. What are the challenges involved in practical implementation?
We can mention a few features that make our work in Hungary unique: the first is the intercultural approach, and the second is the special treatment of underprivileged – mainly Gypsy – students.

3.1. Intercultural direction
There is no separate human and natural science, only one culture. Human culture makes a deep impression on the human way of thinking. Making a sculpture requires material and knowledge of the material, both of which belong to the sculpture. Material and the method of working with it mutually affect each other, not to mention the artist, who chooses the theme of the future artwork.

Our aim is to help our students see and understand the connections between the human and natural sciences. A lesson should not consist of boring piles of data, but it should be interesting, full of exciting adventures and experiences.

3.2. Children with disabilities

The Gypsy population is estimated to be 8% of the population in Hungary. Gypsy families have a much higher the rate of low education and unemployment than is found in the general population. There are many more children in gypsy families, which means much less money and the spreading of a disadvantageous intellectual background. Nevertheless this ethnic group has lived here for more than 500 years, and they have kept strictly to their tribal traditions and nomad morals. The only change happened during the past 50 years and entails that they no longer wander, though they still have a nomadic way of thinking.

Upon entering school, the Gypsy child has habits different from the mainstream and gaps in knowledge compared to most Hungarian children. Throughout the school career, he/she encounters more and more failures, making it difficult to assimilate. The Gypsy child often lags behind in writing, reading, maths, and is often obliged to change schools, though the main problem remains.

It was our College in Europe that established a separate department for Gypsies. We teach them and give them training so they can become nursery and primary school teachers.

In our new residence (Vác), we organized a conference in the framework of the Scienceduc project. We have a special school in Vác for children with disabilities (mainly Gypsies), and the teachers were glad to learn about hands-on methods, which facilitate teaching and dealing with these children. These methods (experiments, observations) are very suitable, and create circumstances that allow Gypsy children to feel equal to others, the majority. These children will achieve success, rather than failure. This success will help them assimilate, and perhaps facilitate their performance in other subjects.

We have the possibility to spread these effective methods by joining in the Pollen project, where our key issue also focuses on the Gypsy minority, which is strongly present in the region, and on providing them a specific approach to the world and developing their scientific knowledge. The need to educate Gypsy children for their better integration is pressing in Hungarian society, because the number of Gypsies in society is rapidly increasing.

Scienceduc action and some perspectives on curriculum and inquiry in Italy

Anna Allerhand,
LUMSA University, Rome, Italy

The only contribution expected from the Italian partner to the Scienceduc project was the national meeting, which took place in Foligno on October 19-20, 2005.

The Italian partner, CIFRE (the National Consortium for Innovation, Formation and Educational research), organized a national meeting devoted to experts at the Regional Institutes for Educational Research (IRRE), which are the local branches of CIFRE itself, and to head teachers and teachers.

The aims of the meeting were to plan and organize the operative national network between the Institutes in order to promote scientific education in the primary schools.

There were thirteen representatives from over twenty regional institutes.

The meeting was located in the Laboratory of Experimental Sciences of Foligno. This laboratory was built in the sixties, but has been renovated and enlarged from 1999 on. It is now working with educational authorities, local authorities and universities to develop didactics for the Sciences and to popularize scientific knowledge for the public. Legally speaking, the Experimental Science Laboratory is an association of 17 schools, formed according to the Italian laws on educational autonomy. It organized refresher courses for teachers of primary and secondary school and took responsibility for the initial training of future science teachers (SSIS - Specialization school for secondary schools). The intervention was focused on the need for an experimental approach to teaching sciences. That means that every school should have an experimental laboratory with the right equipment, a person who is responsible for it, time to plan and conduct experiments, time for stimulating and retraining teachers.

During the meeting, the first day was devoted to presenting innovative projects about science education:

- the national project “KISS” (how to teach experimental sciences), financed by European Social Fund;

- “The word of the science”, a ministerial pilot plan financed by the minister of education;

- the Pollen project

Professor Mingarelli, director of the Laboratory, illustrated the activities of the center, then participants visited all the laboratories and saw the equipment. The first day ended with a visit to the Planetarium.

On the second day, a round table took place about “The experiences of science education in the primary schools”. During this round table, the IRRE experts and teachers from some schools in the area introduced their experiences and the needs of the schools with regard to science education.

The Pollen project, extended to more seed cities throughout Italy, was identified as the key project for achieving real innovation and supporting the schools.

At the moment in Italy, the national curriculum for primary school is temporary. There is a strong ongoing debate about the duty of the central educational authority, the local authorities and the schools to define the curricula.

In the temporary “Indications for infant schools” (age 3 to 5 ½ -6), something is mentioned about direct experiences of having contact with nature, things and materials, the social environment and culture in order to increase and guide the natural curiosity of children, through activities that are increasingly organized. The indications also mention the possibility of performing experiments to manipulate things, clarify situations and explain processes.

In the temporary “Indications for primary schools” (age 5 ½ - 11), the first year can be devoted to exploration activities, in order to compare and classify. For the second and third year, it is recommended that instruments be used and that activities be arranged to transform objects and materials. For the last two years, it is recommended that students perform experiments to increase their comprehension of natural phenomena.

Every single school institution must adapt the national indications to the context in which they actually work.

The most important characteristics of inquiry at this level are:

- The possibility to involve children in the planning, implementation and discussion of experimental results. Only if they control all the processes it is possible for them to achieve real understanding.

- Attention to clarification of all details of the process and documentation (oral or written).

- Attention to using errors as a key to correct methods and to believing that everyone can understand each topic.

Practical implementation requires more resources in order to realize:

- The right environment in every school for engaging in practical activities (equipment, a special room devoted to these kinds of activities, assistants and so on);

- More teacher training, because practical science activities are not common in the curricula of future teachers.

Status report: Portugal

Luz Figueiredo, Serrado Elementary School, Portugal

Science teaching – (inquiry-based) learning in the Portuguese curriculum
The *Portuguese curriculum* for elementary education aims at having teachers plan and develop activities according to an inquiry-based learning methodology.

Examples:
1. The national curriculum: General competences - Guiding principles and values
At the end of elementary education, students should be able:

- To mobilize cultural, scientific and technological knowledge in order to understand reality and deal with situations and problems common in dally life;
- To research, select and organize information so as to transform it into transferable knowledge;
- To adopt strategies appropriate to problem-solving and decision-making;
- To carry out activities in an autonomous, responsible and creative manner;
- To co-operate with others on common tasks and projects.

Source: http://www.dgidc.min-edu.pt/public/compessenc_pdfs/en/national_curriculum.pdf

2. The national curriculum: Learning experiences in science
Undertaking the following learning experiences is considered fundamental:

- Observing the surrounding environment. (…)

- Planning and developing different types of research. Problem-solving situations are fundamental (…)
- Designing projects, predicting all the steps to be taken (…)
- Carrying out experimental activities. Start with simple experiments involving curiosity or questions related to students (…)
- Formulating hypotheses, predicting results, observing and explaining ought to be included

3. The national curriculum: Specific competences for students' scientific literacy
- The development of specific competences in different fields requires student involvement in the teaching-learning process through differentiated educational experiences.
- Reasoning
- (...) interpretation of data, formulation of problems and hypotheses, research planning, prediction and assessment of results, establishment of comparisons, carrying out inference, generalization and deduction.
- Communication
- (…) development of the capacity to present ideas and defend and argue for them, the capacity to carry out analysis and synthesis and to produce written or oral texts (…)
- Attitudes
- (…) respecting and questioning the results obtained, critical reflection on the work carried out, flexibility to accept errors and uncertainty, reformulation of the student's own work (…), respecting ethics and awareness of scientific work, evaluating its impact on society and the environment.

Science teaching – (inquiry-based) learning: the reality in schools
Despite the principles expressed in the curriculum, only a minority of teachers teach science according to an inquiry-based learning methodology.
Several *reasons* account for the situation.
Teachers:
- are not prepared to teach science (some teacher training schools are not science oriented)

- have limited access to information (sharing examples of good practice is not a common practice amongst teachers; access to articles from the expert literature is limited)
- have few resources available to them
- use textbooks that present science using a NON-inquiry-based approach
- consider that science is for scientists, too difficult to be taught by elementary teachers
- have difficulty in handling the class when carrying out experiments (too noisy and restless)
- feel guilty for taking up time for other subject areas considered more important (mother tongue and maths)

Suggestions for changing the situation in the country
Teacher training sessions are essential as a means to improve the situation.
- These in-service training sessions should give teachers the opportunity to carry out practical activities, to realize what science teaching means (you do not have to be a scientist to teach science), and to become familiar with examples of good practice.
- Facilitating teachers' access to experts (scientists) for advice/support, that is, making it easy for teachers to *reach a researcher* when they have a doubt. Ciência Viva is essential in providing help here.
- Making resources *(articles + materials) easily available* for teachers is also important.

- It is also important to *create networks* of teachers so that they can exchange ideas and share resources and practices.

SciencEduc in Portugal: the conferences
Ciência Viva organized two conferences in the country, one in September 2005 and another in January 2006.
The aim of the two conferences was to understand the situation as concerns science teaching in elementary schools and to set up a network of teachers to share experiences and materials.
Participants:
Teachers with different backgrounds and teaching experiences (teachers from Science Centres, form teacher training schools, from previous Ciência Viva projects and scientists).

Conference 1: September 2005
Program
Presentations: activities using an inquiry-based and hands-on approach carried out in elementary and kindergarten schools and in science centres
Debates: science teaching/learning using an inquiry-based approach

Activities in schools as an outcome of the conference
The outcome of the conference was the development of activities in schools followed by the sharing and dissemination of materials under the heading "Science in Autumn". The activities were carried out during Science Week, in November 2005.
Topic: Science in Autumn (field trips to forests / Autumn fruit: jellies and jams)
Schools: 40 schools all over the country with several classes each
Support materials: the project site was used for the publication of support materials for the teachers' activity preparation.

Science and Technology Week: Activities in Serrado Elementary School
Activity 1: The Jam Trail
Interdisciplinary activity involving making jam and jellies at school

> *Curriculum Areas*
> *Environmental Studies:* the senses: smell, sight, taste (representing the sensations, describing sensations verbally); Safety and hygiene rules in the kitchen; Conserving food: Why do we make jam in autumn (A survey of family and friends, interpreting the results of the survey)?
> *Experiment* - "Which keeps fresh longer: raw pumpkin or pumpkin jelly?" Predictions, observations, recording, conclusions.
> *Maths:* Calculating the quantities (how much pumpkin, how much sugar, ...), calculating the production costs, doing the accounts, weighing, measuring.
> *Artwork:* Making a label for the jelly jar.
> *Reading and writing:* Collecting jam recipes, a traditional tale: reading, telling the story, watching a cartoon film, acting out the story, creating a cartoon strip of the recipes ("filmed" recipes), based on 'from seed to fruit' – using action verbs (sequencing, dramatizing, illustrating and writing captions); Designing promotional posters for the jams (advertising).

Activity 2: An Autumn Field Trip to the Forest

Conference 2: January 2006
The second SciencEduc conference aimed at allowing teachers to share the work they had done so far with regard to results and difficulties as well as to plan new activities.
Easter seemed to be the right time for activities with eggs.
So a session with pactical activities was included in the second conference.
Paulina Mata was in charge of it and invited teachers to take part in activities with eggs.
Another session with an expert from one of the country's universities also took part. Topic: chromatography/fruit extracts.

Activities in schools as an outcome of the conference
During Easter time, teachers carried out activities with eggs, fruit extracts (based in the activities carried out in the sessions).

Activities in Serrado school
Children went on a field trip back to the forest in order to compare what they had observed during autumn and the situation at Easter time.
Activities: practical activities to discover the characteristics of eggs; egg decoration with fruit extracts.

Final remarks
- Ciência Viva managed to create a community of elementary and kindergarten teachers interested in sharing ideas concerning science activities in schools.
- The Pollen project, although being developed in one specific region, will be an opportunity for teachers in the network to benefit from the support materials and activities created within the project. The project site will allow dissemination to take place.
- Ciência Viva, a designer, was responsible for creating the SciencEduc logo as well as the design of the European site of the project.

SITES:
www.cienciaviva.pt/scienceduc.pt
www.cienciaviva.pt/pollen

The Swedish NTA Program for Primary Science: Its Relation to Inquiry

Per-Olof Wickma
Stockholm Institute of Education, Sweden

During its 10 years of existence NTA (Science and Technology for All) has grown from a small project in a few schools to a nation-wide, well established program for developing science and technology education in primary school. Together with the Royal Academy of Sciences and the Royal Academy of Engineering Sciences it is now endorsed by more than 60 out of 290 Swedish municipalities, 10 independent schools and the Schools for Deaf and Hard of Hearing in Sweden. The program offers 14 units for primary school, and each unit covers all science and technology lessons for a period about 10 weeks. Each unit consists of complete materials (kits) for the students, guides for the teachers and for students and continuous in-service training for teachers. The NTA program continually updates the material and helps creating contacts between schools and local enterprises, with research institutions and higher education. NTA also supports evaluation and research concerning the program.

One core idea of the NTA units is inquiry. Inquiry has been defined as ”a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations.” (US National Science Education Standards)

In this more restricted scientific rendering, inquiry deals with the cycle of 1) asking questions, 2) collecting data, and 3) discussing how the data can be used as evidence to answer the question. In an extended sense inquiry 1) situates a question within an issue (scientific, technological or societal), 2) collects data and relates them to the interest or values in which the question is embedded, and 3) deliberates more generally about how the data can be used as evidence and be related to human interest to solve the issue at stake.

Inquiry fits the Swedish National Curriculum well. Since 1962, Sweden has one compulsory school form of nine years that should give equal opportunities to all students. Democracy forms the basis of the national school system and students should be engaged in an education where they can learn to critically examine facts, communicate, discuss, see consequences, work independently and with others to solve problems etc. Since 1994 students should take science and technology also in primary school and the science curriculum covers biology, chemistry as well as physics. The specific syllabi in all four subjects mention most of the concepts of inquiry in the restricted as well as in the extended sense.

The major challenge to NTA is that the majority of primary teachers have just a few weeks training in science or even less. Most teachers have traditionally covered just some biology, because of short training. Typically teachers have little science and technology subject content knowledge and virtually no experience of inquiry beyond NTA. Their limited education in science also means that they have little knowledge about the nature of science and about science in society and about technology at large.

NTA’s contribution to meet these challenges is mainly to introduce detailed aids in terms of ready made units and associated training opportunities, which teach teachers how to teach science and technology by doing such teaching in their own classrooms. To use Lee Shulman’s terminology, teachers can be said to learn *pedagogical content knowledge* directly, without the detour through subject content knowledge and methodology as separate subjects, as is usually the case in pre-service teacher training. Although this is a very successful way of implementing science and technology education in schools, evaluations have shown that more efforts are needed to develop teachers’ more general knowledge base concerning methods and subject content knowledge, so that they better can reflect on the content of the units and adapt it to local needs. NTA also needs to better develop teachers competence in doing inquiry extended in relation to technology and societal issues. NTA today is mainly focused on inquiry in its restricted sense to develop the scientific concepts of children, but efforts are made to also include inquiry extended.

SciencEduc : Evaluation database

Britt Lindahl,
Kristanstad University , Sweden

The objective of this work package is to develop a database of all evaluations made within each partner country and to compare the results obtained. Here, “evaluation” means: evaluation of the systemic aspects of science education renovation, and whenever possible, evaluation of differential performance achievements of pupils in the schools. The participant countries in this work package are Estonia, France and Sweden.

During the first year, Estonia, France and Sweden collected “everything” written about their own program. By “everything” we meant documents written by researchers, school inspectors, teachers or student teachers. We found many different types of documents, such as investigations, evaluations, articles, book chapters, conference papers, proceedings, master thesis, thesis for teacher examination (Bachelor’s degree), development work at schools and reports of different kinds. The problem was that most of them were written in the respective native language. We decided to write a short abstract in English for the most important papers. In this we describe background, aims, framework, methods, sample and results. These documents show a change in curricula towards more inquiry-based science education and a very positive picture of the results of the projects.

This year, we started by asking all the other partners (Germany, Hungary, Italy and Portugal) to send us evaluations and articles about their program, but we got no responses. The reason was that inquiry-based science education has just started in these countries and therefore they have no written documents about their programmes. So instead we decided to search for publications about Inquiry-based Science Education in Primary Schools in different databases, such as ERIC and EBSCO. When searching we tried different combinations of these words and also used ‘elementary’ instead of ‘primary’, but found few publications. Using a broader search gave us about 100 articles, and we think that about 50 of these can be relevant to our projects. So instead of a database of all available evaluations made in the partner countries, Deliverable 3 in SciencEduc will be a database of relevant articles about Science Education in Primary School. The database will be created in a program called EndNote, but also accessible as a Word document.

The role of assessment and accountability in improving science education
Lessons learned from two decades of science education reform

Sally Goetz Shuler
Executive Director, National Science Resources Center, Washington DC, The USA

Introduction

Many kinds of assessments occur over the course of the school year, from casual classroom conversations between teachers and students to national tests. These assessments provide different people with different kinds of information. Teachers learn about the understandings of their students so that they can adjust instruction, measure student progress, and assign grades. Parents learn about the educational achievements of their students, both in terms of mastering a given curriculum and in comparison with other students. University admissions officers and prospective employers acquire data that they can use to make admissions or hiring decisions. School and district leaders, policymakers, and the general public learn about the achievements of individual students, teachers, schools, districts, and states, in part so that they can hold each of these actors accountable for meeting specified goals.

No one assessment can provide all of these individuals and groups with all of these kinds of information. As the Committee on the Foundations of Assessment points out, "the more purposes a single assessment aims to serve, the more each purpose will be compromised" (National Research Council, 2001a). In addition, scientific understanding encompasses such a richly interconnected web of knowledge, abilities, and practices that assessments need to be equally diverse to gauge the full measure of a student's understanding. One important measure of a healthy science assessment system is a variety of valid, reliable, and fair assessment strategies that together address individual students' academic needs (National Research Council, 2006).

To provide a broad and thoughtful perspective about this topic, four themes have been identified. These themes, listed below, are addressed in the pages that follow.

- Historical overview of assessment in K-12 education
- Elements of a successful assessment system
- Use of assessments in research-based instructional materials
- Lessons learned

Assessment in K-12 Science Education: A Historical Perspective

Several times over the past half century, concerns over the competitiveness of the United States in science and technology have led to widespread calls for the reform of U.S. science education. Over that same time, the focus on assessments and accountability has steadily increased. As a result, the emphasis now being placed on both science education and science assessments is near an all-time high.

The first major wave of concern over U.S. science education followed the Soviet Union's launch of Sputnik 1 in 1957. Policymakers realized that the rapidly expanding science and technology enterprise spurred by the Cold War demanded a steady supply of students who were well trained in science. In addition, scientists saw an opportunity to correct the dominant public perception of science as little more than a source of new technologies (Rudolph, 2002). Both of these interests informed the 20 or so large-scale science curriculum development projects sponsored by the National Science Foundation in the 1950s and 1960s, which marked the first major involvement of the federal government in curriculum development. These curricula generally sought to expose students to "authentic" science, both to improve public understanding of science and to attract talented students to advanced study. Broadly speaking, these curricula aimed to help students think and act as scientists do, which was a substantial departure from textbooks that present science as a collection of loosely connected facts and principles.

Assessment was not a major focus of the post-Sputnik curricular reforms. But the broader examination of the science curriculum in the late 1950s and 1960s led to many innovations that prefigured future developments. For example, the Project Physics Course developed at Harvard included a number of novel assessment techniques (Rutherford, 2003). In one, students watched a film and wrote essays about what they had observed. In another, students could choose one of several different tests, each of which assessed their knowledge in a different way.

A loss of political and popular support for the curriculum reforms of the 1950s and 1960s limited the long-term influence of these innovations. But to the extent that the goal of the post-Sputnik reforms was to increase the number of future scientists and engineers emerging from the K-12 system, those reforms were a success. Between 1966 and 1976 the number of U.S. students receiving bachelor's degrees in the natural sciences, mathematics, and engineering doubled, and the number of doctorates awarded in those fields rose by almost 50 percent (Cohen 1998). Moreover, by the mid-1970s, two thirds of school districts had adopted curricula developed in response to Sputnik (Rudolph, 2002).

By the time of *A Nation at Risk: the Imperative for Educational Reform* was published (National Commission on Excellence in Education, 1983), two important changes were apparent. Science literacy for all had moved from being an implicit goal of reform to being an explicit goal, as high levels of scientific literacy were seen as critical in meeting economic challenges from Japan and other growing economies. Also, the importance accorded to assessment as a way of measuring progress toward the stated objectives of science education had grown substantially. The report opened by proclaiming that "all, regardless of race or class or economic status, are entitled to a fair chance and to the tools for developing their individual powers of mind and spirit to the utmost." To achieve this goal, the report called for "high expectations and goals for all learners," to be achieved largely through enhanced course-taking requirements. To ensure that students met these expectations, a system of rigorous large-scale assessments was necessary:

Standardized tests of achievement (not to be confused with aptitude tests) should be administered at major transition points from one level of schooling to another and particularly from high school to college or work. The purposes of these tests would be to: (a) certify the student's credentials; (b) identify the need for remedial intervention; and (c) identify the opportunity for advanced or accelerated work. The tests should be administered as part of a nationwide (but not Federal) system of State and local standardized tests. This system should include other diagnostic procedures that assist teachers and students to evaluate student progress.

The publication of *A Nation at Risk* had a greater influence on course taking in U.S. high schools than it did on assessment (Education Week, 1993). But it reinforced the idea that proficiency in science could be achieved through large-scale testing that would hold students, teachers, schools, districts, and states accountable for meeting high standards.

Beginning at the end of the 1980s, the movement to develop national standards in particular academic fields, including science, highlighted assessments to a greater extent than had previous reform efforts. The National Science Education Standards (National Research Council, 1996) included a separate set of standards on "Assessment in Science Education" (chapter 5 of the Standards). The expressed goals of the assessment standards were to "provide criteria to judge progress toward the science education vision of scientific literacy for all.” The data provided by assessments were meant to “provide students with feedback on how well they are meeting the expectations of teacher and parents, teachers with feedback on how well their students are learning, districts with feedback on the effectiveness of their teachers and programs, and policy makers with feedback on how well policies are working.” A follow-up volume (National Research Council, 2001a) focused specifically on the formative assessments that teachers and students can use in the classroom to monitor and improve learning.

A growing body of research related to assessment further heightened interest in using assessments to achieve educational objectives. For example, studies of how children learn and how knowledge is structured have pointed toward those aspects of learning that are most important to assess (National Research Council, 2001b). Also, advances in the science of assessment have enabled the interpretation of more complex forms of evidence derived from student performance. For example, much of what a person knows is embedded within specific domains or tasks. Thus, it is important to assess how a person organizes information, uses information to solve problems, and sorts information into manageable units. These research results figured prominently in calls to construct assessments that would yield more a more accurate sense of what students know and can do (Shepard, 2000).

Another source of increased attention to assessment has been changes in the workplace. As jobs have been structured in new ways and have become increasingly dependent on technology, new sets of skills have come to be valued by employers. To succeed in this new economy, students need to learn how to reason effectively, solve complex problems, make judgments about the accuracy of information, and collaborate in diverse teams. In addition, growing social, economic, linguistic, and cultural diversity has put new demands on assessments to judge individuals and groups fairly. These economic and demographic changes have created a demand for forms of assessment that can gauge more complex abilities in a broader context than in the past.

Finally, the passage of the No Child Left Behind (NCLB) Act in 2001 had a profound effect on discussions of assessments and accountability in U.S. education (National Research Council, 2006). The requirement that all students in grades three through eight be tested annually against challenging state standards in reading and mathematics -- with separate reporting of advances made over time by particular subgroups -- has forced many states to reexamine not only their systems of assessment but the curricula and instructional practices through which students are supposed to reach high standards. In addition, beginning in the 2007-08 school year, the act requires states to assess students’ achievement in science at least once per year in three grade bands. Though the examinations mandated by NCLB will be a small fraction of the total time spent on science assessments, these tests can be expected to exert a strong influence on science curricula and instruction.

The Elements of Successful Assessment

Even this brief review of the growing role of assessments in U.S. science education reveals several major themes that have shaped the work and the major discussions that are ongoing among the broader education community. The following outlines these themes.

The Need for Diverse Assessments

Many kinds of assessments occur over the course of the school year, from casual classroom conversations between teachers and students to national tests (Hein and Price, 1994). These assessments provide different people with different kinds of information. Teachers learn about the understandings of their students so that they can adjust instruction. Parents learn about the educational progress of their students, both in terms of mastering a given curriculum and in comparison with other students. School and district leaders gain information about the achievements of particular students and classes. Policymakers and the general public learn about the effectiveness of programs, in part so that they can hold schools accountable for meeting specified goals. University admissions officers and prospective employers acquire data that they can use to make admissions or hiring decisions.

Assessments are most effective when they are directed at a particular goal. As the Committee on the Foundations of Assessment points out, "the more purposes a single assessment aims to serve, the more each purpose will be compromised" (National Research Council, 2001b). These compromises may be acceptable within a particular context, but they need to be explicitly recognized. Thus, to provide the range of information needed by different actors within the educational system, a diversity of assessments is essential.

Scientific understanding encompasses a richly interconnected web of knowledge, abilities, and practices. As such, assessments need to be similarly diverse to gauge the full measure of a student's understanding in science. A number of factors are working against such diversity, including the costs of performance assessments, inadequate teacher preparation, and an emphasis on the learning of disconnected facts and procedures in science instruction. Teachers, school administrators, and district and state officials need compelling rationales if they are to counter these factors and work toward diverse and rich assessments in science.

The Need for Fair Assessments

Fairness encompasses a range of issues associated with the design, administration, interpretation, and use of assessments. At a basic level, fairness applies to the design of a test -- whether it produces reliable results that accurately measure a student's knowledge, and whether the information from that test is used to make valid decisions about educational outcomes (Le and Klein, 2002). Tests also should be fair in that they produce the same score for two test-takers who are equally proficient, so that unrelated characteristics such as gender, ethnicity, or physical disabilities do not affect the scores.

Fairness has broader connotations as well. As Grant Wiggins has written, "tests are intrinsically prone to sacrifice validity to achieve reliability and to sacrifice the student's interests for the test maker's" (Wiggins, 1993). All testing involves compromises and costs, depending on the nature and purpose of the assessment. Classroom assessments can disrupt the learning process and damage the trust between students and teachers. Externally imposed, high-stakes test can distort the curriculum, detract from important learning goals, and place considerable stress on students and teachers. Assessments should promote the learning of individual students. When they do not, they fail to meet the criterion of fairness.

The Need for Alignment

Education systems consist of many pieces, and the sum of the pieces is much greater than the parts only if the pieces work together. Thus, assessments can be effective only when they are closely tied to the curriculum, to instruction, and to the intended uses of the assessments. In addition, different forms of assessment need to be coherent so that they work toward common objectives rather than at cross purposes.

In an ideal world, a shared vision of what is most important for students to know and understand about science would motivate the structure and content of science classes, but the real world is rarely ideal. In some cases, large-scale assessments may force the curricula and instruction along paths that do not serve students well. In other cases, poorly designed learning objectives can lead to frustration and disappointment when they are not matched with assessments.

The alignment of learning standards, the curriculum, instruction, and assessment must be a continuous process rather than a discrete event. New ideas and approaches need to be assimilated into practice so that the culture of a classroom or school gradually changes over time (Elmore, 2002).

The Use of Assessments in Research-based Instructional Materials

One consequence of this extensive research and development processes was that new thinking about assessment could be incorporated into research-based instructional materials much more quickly than is the case for conventional curricula. As a result, all of the instructional materials disseminated by the centers incorporate assessments drawn from current research findings. They typically include matched pre-unit and post-unit assessments, so that teachers can evaluate student growth. Assessments embedded within each unit enable both students and teachers to evaluate performance and adjust their learning experienced according. Self-assessments encourage students to be reflective about themselves and to develop an understanding of what they know and do not know. Additional assessments include review of student portfolios, field observations, paper-and-pencil assessments, and debates.

Evaluations of the effects that material distributed by the centers had on student learning were extremely positive. For example, in those districts in Michigan that used instructional materials developed by the National Science Resources Center, test scores on the Michigan Educational Program for Science improved by 6 to 32 percent, compared to a state average increase of 3.6 percent. In Delaware, where elementary school science programs are based almost entirely on the use of research-based instructional materials, 87 percent of students at the end of grade three and 70 percent of students at the end of grade five met or exceeded the state's performance standards for science, whereas their performance the year before the new materials were adopted was 63 percent. In California, test results from the Valle Imperial Project indicated that students enrolled in research-based science programs performed better on nationally normed science tests than did students enrolled in programs using a traditional textbook approach.

Lessons Learned

Schools, districts, and states are under great pressure to raise student performance on assessments. This pressure can have positive or negative effects on students' learning of science. State science standards and large-scale assessments that are poorly designed or mismatched can force curricula and instruction along paths that do not serve students well. But if state standards and assessments can be aligned with each other and with high-quality curricula, the combination can be a powerful force for improving science education (National Research Council, 2003; Shepard, 2003).

Changes in science education systems create opportunities that may not have arisen otherwise. For example, if randomized, controlled trials are to be performed to gather data on student achievement, it is important to fund the development of assessment measures in the initial phases of the work. In this way, improvements in learning can be rigorously studied and documented to support the adoption of new programs.

The alignment of learning standards, the curriculum, instruction, and assessment must be a continuous process rather than a discrete event. New ideas and approaches need to be assimilated into practice so that the culture of a classroom or school gradually changes over time (Elmore, 2002). Core principles for education -- including the need for alignment -- can serve as guideposts for a process of continuous improvement. In addition, this process of improvement must extend beyond particular classrooms or schools. Good ideas need to be able to spread from one place to others; thus, mechanisms need to be in places that replicate productive innovations so that those innovations can overcome institutional and individual inertia.

Improving science education in U.S. schools remains a formidable challenge. But the combination of the effects of the No Child Left Behind Act and the concerns of national leaders about U.S. competitiveness in science and technology make this an opportune time to pursue new and far-reaching initiatives.

References

- Cohen, A.M. (1998.) *The Shaping of American Higher Education: Emergence and Growth of the Contemporary System*. San Francisco: Jossey-Bass.
- Education Week. (1993.) *From Risk to Renewal: Charting a Course for Reform*. Washington, D.C.: Editorial Projects in Education.
- Elmore, Richard F. (2002.) "The Limits of 'Change,'" *Harvard Education Letter* (January/February).
- Hein, George E., and Sabra Price. (1994.) *Active Assessment for Active Science: A Guide for Elementary School Teachers*. Portsmouth, NH: Heinemann.
- Le, Vi-Nhuan, and Stephen P. Klein. (2002.) "Technical Criteria for Evaluating Tests." Pp. 51-77 in *Making Sense of Test-Based Accountability in Education*. Laura S. Hamilton, Brian M. Stecher, and Stephen P. Klein, eds. Santa Monica, CA: RAND.
- National Commission on Excellence in Education. (1983.) *A Nation at Risk: The Imperative for Educational Reform*. Washington, D.C.
- National Research Council. (1996.) *National Science Education Standards*. Washington, D.C.: National Academy Press.
- National Research Council. (2001a.) *Classroom Assessment and the National Science Education Standards*. Committee on Classroom Assessment and the National Science Education Standards. J. Myron Atkin, Paul Black, and Janet Coffey, eds. Center for Education, Division of Behavioral and Social Sciences and Education. Washington, D.C.: National Academy Press.
- National Research Council. (2001b.) *Knowing What Students Know: The Science and Design of Educational Assessment*. Committee on the Foundations of Assessment. J. Pelligrino, N. Chudowsky, and R. Glaser, eds. Board on Testing and Assessment, Center for Education, Division of Behavioral and Social Sciences and Education. Washington, D.C.: National Academy Press.
- National Research Council. (2006.) *Systems for State Science Assessment*. Committee on Test Design for K-12 Science Achievement. M.R. Wilson and M.W. Bertenthal, eds. Board on Testing and Assessment, Center for Education, Division of Behavioral and Social Sciences and Education. Washington, D.C.: The National Academy Press.
- Rudolph, J.L. (2002.) *Scientists in the Classroom*. New York: St. Martin's Press.
- Rutherford, F. James. (2003.) "Reflections on Assessment." Pp. 147-157 in *Everyday Assessment in the Science Classroom*. J. Myron Atkin and Janet E. Coffey, eds. Arlington, VA: NSTA Press.
Shepard, L.A. (2000.) "The Role of Assessment in a Learning Culture," *Educational Researcher*, 29:4-14.
- St. John, Mark, Barbara Heenan, Nina Houghton, and Pam Tambe. (2001.) "The NSF Implementation and Dissemination Centers: An Analytic Framework." Inverness Research Associates.
- Wiggins, Grant P. (1993.) *Assessing Student Performance: Exploring the Purpose and Limits of Testing*. San Francisco: Jossey-Bass.

Session 1. Inquiry, evaluation and assessment in a primary class room

Assessment of Early Childhood Students' Conceptions of Scientific Inquiry and Nature of Science

Judith S. Lederman
Teacher Education, Illinois Institute of Technology,
Chicago, The USA

Students' understandings of science and its processes beyond knowledge of scientific concepts have been emphasized in the current U.S. reform efforts in science education (AAAS, 1993; NRC, 1996; NSTA, 1989). In particular, the National Science Education Standards (1996) state that students should understand and be able to conduct a scientific investigation. The Benchmarks for Science Literacy (AAAS, 1993) advocates an in-depth understanding of scientific inquiry (SI) and the assumptions inherent to the process. Both reform documents consistently support the importance of students' possessing adequate understandings of nature of science (NOS). Although NOS and SI are not the same, their overlap is significant and it is difficult to discuss one without the other. Research, however, has shown that teachers and students do not possess adequate views of NOS and SI that are consistent with those advocated in reform documents. Moreover, it is difficult for teachers to create classroom environments that help students develop adequate understandings of NOS and SI (Lederman, 1992; McComas, 1998; Minstrell & van Zee, 2000) without explicit instruction and assessment.

Scientific inquiry has numerous definitions, but it most commonly refers to the activities performed by scientists as they develop scientific knowledge. Students are expected to at least approximate such activities (e.g., observing, inferring, etc.). In addition, current reform efforts have placed value on students having an understanding of scientific inquiry (e.g., understanding that no single scientific method exists, understanding that all scientific inquiry begins with a question). The aforementioned are often referred to as the DOING of scientific inquiry and the knowing ABOUT scientific inquiry. As a consequence of how scientific knowledge is developed, the knowledge has certain characteristics. These characteristics are often called NOS and are so closely related to SI that it is not practical to discuss/assess one without the other.

Nature of science (NOS) refers to the values and beliefs inherent to scientific knowledge and its development (Lederman, 1992). Although disagreements exist among philosophers of science, historians of science, scientists, and science educators regarding a universal definition for NOS, these disagreements are irrelevant to K-12 students (Abd-El-Khalick, Bell, & Lederman, 2000). NOS typically refers to characteristics such as: scientific knowledge is tentative, subjective, empirically based, socially embedded, and depends on human imagination and creativity. Two additional aspects involve the distinction between observation and inference and the distinction between theories and laws.

The history of the assessment of nature of science and scientific inquiry mirrors the changes that have occurred in both psychometrics and educational research design over the past few decades. The first formal assessments, beginning in the early 1960s, emphasized quantitative approaches, as was characteristic of the overwhelming majority of science education research investigations. Prior to the mid-1980s, with few exceptions, researchers were content to develop instruments that allowed for easily "graded" and quantified measures of individuals' understandings. In some cases, standardized scores were derived. Within the context of the development of various instruments, some open-ended questioning was involved in construction and validation of items. It should also be noted, that with respect to scientific inquiry, assessment was limited to students' ability to do inquiry with no attention given to what students understood about inquiry. More recently, emphasis has been placed on providing an expanded view of an individual's beliefs regarding nature of science. In short, in an attempt to gain more in-depth understandings of students' and teachers' thinking, educational researchers have resorted to the use of more open-ended probes and interviews. The same has been true with the more contemporary approaches to assessment related to nature of science.

When it comes to the assessment of SI and NOS with paper and pencil instruments, two critical issues emerge: 1) some assessment instruments appear to be poorly constructed, 2) researchers' interpretations of answers may not be consistent with the intended meaning of the respondent. When it comes to the assessment of the understandings of very young students, a third issue quickly emerges. Existing assessment instruments are clearly problematic with respect to young children (grades K-2), for several reasons. Most obvious, is the inability of very young students to read and express their thoughts in writing in a coherent manner. There are also difficulties in simply reading the existing assessment probes to students. The developmental level of the vocabulary in these instruments is inappropriate for young students to understand and many of the examples used to illustrate several aspects of NOS and scientific inquiry are not familiar to many of these students. Consequently, more appropriate instruments are needed. The solution is clearly to use an oral administration of assessment instruments to small groups (e.g., five) of students and then record their answers. Interviewing students in small groups seems preferable given the problems with the dynamics of whole group discussions with young children. The diversity of responses is much greater for young children in small groups than during whole class discussion.

If we accept that young children are capable of developing understandings of nature of science and scientific inquiry and that young students should develop such understandings as part of the science curriculum, a clear problem exists. There is a clear mismatch between the nature of existing paper and pencil instruments and the abilities and skills of very young children. Consequently, this session will provide a concrete research-based approach for the assessment of very young children's understandings of SI and NOS. If students are to become knowledgeable by the time they graduate high school, attention to these educational outcomes should start as early as possible. Without valid and reliable assessment techniques, teachers are unable to discern the effectiveness of their efforts. Hence, the importance of alternative assessment techniques.

Poster Session 1. Inquiry, evaluation and assessment in a primary class room

Chaired by: Judith S. Lederman

Science Activities with Computers in a Learning Centre

Ed van den Berg, Ton Ellermeijer
AMSTEL Institute, University of Amsterdam
Amsterdam, Netherlands

Introduction
Computers have entered all forms and levels of education. In primary education, computers are used for word processing, searching for information, e-mailing, exercises, and artwork, but rather rarely to support science education. In secondary education, the use of ICT in science lessons has become quite common. For example, in a microcomputer-based laboratory (MBL), the computer collects data from sensors, organizes data in the form of tables and graphs, and carries out computations. ICT also offers opportunities for modelling, for controlling objects (robotics), and for networking of students with regard to research projects. Yet even at the primary level, ICT has a great deal of potential. In the present paper, we provide a brief outline of possibilities and then include a case study, which was carried out by our Institute at the 6th grade level.

Potential
The NSF-funded project Technology Enhanced Elementary and Middle School Science II (TEEMSS-II) in the US stated its findings as follows:
Educational technologies – computers, probeware, and networking – can significantly enhance science learning at elementary grades. ICT is particularly valuable at helping students to:
understand cause-and-effect relationships;
visualize change;
gain insights into the ways systems act;

relate math, science, and technology, and
support explorations of emergent behaviour (Concord Consortium, 2003).

Novak and Krajcik (2004) formulated this as follows:
Various learning technologies (ICT)…allow students to engage in aspects of inquiry that they would not otherwise be able to do. Learning technologies allow students to explore their “What if..? questions. They allow students to use similar tools and engage in similar activities of scientists. Because less time is needed for gathering and recording data, more time is available for interpreting and evaluating data.

In traditional laboratories, once equipment has been set up, students are busy reading meters, recording data, carrying out computations and making graphs. Their attention is directed at the details of these activities and often not at the level of concepts and theories (Osborne & Freyberg, 1985; Berg & Giddings, 1992). In MBL, the details of data gathering and organization are taken care of and students’ attention can be focussed on the behaviour of graphs, which “grow” on the screen as the lab activity proceeds. The fact that phenomena and graphs are linked instantaneously seems to have important effects on students’ understanding. For example, Brasell (1987) reports that the use of MBL activities improves students’ comprehension of distance and velocity graphs. According to her, the “linking in time of a physical event with a simultaneous graphic representation may facilitate an equivalent linking in memory” (p. 386). This real-time linking avoids usage of the limited short-term or working memory. In her research, she compares a control group with paper-and-pencil activities with a group of standard MBL activities and a group of ‘delayed’ MBL activities. Her research findings support her hypothesis:
“This research indicates that MBL activities have pedagogical promise for learning science concepts and graphing skills” (p. 394).
Other research reports about the successful confrontation of misconceptions (Metcalf & Tinker, 2004); the productive use of time saved by having computer drawn graphs to explore ‘what if…?’ questions (Novak & Krajcik, 2004); and the much-appreciated development of graphing skills (Mokros & Tinker, 1987), to name a few. With respect to using MBL as part of a strategy to overcome misconceptions, it should be pointed out that one needs an overall strategy that includes much more than just some MBL experiments and that considerable fine-tuning is needed to get an effective sequence of activities and to get the teaching right (Linn & Hsi, 1999).

The National Curriculum in England has formulated goals for ICT education as follows:
Key Stage 1 (until age 7): Pupils could use sensors to detect and compare sounds (optional)
Key Stage 2 (age 7 – 10): Investigative skills: Obtaining and presenting evidence – make systematic observations and measurements, including the use of ICT for datalogging.
Knowledge and understanding of materials and components – how mechanisms can be used to make things move in different ways, using a range of equipment including an ICT control program.
So the National Curriculum encourages ICT use at all grade levels of elementary science education and also includes control activities (making things move…robotics).

AMSTEL Institute
The AMSTEL Institute at the University of Amsterdam has been working in this field of MBL activities or probeware for over 20 years. Hardware and Software have been developed to produce a versatile measuring, analysing and controlling environment. This environment, known under the name Coach, is extensively used in Dutch secondary and further education. Apart from collecting and analysing data, Coach can also control sensors, motors, buzzers,

lights, and Coach can do modelling and take measurements from video. The AMSTEL Institute has been designated as the centre of expertise for the use of ICT in science education by the Dutch Ministry of Education.

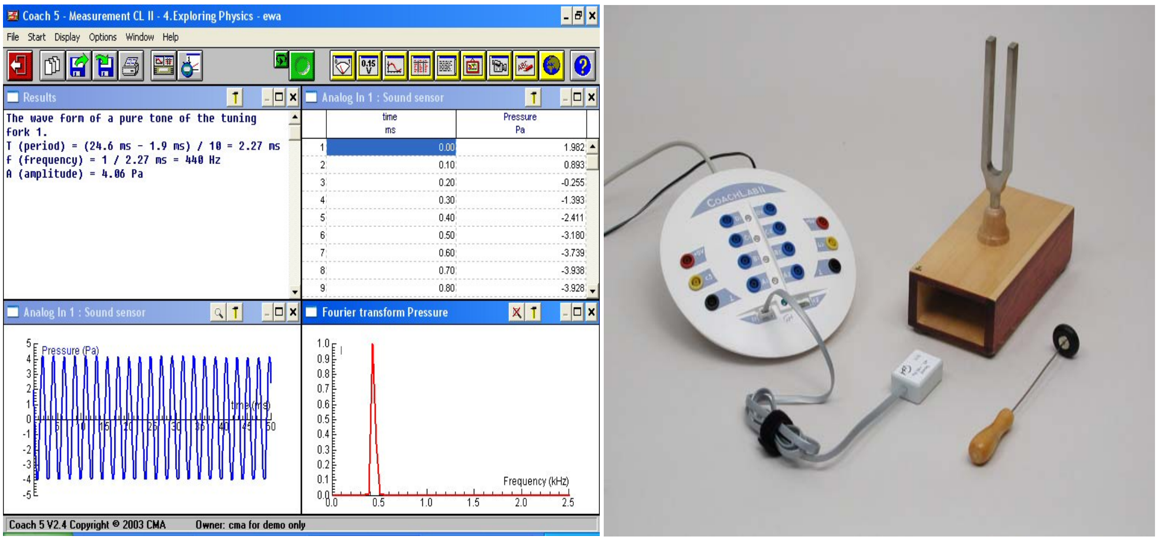


Figure 1: The Coach Lab panel, a microphone as sound sensor, a tuning fork, a typical graph of sound intensity versus time, and an intensity versus frequency plot.

Until some years ago, the AMSTEL Institute was primarily involved in secondary and further education. Over the past few years, AMSTEL has gotten involved in primary education as well.
The Coach learning environment is very sophisticated and complex, but by locking a few doors to the many alternatives, it can be turned into an environment that can be easily controlled by elementary students. Coach can then acquire data through sensors; represent data through meters, numbers, graphs, and tables; and process data with simple tools.

Coach can also control hardware as suggested in the National Curriculum of England. This can be done in a rather fixed setting such as the programming of sensors and traffic lights in Crossroads (Figure 2). Children may first program the lights to switch at fixed times. Then they may create a more sophisticated program that uses the sensors to “feel” cars coming. The traffic lights should then be programmed to use the information from the sensors. In a more open situation, children can also program building blocks such as Fischler and Lego equipment, or control a self-designed open situation by using the Coach Lab interface to control lamps, motors, etc. The programming language makes use of a limited set of commands, which are formulated in everyday language. Children can learn this quite fast, faster than adults can.

Figure 2: Elementary students can program sensors and traffic lights.

In the school year 2002-2003, a pilot study called "across the threshold" was conducted among the 6th grade students at two primary schools in Amsterdam. The purpose was to lower the threshold for primary schools and teachers to start using their computers in lab activities by showing that a) elementary students can control the Coach software and hardware environment and can use it to learn, and b) that use of ICT in elementary science does not have to be expensive. Activities were designed that incorporated the use of light, sound and temperature sensors and the use of light actuators. The science activities took place in a 'learning centre' with two computers. In one school, this was in a quiet place in the hall. At the other school, it was in the corner of the classroom. While the teacher was busy with the rest of the class, pairs of students did the activities. When students got stuck, there was assistance from a student teacher. The experiences have been recorded in the following case study, which we carried out in 2003.

Case Study: Trials with Microcomputer-Based Laboratory in Dutch Elementary School[2]

Compared to other countries, elementary science education is weak in the Netherlands. For example, in England there have been many complaints about the time and attention given to science and technology education and about the weak preparation of students (Osborne & Simon, 2000). However, Peacock (1997) indicates that 38% of the time spent on science lessons in elementary schools is spent in lab activities and "science" is being tested at the end of key stage 2, at age 11. In the Netherlands, there is no compulsory testing, thus a lower priority for science. At most schools, science is a subject studied from a book with no or little lab activity. In elementary teacher education, a total of only 200 hours is spent on science and environmental education (Graft 2003a, 2003b). Of course there are exceptions. Several hundred schools out of 7000 do have science and/or technology programs that are partly activity based.

Our AMSTEL Science and Mathematics Education Centre has been mainly focused on secondary and tertiary education, and the most successful product is the Coach platform for Microcomputer-based Laboratory (MBL). In several projects, we have tried to get some experience in elementary science education and our activities in this area are now expanding.

[2] With thanks for the collaboration of Ron Vonk, Willem Bustraan, Jerry Hazes, Rene Onclin and Ank Ninteman

Here, we would like to report about some exploratory experiences with MBL in the "threshold" project. We decided to take our sensors and adapt some activities to the elementary school environment, and in this way, we discovered some things that work and some that do not.

Samples and methods

Figure 3: A learning center in a corner of the classroom

The trial schools were in Amsterdam, with children who both represented a colorful mix of ethnic backgrounds and had a relatively high academic performance. We experimented in grade 6 with 11- and 12-year-old students. At one school, there was a teacher who had been active in developing a technology program and was responsible for the computer system in the school. In the other school, there was a competent teacher, but with no special affinity for science and technology. The science activities took place in a "learning centre" with two computers. In one school, this was at a quiet place in the hall. At the other school, it was in the corner of the classroom (Figure 1). While the teacher was busy with the rest of the class, pairs of students did activities in measurement and control using the computer, working from activity cards, as eventually the learning centre was to be able to run rather independently from the teacher. When students got stuck, there was assistance from a teacher education student. This student also taught the first pair how to use the computer. Subsequently these students were paired with classmates and taught them. Most lessons were attended by an observer from our team (Ed van den Berg) who evaluated and revised the activities. Evaluation was done by observing the work of students in the learning center and through in-depth interviews of 8 students several weeks after the activities ended.

Results: Coach measurement, graphs, and control by programming

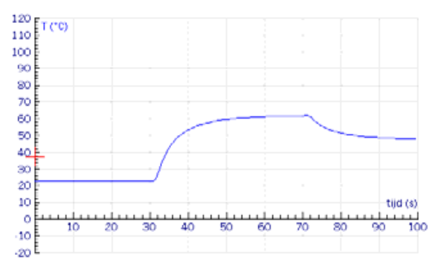


Figure 4: A graph of temperature versus time obtained by adding hot water to cold water and then adding cold water again.

Within the Coach MBL environment, many doors/choices can be locked and this results in a very simple environment. Children very quickly learned to control this environment. Within 20 minutes, they were able to log in, choose a sensor, do measurements with it and produce graphs. Children could teach each other. Thus, a student would typically carry out the activities with the sensors and then would be paired with another student. The experienced one then taught his/her computer skills to the next student (Box 1), who was in turn paired with a new student, etc. Students understood the meaning of the graphs quite quickly. They could read values, point out events, and explain what happened at certain points in the graph. In one activity, students started with a beaker of tap water. First they added hot water and then some cold water. In the graph (Figure 4), they could point out exactly where these events had taken place. In post interviews, students were able to invent correct and realistic alternative ways in which a graph like Figure 4 could be produced, for example by putting the sensor in a cold place, then a hot place, then in a place with an intermediate temperature. They understood the concepts and methods well enough to do that.

They could also explain why the graph cannot go straight up as time is needed for heating the sensor. Measurements with sensors produce graphs immediately.

> Box 1: Teaching each other……and inquiry
> (from the researchers' logbook, names are pseudonyms)
> Chantal used the Coach environment already 2 or 3 times. For Christine it is the first time. The girls first read the activity card and look at the card with the Coach buttons and explanation. Then Chantal starts the computer. It takes a while for her to remember the password. But then she enters Coach and happens to remember that the sensor has to be attached to a circuit not only physically, but also on the screen. Chantal rubs the sensor so it gets warm. She also remembers how to enlarge the graph. She uses words such as friction. Christine tests how much she can "rub" the temperature up. Can she get it to 50 oC? Once in a while she puts the sensor to her cheek to feel the heat. Other girls pass by: come here and feel! Then they start to investigate. Chantal discovers a glass with cold water. Can we use this? Christine: Oh, the measurement goes down. She points to the graph. Christine: would it go down if I stir? No, it does not. And they keep going on like this asking questions and trying. I ask them to close the Coach window on the computer and then I ask Christine to start and configure Coach again and do a series measurements. After the login screen, there is some hesitation but then she herself discovers the activity button. She measures and produces a graph. Then I ask about the graph. They know how to read it. Chantal immediately enlarges part of the graph. They are a bit sloppy in reading values. They can indicate when an event happens and what happens. They also understand that the sensor needs time to cool down when cold water is added and how one can see that in the graph.
> The activity of the girls was "self-sustaining". They kept asking questions and thinking of new measurements such as using the hot tea somebody came to deliver to the teacher. This inquiring attitude differed greatly across different groups. Some students went quite mechanically through the activities on the activity card and accepted outcomes as self-evident and did not get ideas, unlike Chantal and Christine.

When a light sensor is covered, the light intensity graph on the computer screen immediately dives down. That is the power of MBL. In another experiment, students spread out their hands and let their fingers pass through the light beam. Students could immediately explain the graph and link the events with points in the graph. For example, they could see in the graph that two fingers were not spread but touching each other. Graphs of temperature and light versus time went very well.

Graphs of sound versus time did not. Students mixed sound intensity and pitch. Trying to get pitch/frequency from the graph is something that should be postponed until the upper level of secondary school. A recent new investigation about sound absorption has worked much better. In this new activity, the focus is only on loudness and materials that can be used to reduce the loudness of a buzzer.

In short, controlling the computer, carrying out measurements, and producing graphs are surprisingly easy to learn. We did have the advantage that the teachers had done a good job in teaching graphs (without computer). There might also be more problems at schools ranking lower in academic performance.

Something else students can learn rather easily is controlling objects such as light bulbs, a toy car, or other apparatus using a computer program. Making a program to control light bulbs, it is immediately evident to students whether the program is correct or not. Either the light bulbs do what students want them to do, or they don't. Quality control is built in. There is immediate feedback from the apparatus, something quite rare in many educational tasks. Students worked with three light bulbs, which could be controlled independently. They could program all kinds of patterns such as ABC-ABC-ABC in which bulb A, B, C would be switched on and off one after the other. They could also control the time during which the bulb should light or be off. Repetitions can be programmed in. In follow-up activities, which we have not tried yet, students can then continue to control sensors and actuators such as a heating element. For example, lamps can be switched on and off dependent on light intensity measured by a light sensor or temperature measured by a temperature sensor.

The Coach programming language for controlling objects is simple, intuitive and yet challenging enough to let 6th grade students work with great motivation. As with Coach measuring, Coach programming could be learned fast. Students quickly realize how they can switch on and off lamps using the computer. The initial programming activity took 20 minutes (we ourselves had expected 40 minutes). Two and for some students three weeks later (without intermediate practice) students were asked to complete the following task:

The following program to lamps on and off is not complete yet:
Lamp (A) = on
Wait (….)
Lamp (….) = off
Wait (….)
Lamp (….) = on
Wait (….)
Lamp (B) = off

(a) Complete the program: Lamp A should be on for 5 seconds and then it should go off. Then we wait 3 seconds and then lamp B should be on for 5 seconds.
(b) Write your own program in which lamps A and B are switched on simultaneously for 5 seconds and then switched off.
(c)

Even with their limited 20 minutes of programming experience, the boys and girls did not encounter problems with this task. Of the 8 students interviewed, 7 came up with perfect answers. One student wrote a program that did not fulfill the requirements, but he could explain well what his program would do.

Limitations of a Learning Center

The Coach software and hardware environment is a tool for learning and not a goal in itself. Using Coach, students can gain insight into how sensors and actuators at home (heating systems, washing machines, ovens, cars) do their work without us noticing or paying attention unless the apparatus fails. In addition to the learning center with its computers and sensors and activity cards, students will also need classroom discussion to achieve that aim. We did show that the Coach environment is very suitable for learning to understand and interpret graphs and connecting them with real phenomena. We also showed that the Coach environment is successful at teaching control through programming actuators.

The computer is often considered as a magic learning tool that can achieve a wide variety of learning goals such as concept development for science and technology. However, concept development does not only require sensory input from the environment, experiments, or a textbook, but also interaction with the teacher, who is responsible for quality control. Concept formation requires a complex interplay between small group activities with or without the computer, interaction between students, and interaction between students and the teacher, including quality control. A learning center, as described in the present article, can only constitute one of several necessary components. Experiences with ICT and learning (Linn & Hsi, 2000) show that the "fine-tuning" of a learning strategy and system, and especially the necessary teacher development component, takes a long time. Linn and Hsi were only satisfied with their module on heat and temperature after 7 cycles of classroom experiments and extensive revision in each round at several schools. This process took several years. The conclusion that revising learning strategies takes time is valid for all educational reforms, both small and large (Fullan, 2001; Joyce & Showers, 1996). Research on the use of ICT in conceptual development takes a broader and more comprehensive approach than we were able to apply in our learning centers. Students were able to apply concepts at a simple level in interpreting graphs. Overcoming misconceptions at a more complex level will require more than a learning center can offer. Of course an experienced teacher can use results from measurements in a plenary lesson. For example, when many students had already used the temperature sensor, the teacher did a 24-hour measurement in the classroom and showed the graph. It turned out there was an anomaly during the night; students spotted this and came up with explanations.

In short, what worked was learning to measure with Coach, analyze results in graphs, and control equipment through simple programming. What also worked was learning to interpret simple graphs and link them to events, which shows that conceptual learning had taken place. With respect to the latter, we should acknowledge that students already had a reasonable general understanding of graphs prior to their learning experience in the learning center.

Activity cards, learning sequences

Our lesson materials came from lower secondary activities that were adapted to be suitable to the 6th grade. The adaptation was rather substantial. Language and layout had to be changed a great deal. Language and reading were reduced to a minimum. Much of the text could be replaced by figures and photographs. The amount of information per page was greatly reduced, and this turned out to be feasible.

The first activity with temperature sensors went well. Students first looked at rubbing of the sensor and the pattern that produced. Then they looked at a cooling curve of hot water. That turned out to be boring. By letting students add cold water, or measure hot tea, which happened to pass by in the hallway, more interesting graphs were produced. This also constituted a nice opportunity for discussing graphs. As it turned out, the activity ran quite fluently and was within reach of the typical 6th grade student.

The second activity concerned sound and used a microphone. This did not work out well. Signals on the screen are complex. The frequency concept is difficult and in the graphs frequency/pitch, loudness, and time are juxtaposed for the students. Having difficulty with graphs and concepts easily translates into non-serious behavior on the part of students. (As indicated earlier, we now have a more interesting activity with sound that works better and triggers inquiry.)

The third activity with a light sensor gave better results. The activity was planned for 30-40 minutes, but the children were fast and could complete the activity in 15-20 minutes. So we improvised additional experiments on the spot, such as moving a light sensor toward and away from a lamp. The resulting graphs were easy to understand and still rather intuitive. On the other hand, there are also surprising graphs, such as those of a computer monitor (CRT), which turns out to produce flashes rather than continuous light. The same is true for some other kinds of lamps, such as fluorescent lights. Even regular 220V bulbs produce a varying (sine wave) pattern.

We also tried some open investigation. This worked well with some students and they got quite involved. With others it did not work. For them it was either a bridge too far or we did not have the proper task. Managing the Coach learning environment was not a problem, but intensive guidance was needed to make open activity meaningful.

A fourth activity was a mix between directed and open. Students pulled a card through a light beam, observed the graph, and were then asked whether the light sensor could be used to measure speed. This was a difficult question for them. Yet some children came quite far and became very interested. With some assistance, they were able to make the conceptual jump and build a set-up in which they could and did measure speeds. A smaller jump would be to just ask students whether they could use the light sensor to measure time.

The experiences described above show that we still have a long way to go, but that it is possible to work with the Coach environment, sensors and actuators in the elementary school. Our recommendation is to focus attention on controlling actuators and start with the activity of programming a traffic light. That can be done with real bulbs, a control panel, and a computer, but it can also be done with bulbs on a computer screen (Activity 1). After that, one could introduce real bulbs and the Coach Lab interface (Activity 2). The next step is then the temperature sensor (Activity 3). In that activity, children learn about controlling the sensor, measuring and graph making. Subsequently, the temperature sensor could be used to control heating lamps and a fan to keep the temperature in a small dollhouse within a certain range (Activity 5). At this point, it may be time for an open activity in which students have to design a program for controlling the temperature of a baby bath or a traffic light system (Activity 6). In our experiments in 6th grade, we did not get that far, but we had some successful trials with weak 8th grade students.

What do children think they learned?
We also wanted to see what children themselves thought they had learned. We asked 8 children this questions in interviews. They primarily mentioned very concrete things such as:
-how one works with a sensor
-how the computer program is started
-switching on, switching off, making graphs, enlarging parts of graphs
-how you can switch light bulbs on and off
-how one can make something warmer or colder

The children do not think of more abstract skills such as reading and interpreting graphs, translating activities into steps while programming, and learning to investigate phenomena. So the teacher will have to focus on explicitly teaching students about metacognitive awareness of their own learning. The children should become aware that they are expected to learn more than "how one can heat or cool things".

We also asked children whether they were familiar with sensors and actuators in their everyday life. We had not paid attention to this in the learning center. Usually students answered “no”. But after questioning further or mentioning one example, the children could quickly supply new examples such as sensors to measure temperature in washing machines, the gasoline indicator in a car, speed sensors in cars, and lighting controls in parents' bar/disco. It is important to pay attention to this so that computer activities are experienced not only as fun, but also as relevant.

Fun or not

We also asked which activities students liked most. In one school, controlling light bulbs through a self-made computer program ranked highest. That is why we propose to make computer control the central theme of future activities. But the light and temperature activities were popular as well. When we asked about the least interesting activity, most students were quite polite and said that they enjoyed everything. A few mentioned the sound activity, but there was also one student who thought that was the most interesting activity. While at one school both boys and girls were engaged quite actively, at the other school girls reacted differently. During an evaluation group discussion, some girls asked explicitly what this all was for, what was the relevance…. Thus, it is important to pay attention to the question of relevance.

Literature

Berg, E. van den, Giddings, G. (1992). Teaching in the Laboratory: An alternative view. Monograph. Perth: Science and Mathematics Education Centre, Curtin University of Technology.

Berg, E. van den, Bustraan, W.J., Vonk, R. (2003). Vingeroefeningen met Coach in het Primair Onderwijs. AMSTEL Instituut, Universiteit van Amsterdam.

Brasell, H. (1987). The Effect of Real-Time Laboratory Graphing on Learning Graphic Representations of Distance and Velocity. Journal of Research in Science Teaching, 24(4), 385–395.

Fullan, M. (1991). The new meaning of educational change. London: Cassell Education Ltd.

Graft, M. van (2003a). Woudschoten verslag op CD.

Graft, M. van (2003b). Natuurkundeonderwijs op de basisschool? Natuurlijk! NVOX, 8, 365-367.

Joyce, B., Showers, B. (1986, 2003). Student achievement through staff development. London: Longman.

Linn, M. C. and Hsi, S. (1999) Computers, Teachers, Peers: Science Learning Partners. Hillsdale, NJ: Lawrence Erlbaum Associates.

Metcalf, Shari J., & Tinker, Robert F., 2004. Probeware and Handhelds in Elementary and Middle School Science. Journal of Science Education and Technology, 13(1), 43–49.

Mokros, J. R., & Tinker, Robert F., 1987. The Impact of Microcomputer-based Labs on Children's Ability to Interpret Graphs. Journal of Research in Science Teaching, 24(4), 369–383.

Novak, A. M., & Krajcik, J. S., (2004). Using Technology to support Inquiry in Middle School Science. In: L.B. Flick & N.G. Lederman, eds. Scientific Inquiry and Nature of Science. Dordrecht: Kluwer Academic Publishers, 2004, p. 75–101.

Osborne, R., & Freyberg, P. (1985). Learning in Science: The Implications of Children's Science. London: Heinemann.

Osborne, J., S. Simon (1996). Primary Science: Past and Future Directions. Studies in Science Education, 27, 99-148.

Peacock, A. (1997). Opportunities for science in the primary school. Stoke on Trent (UK): Trentham Books Ltd. ISBN: 1 85856 017 9.

Vonk, R., Berg, E. van den, Bustraan, W.J. (2003). Website met verslagen, foto's en lesmateriaal http://www.science.uva.nl/research/amstel/dws/drempel/

Students and inquiry-based science

Nada Razpet
Faculty of Education Koper, Faculty of Education Ljubljana, Slovenia

Abstract: Those who wish to teach science through experience, should first gain sufficient experience of science themselves. Our students, future primary school teachers, are inspired to gain their experiences while realizing their science projects and presenting them to their colleagues. This is part of their regular obligations in the course 'Science' in their first year at university. Each student must complete a simple research project on a given scientific topic. The research includes planning of objective trial(s), realization of measurements, presentation of obtained results with tables and graphs, and reaching and explaining conclusions based on their results. They should also indicate how their theme could be presented in school. Some of the students have already worked the theme out with small groups of children and reported about the goals achieved. At the end, they present their projects with posters, which they comment on for colleagues.

Introduction: Primary school teachers must complete a 4-year university program. During their first year, they have 180 hours of science, divided between biology, chemistry and physics. A total of 60 hours of physics comprises 30 hours of lectures, 21 hours of laboratory experiments, 5 hours of seminars and 4 hours of field work. During the past 2 years, we have focused on seminars, which are actually short "scientific researches". These researches are discussed in the present paper.

Each student chooses one of the suggested problems (or proposes a new one), prepares a draft of the experiment and discusses it with his/her supervisor. Most students experience initial problems with finding the equipment for the experiment and the control of variables. Two or three meetings with the supervisor are usually necessary to solve these problems. Each student prepares a poster with his/her research (including tables and figures) and presents it in a 15-minute session to the group of colleagues. Presentation includes a demonstration of the experiment; posters are displayed in the hall.

Instructions for students concerning the research are written in a telegraphic style:
Write down your hypothesis, plan the experiment to confirm or disprove it, define variables and constants, carry out the experiment, interpret results of measurements, prepare action questions on your subject for other students, and prepare poster and presentation.

Topics
Research topics require easily obtainable material, either from a nearby location (water, snow) or topics appropriate to special occasions (The World Year of Physics). Some equipment is available at the faculty (thermometers, cups, burners, fans…). Some of the analyzed problems included: in which mug does the tea cool faster, which footwear is more slippery, which shopping bag is the strongest, which paper towels are better.

Let's take a closer look at the last problem. A student wanted to investigate which paper towel absorbs more water. She collected several brands of paper towels of different quality. First, she checked the attached information on towel toughness, color, profile, thickness and quality as advertised.

Second, she selected 4 different towels of approximately the same thickness. A 20x20 cm square of each towel was folded into a 10x10 cm square and submerged in 130 ml of water for 60 seconds. Towels were then removed from the water container, excess water was dripped back into the container for 10 seconds. After testing each towel, the remaining water was transferred into a small cylindrical water container. Four such containers were lined up and the most absorbing towel identified.

It must be stressed that the student prepared her research such that it could easily be performed by elementary school children, who mostly come to a conclusion based on experiments with direct comparisons.

Students' response

Most students are not enthusiastic when faced with this type of research task, and most reactions to proposed problems are along the following line: »Oh no, why did I get physics, I had problems with it in secondary school«. Students are also surprised at the absence of recommended literature. Most students have problems when selecting variables and controls, which are best seen during initial individual discussions with the supervisor. For example, they forget that paper towels come in different sizes and thickness and are often unable to summarize the key findings. Poster design (placing text and figures, selecting font sizes, minimizing text) is also problematic; some have difficulties in performing the experiment in front of other students or need more than the 15 minutes available. However, all this is good practice for their future work as teachers, when timing is even stricter. It has to be mentioned that some students display great ingenuity in performing the experiment and can present their findings in a fascinating manner.

With these short researches, students develop their manual skills, and learn how to observe, plan, describe and present their work. In this way, students also realize that planned experiments for elementary school students have to be carried out by teachers themselves before actual performance in the classroom. This personal experience allows them to identify the equipment needed, the most common problems and how to solve them.

Reference

Katarine Hrastnik, poster, Ljubljana 2006

Inquiry, Evaluation, and Assessment in the Primary Classroom

Sally G. Shuler
National Science Resources Center, Washington DC, The USA

Background

The National Science Resources Center (NSRC) was created in 1985 by two of the most prestigious science organizations in the United States, the Smithsonian Institution and the U.S. National Academies. The NSRC's mission is to improve the learning and teaching of science for all children in the United States and throughout the world.

The NSRC fulfills its mission in four major ways:
—Scaling up and sustaining effective science education programs;
—Supporting the professional growth of teachers of science;
—Providing research-based science instructional materials; and
—Developing and strengthening science education capacity internationally.

Inquiry Science Education

All of the NSRC's programs and products are based on research about how people learn. Inquiry—the learning and teaching of science in the way that scientists conduct research—is an important component of the NSRC's philosophy. The NSRC model for science education reform explicitly endorses the use of inquiry-centered science instructional materials, both the NSRC-developed Science and Technology for Children Program and other exemplary programs developed with support from the U.S. National Science Foundation.

Evaluation and Assessment

The NSRC's two curriculum programs provide materials for classroom use from kindergarten through grade nine. These programs comprise 32 distinct units covering the life, earth, and physical sciences and technology. All of these materials were subjected to rigorous subject-matter review during development, and to external academic evaluation and extensive field testing in classrooms prior to release. All include embedded assessments to help both teachers and students alike determine academic progress.

Student Achievement

Where these materials have been used consistently over time, the result has been increased student achievement in science in places as diverse as Delaware, a small state on the east coast of the United States; the Pittsburgh, Pennsylvania, metropolitan area; a poor rural area of south-central California; and Washington State, in the northwestern corner of the United States.

Session 2. Teacher support and training

Some factors influencing the impact of in-service science education in school

Tina Jarvis
University of Leicester, The UK

Achieving long-term impact of science in-service training is very difficult. There are numerous factors that influence impact including participants' gender, initial qualifications, experience, school responsibility and attitudes; pupils' out-of-school situation as well as initial attitudes, language expertise and cognition; location, length and timing of the in-service; available follow-up in-service support, etc.

This presentation examines research on factors that influenced the impact of three in-service programmes that were carried out in the City of Leicester and East Midlands Region, UK. These were:

- AstraZeneca Science Teaching Trust Project, which was a 2-year in-service centre-based programme with 70 primary teachers (1999 & 2000);
- Two-year school-based programme with 11 teachers in Oak Hill Primary school who had problems teaching primary science (2005 & 2006); and
- Several 4-day in-service centre-based programmes for inexperienced and experienced technicians in secondary schools during 2004 and 2005.

Although the three programmes were designed to take account of much research on factors that make good in-service training, the experience for the teachers and their pupils varied. The research set out to explore what factors were significant in influencing impact including:

- Variations in confidence and expertise of teachers;
- Merits of providing in-service in school or at a centre away from the school;
- The influence of the school head teacher or manager; and

- Different rates of development during in-service.

Methodology

The evaluation methodology included collecting data about participants' reactions, attitudes and learning in relation to the in-service though confidence and attitude questionnaires, cognitive tests, observation and interviews. Organisational support and change within the school and its culture were ascertained by interviewing school managers. Amount and type of application in the classroom were assessed through interviews, pupils' questionnaires and results from pupils' national science tests.

Variations in confidence and expertise of teachers

In the AstraZeneca project, no one factor explained the differences in teachers' responses to the in-service programme. Gender, qualifications, experience in teaching, school responsibility and class group interacted to influence impact. Cluster analysis identified 4 teacher types of response to in-service: high attainers who improved attitudes and confidence; teachers with limited science knowledge who found the course difficult but made improvements; unaffected professionals who were already working well and for whom the course had little effect; and disaffected teachers who showed low levels of confidence and competence throughout. Consequently, a one-course-fits-all approach to in-service is unlikely to be as effective or economic as focused differentiated courses. In this case, it would have been appropriate to provide short courses for teachers with a high cognitive base that included innovative pedagogical strategies. Long-term in-service with school support was needed for other teachers. This included addressing issues of self-confidence.

Location of in-service: In school or out of school?

The AstraZeneca Project was primarily a centre-based in-service programme with some tutor support and peer-mentoring in school. There were advantages and disadvantages in this approach. For example, as teachers were away from the immediate demands of school they were more likely to concentrate and reflect. Teachers from different schools could share experiences and good practice. In addition, specialist staff, equipment and facilities were easily available. However, there was sometimes disruption to the school when the teachers were away from school. This was noticeable in inner-city schools where it is difficult to provide replacement cover for classes.

In contrast to the AstraZeneca project, school-based focused in-service training was provided at Oak Hill Primary School. Most of the 11 teachers had very low levels of competence and confidence in teaching science. Following paired or individual interviews to identify personal needs, they were given intensive school-based support in groups of 2-4 directly related to what was currently being taught in the classes. The in-service in the school was successful, but it did not produce particularly different results from the AstraZeneca Project. Again there were advantages and disadvantages. The school-based course was advantageous as the teachers' knowledge and self-confidence was so low. If individual teachers had joined external in-service sessions they would have probably been overwhelmed by the number of new ideas and been subdued by the competence of other teachers on the course. However, their low expectations of pupils were difficult to address as the teachers did not meet colleagues from other schools who knew pupils at the same age were able to achieve more.

Situation with the school & support from school management

In all the projects, the head teachers' support appeared to be a key influence. Once most managers had arranged the in-service, they erroneously felt that little other action was needed.

This was explored in some depth during the research on in-service for technicians. Interviews indicated that where management structures were poor there was a general loss of self-confidence and even a desire to leave the profession as the in-service had raised expectations that could not be achieved.

Building on in-service: Recognising developmental stages in teachers

Some teachers' and technicians' practice changed markedly during the in-service programmes while others made little progress. It may be possible to identify stages of development that can be recognised during a sustained in-service programme to enable trainers to know which teachers need extra support and who might act as mentors or trainers of the future. There are some stages of development before the children are affected by the in-service while the teacher learns necessary knowledge and skills. There are then several stages of varying impact in the classroom which appear to be, at least partly, related to levels of confidence and motivation.

Pollen Project and the Future

The Pollen project in UK will be working with very able, enthusiastic teachers who have chosen to participate. It will be interesting to monitor how these teachers progress. Understanding the additional factors involved in in-service provided in different countries with different underlying educational philosophies is daunting, but exciting.

Poster session 2. Teacher support and training

Chaired by: Tina Jarvis

Teachers' use of practical activities in the primary school classroom

John Cripps Clark
Deakin University/Hazlehead Academy, Australia, The UK

Abstract
Critical to the provision of science and technology education in primary schools that challenges curiosity and develops positive attitudes towards scientific knowledge and practice is the role of the teacher, in particular, how she uses practical activities. I will report on a case study of how activist teachers use inquiry based, hands-on practical activities in their teaching of science and technology and argue that practical activities can serve a variety of roles that are dependent both on the teacher's context and constructivist philosophies. Of particular importance is the provision of extension activities, research projects, competitions, excursions, and visits by parents, tertiary students, and scientists that extend science beyond the classroom.

Introduction
To understand what is possible to accomplish through the use of practical activities in primary science, a case study was undertaken of four teachers of primary science. Experienced teachers of primary science were chosen after a preliminary study in eight schools across three states and territories suggested that studying typical classrooms would not reveal the potential of practical activities in primary science.
The research used videotapes of all science lessons in an eight-week unit of work in each of the four classrooms, student work, teachers' planning documents, and interviews with the teachers and selected students. Activity Theory was used as a framework for analysing the data.

Tools of Analysis

Three of the tools used in the analysis are described and an example of their use is given.

Roles of practical activities

Teachers used practical activities to fulfill a wide variety of roles

Table 1

Roles Suggested in the Literature and Examples of Practical Activities That Fulfill Those Roles

Categories[1]	Roles suggested in literature	References	Examples from my research
Functional understanding of information, concepts and principles	Illustrate and test scientific knowledge and concepts	(Gott & Duggan, 1995; Séré, 2002)	Weather maps Sciencentre Dissections
	Develop concepts by making the abstract concrete	(Gott & Duggan, 1995)	Air activities: magic finger, bag of air, paper in the cup, card under the cup Windmill & parachutes
	Identify and deal with misconceptions	(Driver & Bell, 1986; Lazarowitz & Tamir, 1994)	Ruler and paper/paper drop
Process skills	Develop observation and recording skills	(Kerr as cited in (Hodson, 1993), (Gott & Duggan, 1995)	Weather measurements Bones Dissections
	Develop technical skills such as measurement and the use of equipment	(Gott & Duggan, 1995; Hegarty-Hazel, 1990)	Anemometer Rocketry and robotics Dissections Windmill & parachutes
Elements of scientific method	Generate questions and training in problem solving	Kerr as cited in (Hodson, 1993), (Lave, 1997)	Design task Murder in Menagerie Park Air activities: magic finger, bag of air, paper in the cup, card under the cup Home-based activities

Science learning activity categories

A classification of science learning activities was developed from Schaverien and Cosgrove's (1999.2000) "biological basis for generative learning in technology-and-science". ***Exploring*** occurs when the teacher allows or students initiate free investigations. ***Observing*** structures the process of exploring and directs it towards recording and communication. Examples include: examining a specimen, drawing diagrams of bones, or taking measurements of windspeed.

Experimenting is where science concepts and observations are tested, demonstrated or developed using practical activities in a systematic manner, usually according to a procedure specified by the teacher.
Designing and constructing includes testing models or instruments such as anemometers, rockets, robots, model lungs, pinwheels and parachutes. In the primary classroom it is often regarded as the province of technology.
Researching, or literature searching, is obtaining information from text, diagrams, pictures and computer programs.
Explaining is communicating scientific information using worksheets, posters, presentations, and reports.

The science learning activity categories are used to classify the activities in each unit to analyse their structure.

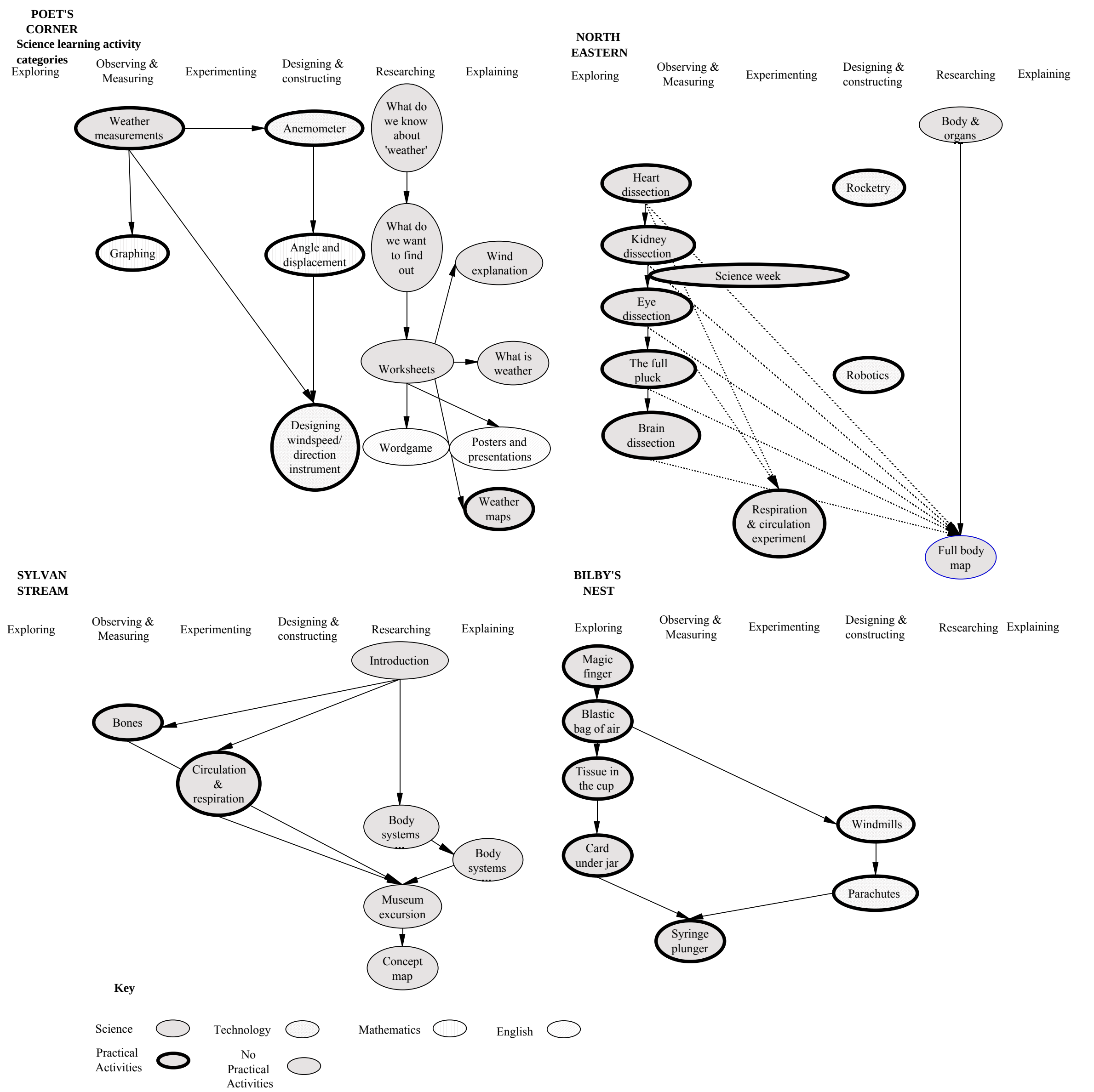


Figure 1 **Comparison of the structure of the four units.**

Activity Theory

Activity Theory has been most rapidly embraced by studies in education that focus on technology as tool that is used to mediate teaching, most notably computers (Groves & Dale, 2004; Hasan, Gould, Larkin, & Vrazxalic, 2001; Jonassan & Rohrer-Murphy, 1999). It has also been successfully applied to more abstract tools such as language (Gutierrez, Baquesdano-Lopez, & Tejeda, 1999). This study contributes to our understanding of the ways in which we can use Activity Theory by applying it to a pedagogical technique, namely practical activities, as a mediating tool and using Activity Theory to gain insight into primary science teaching.

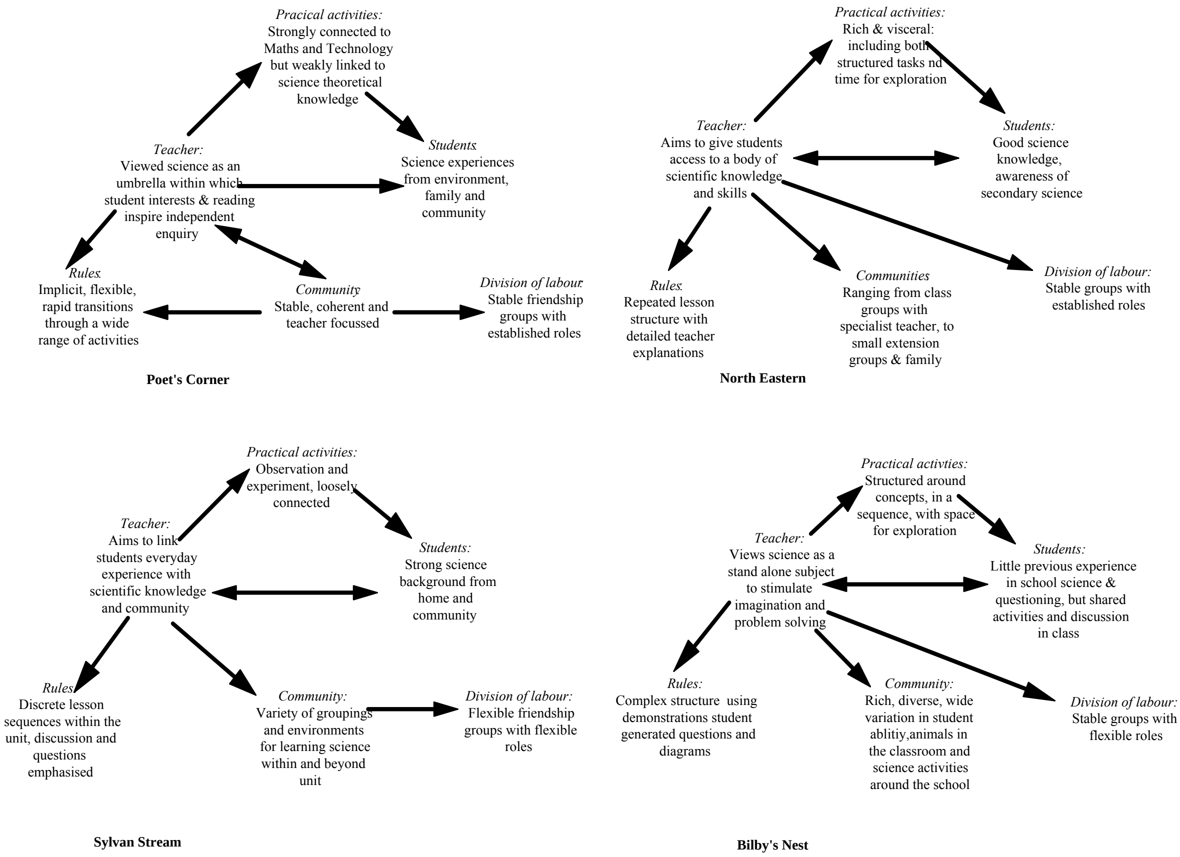


Figure 2: Comparison of the activity systems of the four cases

Beyond the units

A significant unanticipated finding in this thesis is the amount and quality of practical activities that occurred beyond the normal classroom teaching units.

Table 2

Science Beyond the Unit in the Four Schools

Type of activity	School			
	Poet's Corner	North Eastern	Sylvan Stream	Bilby's Nest
Excursions	Museums		Museum	
Within the school	Show and tell	Robotics Rocketry	Solar challenge Streamwatch	Junior science club Inventors club

			Airwatch Rodent research	
Community and home	Sleepover Billy cart derby	Science week activities	School pond	Family science nights
Visitors and incursions			Science and technology students	Visiting scientist Science students CSIRO science show

Each teachers' repertoire of activities beyond the unit reflected their beliefs about science and science teaching. These activities are qualitatively different to the activities in the classroom. It is not just that they are voluntary and take place in smaller groups and thus give students' greater freedom to satisfy individual needs and to socialise, they also engage with different communities and this enables them to perform different roles. The communities engaged by practical activities beyond the unit included:

- parents: for example in the school pond and solar challenge;
- the local community: streamwatch and weatherwatch, and family science nights;
- scientific institutions: Sciencentre, and Melbourne Museum;
- scientists and tertiary science students: visitors/scientist in residence, and rodent experiment; and
- the local business community: science boxes.

Even within the classroom with just the students and teacher, a different context can enable the teacher and students to create a different type of community in which the relationship between teacher and student, and knowledge is changed.

Practical activities beyond the classroom can provide a way to link science with its broader community implications, to represent a richer view of the nature of science (Tytler, 2003, p. 285) or to present "authentic" science (Roth, 1995). Beyond the unit, practical activities performed different roles compared to those within the unit. Motivation and enjoyment was a role in all practical activities but this was more evident in practical activities beyond the classroom. There was also a greater freedom in structure, and more attention given to problem solving and scientific attitudes such as creativity, curiosity and objectivity. This greater freedom and control over their own learning can improve attitudes to science and facilitate students' learning (Ellenbogen, 2004).

When we think about science activities in the primary school it would be a mistake to just consider traditional classroom activities. It raises the question of the importance in schools of science-enthusiastic teachers to organise these events and the educational resources that are given to activities both within and beyond the classroom.

Insights

In the hands of experienced teachers practical activities can be used productively to fulfil any of the possible roles suggested in the literature. The teachers' background and beliefs about the nature of science and primary students are the crucial determinant of the role played by a particular practical activity. The importance of teachers' beliefs and background carries the implication that we cannot view the use of science practical activities as a technical issue that can be dealt with by curriculum solutions. For these *activist* teachers their core philosophy transcends such notions. Thus if we wish to promote curriculum change we need to focus on the beliefs and background of teachers and negotiate pedagogy through these. For non-activist

teachers of primary school science change will not occur through a series of directives about the role of practical activities. Effective primary science teachers draw on resources of belief, experience, teaching and community.
An important and neglected component of the variety of practical activities occur outside the normal classroom units: excursions, science clubs, extension activities, visiting scientists and students, competitions, science fairs, science week, participatory research and family science nights. The greater choice freedom and smaller groups enables these activities to perform a different spectrum of roles to those within the unit. They also engage with different communities. For conceptual learning to occur teachers need to provide a sustained sequence of practical activities that allow students to revisit concepts and skills and give space for exploration. Time needs to be allocated for student exploration. Students need to be prepared to explore and thus exploration can fruitfully occur after teacher directed practical activities. While the expression “inquiry-based” is often used to encapsulate practical activities in primary school science teaching, it does not do justice to the richness and complexity of the ways in which practical activities are understood and used by teachers and students.

Bibliography

- Driver, R., & Bell, B. (1986). Students' thinking and the learning of science: A constructivist view. School Science Review, 67, 443-456.
- Ellenbogen, K., Luke, J., & Dierking, L. D. (2004). Family learing research in museums: An emerging disciplinary matrix. Science Education, 88(Suppl. 1), S48-S58.
- Gott, R., & Duggan, S. (1995). *Investigative work in the science curriculum*. Buckingham: Open University Press.
- Groves, S., & Dale, J. (2004). *Using activity theory in researching young children's use of calculators.* Paper presented at the Australian Association for Research in Education, Melbourne.
- Gutierrez, K., Baquesdano-Lopez, p., & Tejeda, C. (1999). Rethinking diversity: hybidity and hybrid language practices in the third space. *Mind, Culture and Activity, 6*(4), 286-303.
- Hasan, H., Gould, E., Larkin, P., & Vrazxalic, L. (2001). *Information systems and activity theory: Volume 2 theory and practice*. Wollongong: Department of Business Systems, University of Wollongong.
- Hegarty-Hazel, E. (1990a). Learning technical skills in the student laboratory. In E. Hegarty-Hazel (Ed.), *The student laboratory in the science curriculum*. London: Routledge.
- Hodson, D. (1993). Re-thinking old ways: Toward a more critical approach to practical work in school science. *Studies in Science Education, 22*, 85-142.
- Jonassan, D., & Rohrer-Murphy, L. (1999). Activity theory as a framework for designing constructivist learning environments. *Educational Technology: Research and Development, 47*(1), 61-79.
- Lave, J. (1997). What's special about experiments as contexts for thinking. In M. Cole, Y. Engestrom & O. Vasquez (Eds.), *Mind, culture, and activity: seminal papers from the Laboratory of Comparative Human Cognition*. Cambridge: Cambridge University Press.
- Lazarowitz, R., & Tamir, P. (1994). Research on using laboratory instruction in science. In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 94-128). New York: Macmillan.
- Roth, W.-M. (1995a). *Authentic school science*. Dordrecht: Kluwer Academic Publishers.
- Séré, M.-G. (2002). Towards renewed research questions from the outlook of the European project "Labwork in Science Education". *Science Education, 86*, 624-644.
- Tytler, R. (2003). A window for a purpose: Developing a framework for describing effecive science teahing and learning. *Research in Science Education, 33*, 273-298.

Materials, objects and their properties: Didactical resources for primary science education

Martins, I. P. imartins@dte.ua.pt; Rodrigues, A. V. arodrigues@dte.ua.pt;
Nascimento, P. pnascimento@dte.ua.pt; Vieira, R. rvieira@dte.ua.,pt

Centro de Investigação em Didáctica e Tecnologia na Formação de Formadores [CIDTFF]
Departamento de Didáctica e Tecnologia Educativa (DDTE)
Universidade de Aveiro (PORTUGAL)

Introduction

Currently, Portuguese Basic Education is in accordance with the document "National Curriculum of Basic Education - essential competences" ("Currículo Nacional do Ensino Básico – Competências Essenciais") (ME-DEB, 2001). As concerns science education, an STS orientation is *proposed* (Science-Technology-Society), advocating a greater emphasis on scientific literacy. Despite this curricular change, teachers' knowledge, conceptions and practices continue not to follow this orientation (Vieira, 2003; Martins, 2002b).

Therefore, there seems to be national agreement and congruence with international recommendations for a science education reform. Where then are the problems? What is missing that keeps us from achieving these purposes?

A few studies developed in Portugal and in other countries, as well as other sources, illuminate some important factors that can help us understand the actual science teaching practice and the learning situation:

a) deficient teacher training in science education, in general, and in the didactics of science, in particular (Harlen, 2006; Appleton, 2005; Klein, 2005; Harlen & Holroyd, 1995);

b) the great emphasis on other curricular areas (especially Portuguese Language and Mathematics) rather than on Natural and Physical Science (Lakin, 2006; Martins, 2002a; Amadio, 2000);

c) the quality of textbooks (some of which present scientific and methodological mistakes) and the lack of alternative didactical resources to support teachers of science in their classrooms (de Bóo, 2004; Membiela, 2002; Santos, 2001; Sá, 1999).

Based on these concerns and our intention to provide more and better didactical resources, we have been developing, at the University of Aveiro, STS didactical resources to teach and learn science in the early school years. Our present purpose is to present a model developed at the Open Laboratory of Science Education (*Laboratório Aberto de Educação em Ciências* – LeduC), located at the Department of Didactics and Educational Technology, University of Aveiro, to produce these didactical resources within the framework of ***Materials, Objects and their Properties***.

Why materials, objects and theih properties?

Materials and objects have always been a part of human life. We sometimes use them without questioning where they come from, what is involved in their obtainment, whether or not they are finite resources, what their environmental impact is and what the consequences of using them are for future generations.

The didactic exploration of materials has been considered in formal teaching programmes linked mainly to the field of chemistry, which stresses in its approach the conceptual perspective of materials' constitution and ways of representing them and, in the case of synthetic materials, their respective synthesis reactions. Less common is manipulation of the materials themselves to get a macroscopic view of them, and rarely developed are the technological aspects associated with their industrial preparation, recovery and recycling processes.

Regarding the objects the materials are destined for, the outlook on them as simple applications of materials predominates, which contradicts the technical-scientific, socio-technologic and socio-scientific dimensions with which we can view scientific knowledge and on which the STS orientation for science education is based, as is foreseen in the Portuguese curriculum (ME-DEB, 2001). In fact, such a distorted view of concepts (materials) and their applications (objects) ignores the fact that, in modern developed societies, materials are the fruits of research conducted to meet society's needs.

Despite the importance of materials in everyday life, they are not given the attention they deserve in formal education. The approaches used in textbooks designed for Basic Education (6-10 years, in Portugal) are poor and fail to make a clear distinction between materials and the objects made from them.

Nevertheless, our perception of the world begins early in life. This is why it is essential that didactic teaching strategies, concerning the diversity around us, make use of contexts familiar to children so that we can capture their attention and develop their critical and creative thinking and curiosity.

Given the above, it is very important to develop didactic strategies and activities that can promote these abilities and to use an approach that will enable children to, among other things, (i) perceive the huge variety of materials existing around them; (ii) distinguish the concepts of material and object; (iii) understand that objects used every day are made from one or more materials, combined in different ways depending on their use; (iv) recognize the importance of wisely using materials that guarantee sustainable development in the world.

We consider that understanding materials and how to use them wisely will definitely allow children, citizens of the future, to apply the scientific and technological knowledge that will help them make the right decisions, not only personal but also social, in a responsible and conscious way.

Didactical resources conception – which model?

In our conceptualization, a didactical resource should be a concrete support capable of embodying declared ideas, which are constituted, in a social-constructivist perspective, by activities that require the student to be active. Thus, we consider that didactical resources are essential elements of science teaching organization: They are used not only to help children achieve significant learning, during their active exploration, but also to help teachers promote, through their practices, constructive strategies and activities that implicate children in the development of their own skills with a view to scientific literacy.

The didactical resources conception model used in LEduC includes four stages:

1. Topic selection and document-based research and analysis

Deciding on a theme, which may include selection of socially important groups of materials and scopes of application (plastic and metals, for example), presupposes diverse readings and a critical look at reality. Another basic aspect is the age level for which didactical resources are designed. Document-based research and analysis cut across all the processes of planning, conception and validation of didactical resources. However, the stage that follows topic selection demands particular emphasis on the diversified nature of document analysis (curricula, textbooks, national and international research papers, etc.), in order to proceed to the curricular framing of the topic; to the identification of teaching approaches and proposed strategies, and their respective shortcomings; to the topic's importance, as well as the scientific and didactic knowledge inherent in it.

2. Identification of children's conceptions/ideas about the topic

Given the importance of starting from children's previous understandings, it is fundamental to understand what children think about the topic, if we are to identify underlying alternative conceptions to their ideas. This is also a way to establish children's difficulties/needs, interests and curiosities regarding the topic. To accomplish this, data are collected from the literature and/or smaller research projects (validated by experts) are carried out near the children themselves. This stage is the basis for the next.

3. Conception and construction of didactical resources to approach the topic

There are some aspects of the conception of didactical resources that are important to highlight, namely: (i) select wisely what is to be learned and what practical skills are to be developed; (ii) give priority to studying problem situations of interest to children in an STS context; (iii) enable laboratory activities, especially investigations; (iv) develop varied didactic teaching strategies with flexible exploration that stimulate children to apply knowledge and to use their thinking skills; and (v) when possible, encourage use of the New Technologies of Information and Communication (NTIC).

Didactical resources present versatile and diverse formats and have underlying safety principles concerning the handling of some materials. They include devices, samples of materials, current use of objects, organized according to tasks to be carried out by the children, with a degree of openness that is adjustable to their cognitive development and previous knowledge. They also include guiding documents for children (in which the tasks to be done and the necessary registry sheets are included) and for teachers (including the presentation of activities, goals, abilities, work methodology, materials and resources to use, as well as orientation and exploration suggestions).

4. Didactical resources validation

First, the validation of didactical resources is made by an expert panel, consisting of primary school teachers as well as science didactics specialists, to evaluate their potential as concerns the focused contents, learning objectives and skills, the adequacy of the strategies, the clarity of methodological orientations and eventual limitations.

Subsequently, they are validated in a real-life context with children in the age group the resources were designed for, in the course of activity sessions in the classroom and in non-formal sessions for children and their teachers, which take place in LEduC or in the classroom. The main objective is to evaluate children's reactions during their exploration of the conceived activities and their learning progress as well as to standardize some aspects considered relevant (the adequacy of the proposals, expected time, safety and didactic exploration, for instance).

Data collecting for validation is accomplished through observation of the video-taped sessions/classes and through analysis of the registries made either by the children or by the teachers.

Table 1 presents some didactical resources developed in LEduC around the theme ***Materials, Objects and their Properties***.

Table 1: Examples of didactical resources developed to explore the topic Materials, Objects and their Properties.

THEME	TOPIC	CONTENTS/PROBLEM SITUATIONS
Materials, Objects and their Properties	*Materials trip: from substance to object*	• Materials trip. • Solid or liquid. • The natural world. • The origin of materials. • The properties of materials.
	Materials: diversity, properties and transformations	• Discovering materials by touch. • Extracting materials. • Observing materials. • Producing materials.
	Plastics: what do children think about them…	• Am I made of plastic or not? • Are we all identical?
	Textile Fibres: understand fibres and fabrics	• How to treat them? • Understanding labels. • Weaving and unravelling. • Can I change my colour? • Where do I come from? • Are we all permeable?
	Metals and Alloys: special materials for life	• Metals… and other materials! • Identify these metals! • Know aluminium! • From ore to object… • What are the properties of metals? • Are we all equally vulnerable to metals? • Cleaning metals!
	Paper and papers: diversity and properties	• Can we transform old paper into new paper? • Am I made of paper? • Which is the paper that absorbs better or worst? • Do our properties change after being covered? • Which of us is the most resistant?

Final considerations

The developed didactical resources have been requested both by schools, where educators/teachers can explore them in the classroom with their children (formal context), and by other institutions (independent science centres, for instance) that intend to promote science discovery activities, such as science and technology weeks or science fairs (non-formal context).

These didactical resources are also applied in initial, continuous and post-graduate training of primary school teachers and nurse educators, allowing them to become familiar with the resources, learn how to explore them with children, and stimulate interest by coming up with new resources in different curricular areas. On the other hand, didactical resources have also been the subject of a great deal of research in the area of science education.

References

AMADIO, M. (2000). *World data on education*. UNESCO, Paris.

APPLETON, K. (Ed.) (2006). *Elementary science teacher education: International perspectives on contemporary issues and practice*. Laurence Erlbaum Associates with Association for Science Teacher Education, New Jersey.

de BÓO, M. (2004). *Using science to develop thinking skills at key stage I – Practical resources for gifted and talented learners*. David Fulton Publishers, Suffolk.

HARLEN, W. (2006). *Teaching, Learning and Assessing Science 5-12* (4ªed.). Sage Publications, London.

HARLEN, W., HOLROYD, C. (1995). Primary Teachers' Understanding of Concepts in Science and Technology. *Interchange*, n.º 34, SUEID/RIU.

KLEIN, B. S. (2005). Application of the guidelines for effective elementary science teacher inservice education. *Journal of Elementary Science Education*, 17 (2), 57-72.

LAKIN, L. (2006). Science in the whole curriculum. *In* Harlen, W. (Ed.). *ASE Guide to Primary Science Education*. ASE, Hatfield.

MARTINS, I. P. (2002a). *Educação e Educação em Ciências*. Universidade de Aveiro/Departamento de Didáctica e Tecnologia Educativa, Aveiro.

MARTINS, I. P. (2002b). Problemas e perspectivas sobre a integração CTS no sistema educativo Português. *Revista Electrónica de Enseñanza de las Ciencias*, 1(1). (www.saum.uvigo.es/reec)

ME-DEB (2001). *Currículo Nacional do Ensino Básico – Competências Essenciais*. ME-DEB, Lisboa.

MEMBIELA, P. (2002). Las temáticas transversales en la alfabetización científica. *Alambique – Didáctica de las Ciencias Experimentales*, 32, 17-23.

SÁ, J. (1999). Manual do professor para o ensino experimental no 1º Ciclo – um projecto de investigação-acção centrado na escola. In CASTRO, R. et al (Org.). *Manuais escolares – estatuto, funções, história.* I Encontro Internacional sobre Manuais Escolares. Braga: Instituto de Educação e Psicologia, Centro de Estudos em Educação e Psicologia. Universidade do Minho, pp. 441-455.

SANTOS, M. (2001). *A cidadania na "Voz" dos manuais escolares. O que temos? O que queremos?.* Livros Horizonte, Lisboa.

VIEIRA, R. M. (2003). *Formação Continuada de Professores do 1º e 2º Ciclos do Ensino Básico para uma Educação em Ciências com Orientação CTS/PC.* Tese de Doutoramento. Universidade de Aveiro/Departamento de Didáctica e Tecnologia Educativa, Aveiro.

Innovatory approaches in supporting the professional development of teachers of primary science

Keith Bishop
Department of Education, University of Bath, Bath, U. K.

Introduction

Since the introduction of the National Curriculum in 1989, primary science in the UK has undergone a considerable transformation from what was largely nature studies to an approach to science that emphasises inquiry and inquiry skills. The implications of this change for teacher professional development, however, have been profound as it has to be recognised that few teachers have formal qualifications in science. As part of its Millennium project, the AZSTT was established to find new and innovative ways to enhance the learning and teaching of primary science. A major outcome of this work has been the creation of a suite of freely accessible web-based continuing professional development packages (units) designed principally for use by science subject leaders[3]. The purpose of this poster presentation is to explain the AZSTT's approach to supporting primary science.

Continuing professional development (CPD) units

To date the Trust has commissioned the production of twelve CPD units (see Box 1 for further detail). Each is intended to provide science subject leaders (SSL) with up-to-date material created by experts drawn from various areas of primary science. The idea behind the units is that they can be used to serve either as a resource for the purposes of individual personal professional development, or, more importantly, as a flexible resource for science subject leaders to lead their own school-based in-service training.

The unique idea behind these materials is that they are presented in two forms:

i) an on-line (HTML) version which can be browsed at the convenience of the viewer, and
ii) an equivalent downloadable PowerPoint version which can be saved and customised (tailored) as desired.

In most UK primary schools the science subject leader is pivotal in the development of science learning and teaching in the school, but not all SSLs are necessarily science specialists. However, they still need to have credibility with their colleagues as science leaders if they are going to have an impact (Lander, 2003). The on-line material is there to help the science subject leader gain familiarity with new ideas or content and to build personal confidence before taking the more difficult step of moving towards supporting other colleagues. To build confidence the materials provide various combinations of theoretical background information, questions and answers about purposes, teaching techniques, student material and video-clips. Most important of these features are the video clips which aim to offer authentic examples of classroom practice. Science subject leaders are then free to try out

[3] In the UK we refer to primary teachers who have a designated responsibility for science in their schools as science subject leaders or science co-ordinators.

the ideas in the classroom to explore and assess the impact on the children before preparing themselves to introduce the ideas to their colleagues in the context of their own schools.

What do we know about the success of the AZSTT approach?

We know from a recent focus group and telephone survey we carried out in the early part of 2006 that science subject leaders strongly support this as an approach to professional development. For example, a science subject leader referring to her use of the CPD unit on concept cartoons said:

I went in very unsure, not really knowing an awful lot about it. I found my confidence has been built up, my own professional development has been built up, and I feel far more confident in going ahead and doing my job because of what I've gained from the site. It's been great.

As for using the *PowerPoint*, we know that many science subject leaders feel unsure about making their own presentations. Another comment from a science subject leader we interviewed, though, gave us a strong sense that we are moving in the right direction. She commented:

I think you've got options. If you haven't got the skills you've already got the PowerPoint there and you can just go straight ahead with that. But if you have got the skills then you can adapt it how you want to ... You can always use it as a starting point if you want to create [a presentation] from scratch. You've got a starting point haven't you.

Improving science leadership in primary schools

The Office for Standards in Education (Ofsted) suggests that primary schools should make every effort to identify opportunities for professional development (Ofsted, 2005). However, it is well known that for various reasons it is not always possible for science subject leaders to go out on courses; either the budget doesn't allow it, or perhaps there simply isn't time. Our view is that so long as science subject leaders have access to high quality material, input does not always have to come from external courses. In-school in-service training can complement external input, and this approach to professional development is one that shows real signs of promise.

If you want to know more about the AZSTT CPD units and other materials, visit:
http://www.azteachscience.co.uk/
or contact Dr Keith Bishop: e-mail k.n.bishop@bath.ac.uk

References

Lander, E. (2003) The nature of the beast: what makes a good science subject leader. *Primary Science Review*, 79, 13-15.
Ofsted (2005) Science in primary schools. *The Annual Report of Her Majesty's Chief Inspector of Schools 2005/05.* London: DfES.

Box 1: AstraZeneca Science Teaching Trust CPD units

- Strata (Science and Special Needs)
- Whiteboards (how to use the interactive whiteboard in your science teaching)
- Teaching science in the foundation stage (early years science education through play)
- Let's think through science (CASE for the 7-11 age group)

- Floorbooks (formative assessment)
- York STAY project (primary-secondary transfer)
- Effective displays (the pedagogical benefits of interactive displays)
- Concept cartoons (children's conceptual development through talk)
- Concept mapping (a powerful tool for conceptual development and formative assessment).
- The science – physical approach (using dance in science teaching)
- Co-teaching (initial teacher education in science)
- Personal capabilities (developing transferable skills through science)

To come:

- Science and teaching English as an additional language.
- Using thinking frames (structuring children's thinking in investigative work)

Session 3. Engaging the new generation

Engaging the new generation

Brenda Keogh and Stuart Naylor
Millgate House Publishing and Consultancy Ltd, UK

Obviously, science lessons in the primary school need to be engaging, entertaining and fun. Or do they? It's an interesting question. What kind of answer would you give? In our presentation we intend to get you thinking about this question and other questions about primary science and how it should be organised to engage children.

In the UK, primary science is well established in the national curriculum, and primary science is intended to be based around investigation and enquiry. However many pupils do not find science a stimulating or engaging subject. There is evidence that many children lose their initial interest in science before they leave primary school.

This presentation is based on our research, which has included exploring the impact of a range of innovative strategies which aim to promote engagement. It will set out a variety of factors that appear to influence engagement and suggest ways to get children engaged in science lessons and enhance their learning.

If teachers are to be committed to making science more engaging then they need to feel a sense of engagement with what they are teaching. They also need to view any change in their professional practice as realistic and manageable. How can that happen, when the literature suggests that change in professional practice is very difficult to achieve?

In our presentation we hope to model effective teaching which gets you engaged and enhances your learning. With two of us giving the presentation, we should be able to speak twice as quickly and fit twice as much into it.

Poster session 3. Engaging the new generation

Chaired by : Brenda Keogh and Stuart Naylor

Let’s Play with Materials

“VAMOS BRINCAR AOS MATERIAIS”

Alberto Eduardo Morão Cabral Ferro
IST - Departamento de Engenharia de Materiais, Lisboa, Portugal

The project *Let’s play with Materials*, *Vamos Brincar aos Materiais (VBM)*, started in 1997/98, in the framework of the Portuguese Ciência Viva Program and enrols today 50 primary schools, 250 teachers and 5000 children.

The objective is to set up a research learning platform in the classroom where the child plays the central role. The teacher leads the class through a diversified activity carried out by autonomous students. Technology and Materials Science, Physics and Chemistry are the core subjects of the proposals. This core creates opportunities for multiple learnings, for others Sciences, subjects and developments. *VBM* proposes to set up in the classroom a platform to Learn, a platform for Citizenship. Experimental scientific research and Technology are key elements: they form the mental structure of the child and the opportunity for fulfilment, anchors their self-confidence.

The teacher is invited to lead the class, generally five groups of five children, through a diversified, long, experimental activity carried out by autonomous students. The activity includes reading, bibliographic research, registration, technology constructions, calculus, discussion and confrontation.

The main proposed goal is the achievement of a change in attitude, a new way of looking the outside world and life itself. The scientific experimental research activities developed by the student in the classroom are looking after to inducing in the child capacities to questioning what he sees, to setting up strategies to overcome the questions he raises and to using proper methods to research and doing. The acquisition for life of a tool, a method and a thinking strategy typical of experimental scientific research is a fundamental added-value in the development o child-student citizenship.

Technology and examples caught from every day life or from the common students' knowledge are important issues to emphasise. Technology brings about an opportunity for the group to work together, to train skills normally not challenged and for fulfilment. Besides, the construction of their own equipment and the setting up of the hardware needed for the research activities they are carrying out establishes an affective relation with the activity, will to participate and an ownership environment. Examples caught from every day life, their link to the activities developed in the classroom, to the knowledge built, to science and technology are essential to develop science literacy, to establish in the students mind the social relevance of science and technology.

The development of the scientific and technological knowledge is the natural result of the activities carried out. The proposed methodology links experimental learning and theoretical learning. After the activity, new related science subjects are brought to the classroom for discussion. Based on students' knowledge and on the research activity developed, the class moves forward to a set of new topics.

Primary school teachers are the key elements for the success of the activities. Their training is therefore a major task for the VBM project. The knowledge of the addressed subjects, the readiness and self-confidence for using the proposed laboratory and technology hardware and the ability to develop experimental research in the classroom is the standard teacher's platform. It is fundamental to allow a full development in the classroom of the potentialities of the VBM project. Teachers training resources are scarce and a challenge is placed to those involved in teachers training.

To support the activity in the classroom, mainly for new comer teachers, a network of professional monitors has been developed. Monitors are recruited from different profiles, young primary teachers being the preferred option.

The author acknowledges the support of Ciência Viva, Portugal, in the development of the present project.

Science-Lab, a private initiative to innovate pre-school learning

Sonja Stuchtey, Fenita Dyckerhoff & Shadi Mueller-Menrad,
Science-Lab, Germany

The approach

Science-Lab was created as a private initiative in 2002 after recognizing that the German school system does not promote an early passion for science. Both kindergarten and primary school programs lacked age-appropriate concepts for inquiry-based learning of natural sciences. This leaves educators, teachers and parents insecure about how to respond to children's questions in a better way than delivering a one-off answer.

The ambition of Science-Lab is to give this new approach to the natural sciences.

For this purpose, a curriculum has been developed that appeals to the mind of children as young as 4 years. They discover the world that surrounds them in small groups of peers, based on a well-proven inquiry-based methodology.

Today, Science-Lab is Germany's only provider of a stage-based educational system for early natural science learning. It is provided through Science-Lab "afternoon schools" as well as to educators in kindergartens and primary schools.
Science-Lab courses are offered in over 60 German locations today. Earliest enrolment is at the age of four. The curriculum is organized in two semesters and spirals upwards towards the fourth grade, adjusting in scope and depth in a step-wise fashion, continuously changing the angle but never abandoning its basic approach of inquiry-based learning.
The fields of science that are embraced are Biology, Chemistry, Physics, Astronomy, Geology and a great variety of interdisciplinary topics.
The children arrive at the “right” answers themselves. They investigate natural phenomena and observe reaction patterns through a series of experiments. These are specially designed to help the child find the answer to a given question. In this process, the children are always supported by Science-Lab trainers who accompany them on their question-and-answer path. It looks and feels like a game, but it is relentlessly scientific in walking through the stages of asking a question, formulating a hypothesis, designing the experiment, testing and articulating the answer. The choice of topics is tailored to the age group. The courses have been successfully tested with more than five thousand children and are constantly being reviewed and refined by the curriculum coordinator and an advisory board.

Quality control
Important elements of Science-Lab's quality system are the continuous feedback of all Science-Lab trainers who evaluate each and every session with the children as well as the seamless surveys amongst parents after every semester. Parents are involved in more than feedback and quality control. They indirectly "participate" in the courses by being continuously informed about what the children are doing. This happens through the Science-Lab course book, and through Science-Lab Arena, the presentation day organized for parents at the end of the course, where every child presents his/her favourite experiment. In this way, families are involved in the learning process at home, in that they are able to refer to the experiments and reinforce the experience.

Science-Lab Trainers
Science-Lab trainers possess a robust academic background, are enthusiastic about natural sciences and inspired by the curiosity of young children. To be part of the Science-Lab network they need to submit an application. Those applicants accepted to the course will receive a three-day training in the Science-Lab (inquiry-based) methodology, a scientific background in all the topics covered in a given course, hands-on experimenting as well as training in law, marketing and first aid for children. They are offered a franchise agreement to represent Science-Lab in a certain region. Trainers are part of the ever-growing Science-Lab network, but also customers who take a critical view of the curriculum, the course material and the offerings of the network, thus driving Science-Lab to continuously improve its service plan as an enterprise and as a positive force in shaping the education system.

Science-Lab Training for kindergarten and elementary school teachers
Building upon the wide experience of the Science-Lab system, and in collaboration with educators and teachers, we have also developed an advanced training concept, which allows those involved to apply their acquired knowledge immediately. In six-hour seminaries we
• Transmit a robust methodological and didactical foundation
• Illustrate the existing connections between the different scientific subjects
• Provide easy-to-follow entry avenues into the scientific disciplines, overcoming the fear fed by a lack of training and confidence in natural sciences
• Answer questions related to practical implementation of the Science-Lab methodology, and

• Practise with a large number of experiments in an atmosphere of fun and laughter.
The participants frequently emphasize how grateful they are for the practice-oriented training. Whilst many lack confidence in ”treading on scientific ground” in their tutorials, they feel poorly equipped in terms of guidance and classroom materials. Based upon these facts, Science-Lab has developed a Research Box. Filled with experimental materials and easy-to-use manuals, the boxes have proven to substantially lower educators’ reservations about offering scientific class work. The Research Box comes with a training unit within the German Science-Lab network, in which educators receive a short but effective introduction to the inquiry-based Science-Lab system and hotline support for classroom preparation.

The Science-Lab foundation: Finding very young talented scientists as well as supporting those who need it the most
Science-Lab work is complemented by the Science-Lab Foundation. The objective of this institution is to find funding to support the interest of young scientists and to promote them through additional offers. Trainers identify possible scholars and propose them to the committee, which twice a year, based upon resources and recommendations, decides on the number of scholarships to be distributed. Scholars receive a written commendation, financial support and the possibility to join the “Scholar Club”.
The “Club” is periodically invited to special events, such as
• Special summer courses
• Visits to research institutes
• Projects with researchers
• Invitations through technology companies
Moreover, the Science-Lab Foundation includes the Social Fund, which funds science projects and courses for children who may otherwise not get the chance to take a deeper look into natural science. These projects involve, for instance, orphanages or oncology and psychosomatic departments of hospitals.
The Science-Lab foundation also offers a platform for scientific studies based on our methodology, studies related to school development for advanced children, studies related to social determination, speech development, etc.

Our vision

Have you ever observed a child playing in and with water? Have you noticed the precision and logic that accompany enthusiasm and persistence? It has been this sparkle of scientific zeal that moved us to leave our promising business careers in order to follow that one vision: To introduce children to natural sciences at an early age with a hands-on approach, to take their questions seriously and to support them enthusiastically and in a professional manner.
Our world is becoming more and more knowledge-based. Only a solid education that teaches our children the basics of natural sciences and the way to find the answers to any question, no matter what area it comes from, will prepare them for the challenges ahead.
Therefore, we developed Science-Lab as a space that enables children to learn, to investigate and to discover.
And we would like to invite you to get some insight into our steps and achievements by seeing our poster presentation on Monday, October 16th.

Promoting science by Learning in Nature

Ana Gostinčar Blagotinšek and Mojca Čepič,
Faculty of Education, University of Ljubljana and University of Primorska, Slovenia

Abstract

Slovenia has a network of 23 field centres. They are located in various environments throughout the country. They offer curricula–related active learning units in the surrounding nature and other local spaces. Pupils live and learn in nature, become more sensitive to it and start to appreciate school science more.

Schools are obliged to offer at least two "School in Nature" weeks during primary education. To enable the teachers to take advantage of those opportunities, the Faculty of Education organizes field work for the students. A brief overview of these activities will be presented.

History of Field Centres (CŠOD) in Slovenia

A network of field centres (CŠOD in Slovenian) was founded in 1992 by the Government of the Republic Slovenia and is financed by the Ministry of Education. Its aim is to support schools in organizing "School in Nature" weeks. First, pupils stayed at one centre during 1993, and since then, the number of centres as well as the number of pupils staying at the centres has grown. Last year, 65,000 pupils from primary and lower secondary schools and 10,000 pupils from upper secondary schools experienced several days of active learning there.

Initially, the centres were renovated ex-army buildings, which the Republic of Slovenia no longer needed due to political changes in the region. Over the years, renovated school buildings, youth hostels and holiday homes have been turned into centres throughout the country. Many of them are still active as youth hostels during the holiday seasons. Centres offer round-the-clock educational and entertainment programmes, together with accommodation and food during the stay.

Over the years, the offer has grown to include 17 day centres, which can only be visited during the day.

Programme

The programme offered at the centres consists of natural and social science contents as well as sports activities. Educational content varies across centres, depending on local resources. Because Slovenia is very rich in local diversity, geographically and biologically, as well as nationally, linguistically, etc., what the centres have to offer is also very diverse. The educational content is also suited to children of different ages, from pre-school to upper secondary and sometimes even older.

Emphasis is also put on socialization and developing the independence of young people as an important component of development.

Another, equally important aspect is the emotional one – children who learn to appreciate nature are more likely to make an effort to preserve it when they grow up. Sports units for whole classes of pupils, which stay with them, are divided into small groups. Additionally, employees who take care of the organization, catering and the rest, who are required for the centres to operate, are employed. This is also important to sustaining the local economy, especially in remote and undeveloped regions of the country.

Throughout the day, the centres offer curricula–related active learning units in the surrounding nature and other local spaces, in addition to sports and social activities. Their

common scope is active involvement of the pupils and a focus on the opportunities that nature and the local environment everywhere offer us.
As pupils live and learn in nature, they become more sensitive to it, and on the other hand, at least start to appreciate school science as something connected to and useful in everyday life. Through active involvement in the local community, they also begin to see the role of science in our lives.

Teachers' Preparation

Schools are obliged to offer at least two "School in Nature" weeks during nine years of primary education, but tend to organize more. To enable teachers to take advantage of these opportunities, the Faculty of Education organizes field work for all pre– and in–service kindergarten and primary teaching students.
During the one and a half day stay, including astronomy in the evening, the teaching students perform a set of chemistry tests on local water, soil, rocks and vegetation, observe local flora and fauna, make simple measurements and observations of the sun's movement, shadows, weather conditions, energy sources, etc.
Together we try to interpret the observations and findings in terms of the interconnection of all environmental factors, which determine the living conditions for plants and animals, including human beings.
During astronomy evening and night, we first perform some orientation tasks in the unfamiliar surroundings, and when it gets really dark, simple observations of the night sky, supported by the use of stellar maps, astronomy theatre and, when the weather does not permit outdoor activities, also computer simulations.
Every student is also obliged to make a model of boat, plane, mill, etc. in advance, and present it to fellow students during the stay. They are also asked to think of a simple research project, regarding the functioning of the model and with special attention to objective testing, and to prepare the model such that it can support the research (controllable changes of only one property at a time).

Conclusions

Pupils like to learn and teachers like to teach outdoors. Outdoor education (according to the limited research we performed with a generation of our pre- and in-service teachers) also has a positive impact on knowledge gained during the education, sensitiveness to local opportunities, as well as a positive impact on emotional reactions to science and the environment. The same in-service teachers report on their pupils.
The influence of this method of teaching and learning is even greater because the large majority of pupils visit at least one of the centres for several days each school year. This is possible because the state manages and partly finances the functioning of the centres.
Centres in the network are very active in developing new contents and approaches to use in their programmes, in cooperation with universities and research institutions. Staffs from the centres and educational researchers gather every autumn to exchange experiences, talk about good practice and find ways to include new topics in the programmes.
During the holidays, when educational programs stop, centres are opened to the general public at reasonable prices, so whole families can spend holidays there and experience at least some of the activities their children were offered. This may help to improve the general public attitude towards science.
In the field centres, pupils can learn more and better, in a playful manner, but still scientifically correct. As attitudes towards science and learning are not very positive in many countries throughout Europe, this might be one way of changing the situation.

Acknowledgement:

The authors are grateful to the staff of the CŠOD for information and presentation materials.

References: (in Slovenian only)

http://www.csod.si/
V naravo z glavo, CŠOD, 2005.
FERBAR, Janez, GOSTINČAR-BLAGOTINŠEK, Ana, MATI, Danica, ČEPIČ, Mojca . Naravoslovje, Fizika : razredni pouk.
FERBAR, Janez, GOSTINČAR-BLAGOTINŠEK, Ana, MATI, Danica, ČEPIČ, Mojca. Metodika začetnega naravoslovja : fizika.

Sustaining Science - Smoothing the Transition

Lorraine McCormack, Dr. Odilla Finlayson, Mr. Tom McCloughlin
CASTeL, Dublin City University, Dublin 9, Ireland

Introduction

The generation of interested and enthusiastic students pursuing science in post-primary education is vital for the future development of science. To maintain students in science at all levels requires teaching approaches that develop and sustain the natural interest that students of all levels have in science.

Science at primary level in Ireland is a relatively new development being introduced as part of the Social, Environmental and Scientific Education curriculum in 1999 and implemented in 2003. The curriculum aims to provide opportunities for the child to explore, investigate and develop an understanding of the natural, human, social and cultural dimensions of local and wider environments: to learn and practise a wide range of skills: and to acquire open, critical and responsible attitudes (1). The average pupil leaves primary school at the age of twelve to embark on their post-primary education. The post-primary school years usually last from the age of twelve to eighteen. The first course taken in post-primary education is the Junior Certificate, which lasts three years and a terminal examination marks its completion. The Leaving Certificate course lasts two years and is also examined terminally. In 2003 a new revised Junior Certificate Curriculum was introduced to help relate science more to students' life and to develop students' investigative and scientific skills. The emphasis on practical work has been strengthened and it is now worth 35% of the final examination.

In reality the situation has many complications. Many students go into post-primary education after having done science in primary school and are bored by the repetition that they experience. Also, there is anecdotal evidence to suggest that some primary teachers feel inadequately prepared and are fazed by science. As a consequence they avoid doing science in the classroom. This has further repercussions in post-primary school where 1st year students have varying science backgrounds. The difficulty then lies in motivating students that have done science before and teaching those that have not.

Literature

Anecdotal evidence suggests that primary students are enthused about science. This interest and motivation must be maintained through the transition to second level. In Ireland to date, there has been no research in this area. However, internationally there is an accumulation of evidence in recent years suggesting that pupils do not progress as well as they should in science following the move to post-primary school (2). This interest and motivation must be maintained through the transition to second level. In the United Kingdom, OFSTED (3) has shown that increases in science attainment levels at KS2 are not maintained at KS3 and the situation is much worse than in Maths and English. For example, OFSTED, the Office for Standards in Education (England), point out that the continuing rise in the numbers of pupils achieving the target level for science in Key Stage 2 SAT'S in science over the past six years is not matched by a similar rise at KS3 (OFSTED, 2000). It has also been suggested that motivation and interest decline during KS3 as pupils see that work is repeated and lessons underestimate what they are capable of and have already achieved (4).

Evidence to date suggests that students are 'turned off' science at the age of 12-14yrs. Many initiatives have been implemented nationally and internationally to tackle this problem stage e.g. new Junior Science curriculum in Ireland. International research in the form of the ROSE project (5) has shown that students who see relevance and applications of science (science making a difference) in their daily lives are more likely to have ambitions of pursuing careers in science. Data has shown that in developing countries, children think that science has opened their eyes to exciting jobs, while those in the developed countries do not think so (5). This study has clearly shown that young people around the world make choices "based on their own values, motives, interests and self realisation". Therefore in science education, the areas of motivation, interest, attitudes and values need to be addressed (2). Also the STAY project, based in the University of York, is working on the development of methods to smooth the transfer from KS2 to KS3. One of the initiatives is bridging work, which involves pupils beginning work in science in primary school that they will continue and complete in secondary school (6).

Basis of the research

This project will focus on the key transition from primary to second level.
Some of the research questions are highlighted below-

- Do students' expectations of science match their experience?
- Could cognitive acceleration methodologies enhance students' experience and achievement in science?

Methodology

As an initial step, twelve post-primary schools and fifteen of their main feeder primary schools were identified. The schools were selected to include rural and urban, single sex and co-educational schools and schools with both compulsory and non-compulsory science to Junior Certificate. The cognitive level of the primary school pupils was determined using Task 1 developed by the 'Concepts in Secondary Maths & Science' team at Chelsea College, University of London. An intervention programme promoting cognitive acceleration was adapted and compiled to suit the Irish primary education science curriculum. This programme, entitled '*Thinking Science*', involved 15 lessons designed to help pupils develop the general thinking and experimental skills that are required in science (7). The programme was implemented with eight classes and the other seven classes were a control group. A second task, determining the pupil's cognitive level after the programme, was run with the intervention and control group. Initial analysis of the results shows that the cognitive level of the intervention group increased to a greater extent than that of the control group. A more detailed analysis of these research findings will be available for presentation at the European Conference on Primary Science & Technology in October. The experience and cognitive level of these pupils will be tracked through the transition into their secondary science education.

References

(1) Primary Science Curriculum: http://www.ncca.ie/uploadedfiles/Curriculum/Science_Curr.pdf (Last accessed on 28.11/05)

(2) Galton, M., (2002) *Continuity and Progression in Science Teaching at Key Stages 2 and 3*, Cambridge Journal of Education, 32, (2), 2002.

(3) OFSTED (2000) Progress in Key Stage 3 Science

(4) Galton, G., Gray J. and Ruddock, J. (1999) *The impact of school transitions and transfers on pupil progress and attainment*, Research Brief No. 131, Department of Education and Employment, England

(5) ROSE: http://www.ils.uio.no/forskning/rose/ (Last accessed on 28.11.05)

(6) Braund, M. (2002) '*STAYing the course: smoothing the transfer from Key Stage 2 to Key Stage 3*', Education in Science, 197. Pg. 28- 29

(7) Adey, P., Shayer, M. and Yates, C. (2001b) *Thinking Science: The curriculum materials of the CASE project*, (3rd ed.). London: Nelson Thornes.

From the Executive Summary in the Report of the Working Group on International Assistance in the Evaluation of Inquiry-Based Science Education (IBSE) Programs

Glenn Hultman
Linköping university, Linköping, Sweden

IAP Working Group members: Dr. Bruce Alberts, Dr. Jorge Allende, Dr. Philip Bell, Professor Julie Campbell, Professor Ernst W. Hamburger, Dr. Wynne Harlen, Dr. Glenn Hultman, Dr. David Klahr, Dr. Pierre Léna, Dr. Jean Matricon, Dr. Jean Moon, Ms. Senta Raizen, Dr. Jayashree Ramadas, Dr. Patricia Rowell, Dr. Richard Shavelson, Ms. Sally Goetz Shuler.

The International Working Group [set up by the Interacademies Panel (IAP) on International Issues] was charged with developing a proposal for providing assistance with evaluation of the implementation of Inquiry-Based Science Education (IBSE) programs for pre-secondary school students in different countries. At least 30 countries, both developing and developed, are known to be implementing some form of IBSE in some of their pre-secondary schools, creating a need for information about the impact of these programs on students and teachers.

Aims and procedures

The aims of the Working Group are to provide guidance in relation to one or more of the following: the collection of evidence about implementation; the development of instruments for assessing learning; the design of evaluation projects; and the design of research projects.

The meaning of IBSE

The Working Group views IBSE not as a single pedagogical method, but as an approach with key features that can be implemented in various ways. IBSE shares some features with traditional science education, but differs from it in many respects that go beyond the manipulation of materials to the key factor of engaging students in identifying relevant evidence, in critical and logical reasoning about it and in reflection on its interpretation. Some key distinguishing characteristics of IBSE are described.

The Working Group has further spelled out these general statements in terms of the inquiry practices of the teachers, the inquiry experiences of the students and the outcomes of students' learning of inquiry processes, science concepts, attitudes and dispositions.

Evaluation roles

Evaluation has several roles in the development and implementation of IBSE programs. The Working Group has focused its work on the roles that evaluation can take once a program has been developed, or has been adopted or adapted from a program developed elsewhere. The important roles of evaluation in the course of program development are not included, as this would extend the project beyond its capacity. It is recommended that a separate project be set up to serve these purposes.

Implementation of an already identified program passes through various stages along a dimension from early implementation, where only a small number of classes and schools may be involved and not all aspects intended may be in operation, to more advanced implementation, where the program has been well established in most respects in a larger number of schools. The processes and role of evaluation vary according to the point reached along this dimension of implementation. At early implementation stages, the focus of evaluation is formative: to provide information about how the implementation can be improved. The evaluation is designed to address questions such as: Are the activities that the teacher and students are engaged in consistent with those intended in the program? Is the content that engages the teacher and students consistent with the intended content? Do the teacher-student interactions and the student-student interactions match those intended? Is the nature of the classroom discourse consistent with that envisaged in the program? At the early stages the focus needs to be on classroom practices rather than on student achievement; the assessment of student outcomes becomes worthwhile at the later stages, when there is evidence that the students have the experiences that can lead to intended learning. Thus, at these later stages, in addition to evidence about how teachers use the IBSE materials and students' experiences, data are collected on students' inquiry skills, knowledge and understanding of science concepts and attitudes.

Evaluation procedures
When the purpose of the evaluation is to provide and feed back information about the early implementation of a program, the data collected will come from close observation of the teacher and students, from interviews with and questionnaires for teachers, administrators and students, and from reviews of teachers' journals and students' notebooks.

At later stages of implementation, the evaluation will provide summary information on students' learning of inquiry skills, science concepts and attitudes, in addition to information about classroom processes. The design of the evaluation will depend on the questions to be addressed. In some cases, these will be about the extent to which the desired outcomes as specified in the program are realized. In other cases, the questions will focus on whether student outcomes are the same or different (better, worse) when the IBSE program is compared with other science education programs. Addressing questions of IBSE compared with other programs requires careful evaluation design, choice of IBSE and of comparison classes and selection and creation of instruments. Where possible, existing assessment instruments ought to be used, supplemented by assessment items that require the specific skills and understanding that are outcomes of IBSE.

Reporting and feedback procedures
Countries participating in this project will be assisted in producing reports at different levels of detail for different audiences. Where appropriate, local and international evaluators will hold seminars to provide face-to-face feedback to different users of the results. However, the purpose of the international context is to add value to each individual evaluation study by sharing procedures and findings across countries. Thus, in addition to its unique value to the country in which the evaluation was conducted, the findings will contribute to a wider understanding of the effects of IBSE in different circumstances.

Operation of the international evaluation project

It is proposed that the operation of the international project will be overseen by an International Oversight Committee (IOC) of about four or five members. The IOC will initially draw up a list of international experts in IBSE evaluation and research from which members will be recruited for International Evaluation Teams (IET) to support particular evaluation projects.

Pupils’ learning in science education

Jan Schoultz & Glenn Hultman
Department of Educational Science, Linköping University, Sweden

The question of how pupils learn and think has long been discussed, and this discussion was given new life towards the end of the 1990s. This is a main problem in science and in our analyses within this field. One important task for the teacher is to guide the pupil in the culture-specific situations of science teaching. In the present project, we have shadowed pupils in schools that are participating in the NTA project (Science and Technology for All). Our studies are primarily directed towards classes from pre-school to grade six (age 6-12). The NTA materials are built up around certain themes, and for each theme there is a complete set of materials for the pupils’ experiments and written material to support the work of teachers and pupils. We have focused on the teaching in science, as it is conducted within the framework of the NTA project, as a normal experiment. We have studied and analysed what happens in the classroom when the material is introduced and used. What do teachers transfer from the original concept? What do the pupils learn?

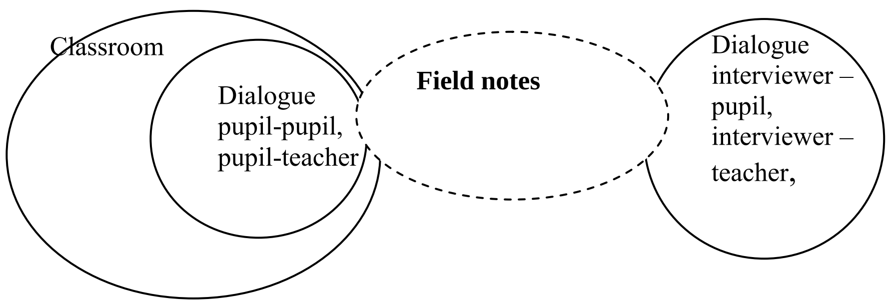
Pupils’ learning in complex environments

A set of specific practices concerning school science subjects, as well as other subjects, has evolved, and one can regard school subjects as subcultures. Learning in science concerns becoming a participant in the scientific way of thinking and acting. But the distance between the everyday world and the school science “world” is often so great that pupils cannot profit from the teaching. You have to “cross the border” into the science arena. Learning science means, among other things, learning to master scientific language usage. Many pupils in today’s schools do not have a command of scientific words and concepts in this respect. An important task for the teacher, thus, is to help pupils cross the language barrier and enter the realm of school science teaching. Learning scientific terms and concepts is a laborious process that mostly takes place in a school context and that involves specific preconditions and activities. An understanding of science concepts often begins with a verbal definition that the pupil then learns to concretize and seek applications for. In the present project, we partly focus on the pupils’ work, how they act in the classroom and how they use scientific terms and concepts in conversations about different science phenomena.

Methods

The empirical material consists of field notes from the observations, taped interviews that have been transcribed and video-recorded lessons and dialogues that also have been transcribed. We have tried to combine the different methods to attain so comprehensive a picture as possible of the classroom activities.

Video observation Interviews on the video observations



Conclusions

First we wish to emphasize the role of the teacher. During our visits, it became obvious how important the teacher is. The slogan in schools has been that the pupil should seek knowledge him-/herself and that the teacher is only a tutor. But our results indicate that there must be a teacher present who not only provides the pupils with material, but who also is an important interlocutor who helps the pupils along and who realizes what problems the pupils might have in interpreting questions and tasks. It is not reasonable to assume that the activities of pupils will lead to their discovering and acquiring scientific knowledge. Experimental material with "hands-on kits" and activity books is not sufficient in itself. Such material requires a teacher who is active, knowledgeable and sensitive and who will lead pupils on the path to new knowledge.

Our study showed that the pupils' tasks were often too much about "doing" and left too little time for reflection and discussion. Therefore, we conclude that the pupils must be given time to reflect upon what they have done in the science project and to discuss their tasks The teacher must give the pupils opportunities to use scientific words in the science classroom. But another picture emerges in our data. In a busy science classroom, pupils or pupil groups are often left on their own and conversations with the teacher are infrequent.

Some teachers reported that they have changed their way of asking questions. They now give more open-ended questions and tasks. One question of general importance is whether this method provides an "arena" for concept development. The picture of the pupil as a little researcher who finds knowledge on his/her own through experimentation is not wholly accurate and at variance with our discoveries in the classroom. It is stimulating to ask pupils questions or to give tasks that pupils themselves are to discover the answer to. But it is not easy to understand what the teacher wants you to see and discover. Here we feel we must advise caution. We noticed that questions and instructions that are too open-ended can be very confusing for pupils, and we find it is essential that the teacher be present and able to support and sum up.

Many pupils give evidence of fragmentary knowledge of science. For them, science seems to be a collection of words and terms, which as such have an explanatory value. But pupils need help in putting the pieces together. This is why the teacher must be present as a discussion partner with the pupils, support them in various ways in their work and help them create a whole from their fragmentary pieces of knowledge. Each theme in the material must be rounded off with a summary and discussion so that pupils can get the help they need to process their knowledge.

When pupils work on a theme, it is important that every task contribute to their understanding of the central content of the theme. Each task should always be related to this central idea. Yet this does not always seem to happen in the concrete school situation. Several of the pupils we talked to had difficulty understanding why they are supposed to work with a specific task. Nor did they see how the task fits into the whole.

This is why introduction of the theme is important. At this stage, pupils learn what the purpose of the work is. Thus, we think it is important to place the theme in a larger context and link it to the community outside school as well as to organize the teaching situation so that pupils see the whole picture and what is meaningful.

Learning and progress in science mean that you acquire concepts and knowledge, which have been developed during a long period of time in cultures using specific terms and rules. In this perspective, learning can be regarded as the individual increasing his/her familiarity with the area of knowledge. This is a slow and demanding process for the learner. But in a science classroom with 30 pupils and one teacher, this is rather problematic. The teacher does not have time to help every student delve further into the science "arena". For many pupils,

the experimental work results in their learning the method and how to handle the material, but not in getting an opportunity to learn more science.
In conclusion, we must say that the result of the work in the science classroom depends on the combination of pupils, teachers and materials. The pupils, the teacher and the materials are not components that can be described separately. They are variables that affect each other and at the same time form a whole, which is in turn affected by the surrounding milieu.

Taking Science to School: Learning and Teaching Science in Grades K-8

Jean Moon
The National Research Council of the National Academies,
The Board on Science Education
Washington D C, The USA

Improving science education in kindergarten through eighth grade will require major changes in how science is taught in classrooms, as well as shifts in commonly held views of what young children know and how they learn, says a new report from the National Research Council. This report brings together research literatures from cognitive and developmental psychology, science education and history and philosophy of science to synthesize what is known about how children in grades K through 8 learn the ideas of science. The research synthesis from this report and the implications from it have the potential to change science education in fundamental ways.

For example, the repeated challenge from science educators is that science education should be for "all" the children. This has been a difficult challenge to meet. While there is general agreement that all children will and must learn to read, historically there has been far less agreement that all children will and must learn science regardless of gender, race, or socioeconomic circumstances.

That issue is addressed in this report. Unequivocally, the research evidence supports this statement: All young children have the intellectual capability to learn science. Even upon entering school, young children have a rich knowledge of the natural world, demonstrate causal reasoning, and are able to discriminate between reliable and unreliable sources of knowledge. In other words, young children come with the cognitive capacities to engage in serious ways with the enterprise of science that are not being utilized in most science instruction.

Underlying all the conclusions and recommendations in Taking Science to School is a redefinition of and a new framework for what it means to be proficient in science. Four intertwined and equally important strands comprise the committee's definition of proficiency in science. First, students should know, use, and interpret scientific explanations of the natural world. Second, they should be able to generate and evaluate scientific evidence and explanations. Third, they should understand the nature and development of scientific knowledge. And finally, students' work should include participation in scientific practices and discussions.

The four strands, plus current scientific understandings of how children think, should be the basis for new science standards, assessments, and curricula. In addition, the four strands of scientific proficiency stretch science educators to think beyond the artificial dichotomy between content and process in science. This dichotomy does not represent the whole of what constitutes the scientific enterprise.

Presentation of this National Research Council report will focus on its conclusions and recommendations.

What pupils want to learn about in a primary science education

Anders Jidesjø
Swedish National Graduate School in Science and Technology Education Research, Linkoping University, Sweden

Abstract
Students' attitudes to science and technology are measured with a questionnaire in an international research project called ROSE, the Relevance Of Science Education. This is done by asking questions about what 15-year-old students want to learn about, their experiences in and outside school and their opinions about science and technology. With one part in the ROSE questionnaire, a small study collected data from 10 and 11 year old pupils in Sweden. The pupils in a primary science education want to learn partly different things when compared with the sample from secondary school. Trying to understand this situation can help in developing a science agenda in service of the learners.

How to treat the science content in school to make young people enjoy it has been brought into general notice. There are many different persons involved in the discussion. Politicians, academics and the public at large take part (Jenkins, 2000). All the same, there is no consensus about what science content schools should teach or how the content should be treated (Fensham, 2000). What makes young people to take an interest in science and relations to how the content is treated in school is a vital question (Osborne et al., 2003).

ROSE, the Relevance Of Science Education, is an international research project in which students' attitudes to science and technology are investigated. ROSE is resided in Oslo University and directed by Professor Svein Sjøberg (Schreiner & Sjøberg, 2004). ROSE wants to show marked attention to the voice of the learners. This is done by asking students in the end of compulsory school (15 or 16 year olds) for example what they want to learn about, what their experiences are and what they think about their science classes. The first analyses show that students are interested in content dealing with what we should eat and how to exercise to keep the body fit and strong. In addition, the students bring out content about space and questions where scientists disagree. They show a lack of interest in many items that traditionally dominate secondary science curriculum, like atoms, molecules and optics. There is a big interest in items concerning health and natural phenomena and many of the most popular items are not contained in the curriculum (Jidesjø & Oscarsson, 2004). These results are in accordance with ROSE data from other parts of the world, mainly developed countries (Sjøberg et al, 2004; also discussed in Jenkins & Nelson, 2005).

In ROSE a questionnaire is used divided into seven different categories, What I want to learn about, My future job, Me and the environmental challenges, My science classes, My opinions about science and technology, My out-of-school experiences and Myself as a scientist. In these categories are questions concerning astrophysics, earth science, human biology with sex and reproduction, genetics, zoology, botany, chemistry, optics, acoustics, electricity, energy, technology, STS (Science, Technology and Society) and NOS (Nature Of Science). The questions are put in different contexts like spectacular phenomena, fear, technological ideas and inventions, aesthetical aspects, beauty, care, health, personal use and everyday relevance.

In Sweden, the first category "What I want to learn about" were used in a smaller study to collect data from pupils in primary schools. Data were collected from four schools in the middle of Sweden, N=112 with 53 girls, 59 boys, 19 ten year olds, 79 eleven year olds and 15 twelve year olds. In my presentation, some international results from the ongoing ROSE-project will be presented together with some national and then compared with the results from this smaller study, what primary school children want to learn about.

The results are interpreted and discussed in the following way. In primary education, pupils have big interests in science and technology and there are differences between boys and girls but also commonalities. The interest is about the content, not subjects or broad knowledge fields like science. Pupils interests in primary science is not society oriented to the same extension as it is in secondary school. It is also oriented to what one could call "collection of facts", like animals in my area, how the eye can see, dinosaurs, cassette tapes, CDs, DVDs and computers. Many of these items do not appear at all at 15 year olds in the ROSE study.

More research is needed to understand what makes pupils take an interest in science and technology, trying to understand what lies behind these conditions. In a research and development agenda, is it possible to find new ways of putting the content in meaningful contexts, i.e. ways of communicating the content that are in line with youth culture and societies interests? Understanding these circumstances in globalization and other trends in modern societies can help in constructing a science and technology education in the service of the learners.

References

- Fensham, P. (2000) Providing suitable content in the "science for all" curriculum. In R. Millar, J. Leach & J. Osborne (ed). *Improving Science Education: The Contribution of research* (Buckingham: Open University Press).
- Jenkins, E. (2000) "Science for all": time for a paradigm shift? In R. Millar, J. Leach & J. Osborne (ed). *Improving Science Education: The Contribution of research* (Buckingham: Open University Press).
- Jenkins, E. W. & Nelson, N. W. (2005) Important but not for me: students' attitudes towards secondary school science in England. *Research in Science & Technological Education 23:41-57.*
- Jidesjø, A. & Oscarsson, M. (2004) *Students´ attitudes to science – Some results from the ROSE-project in Sweden.* Paper presented at the 11th IOSTE Symposium, Lublin, July.
- Osborne, J., Simon, S. & Collins, S. (2003) Attitudes towards science: a review of the literature and its implications. *International Journal of Science Education 25: 1049-1079.*
- Schreiner, C. & Sjøberg, S. (2004) *Sowing the seeds of ROSE. Background, rationale, questionnaire development and data collection for ROSE (The Relevance of Science Education) – a comparative study of students´ views of science and science education.* (Oslo: Unipub AS).
- Sjøberg, S., Schreiner, C. & Stefánsson, K. K. (2004) *The voice of the learners, international perspectives on science and technology based on the ROSE Project.* Paper presented to the *11th IOSTE Symposium*, Lublin, July.

Support for European Collaborative Projects on Science Education

Stephen Parker
Science and Society Directorate - DG Research
European Commission

.

The strategic agenda agreed upon by European Heads of State and Governments at the Lisbon Summit of 2000 highlighted the importance of supporting the emergence of a truly knowledge-based society. It was quickly realized, however, that Europe was not producing or employing enough researchers and scientists compared with the US and Japan. The spotlight was soon turned on science education and why young people were losing interest in studying key science subjects at school.

Quantitative data are scarce, but recent work by the OECD has shown that while enrolments at university level have increased, largely due to better access to higher education, the number of young people studying maths and the physical sciences is falling in absolute terms. According to surveys, young people find science curricula too hard and uninteresting, and knowledge about careers in science is very limited.

A closer look reveals that science curricula tend to be too content heavy and decontextualized, and furthermore, especially at the elementary and primary school level, teachers themselves need more support and training in order to cope confidently with scientific concepts.

Since 2000, the Research Directorate General of the European Commission has been increasing its budget for support for science education. The rationale is not just expressed in terms of increasing the number of scientists and researchers in Europe, but also in terms of increasing the appreciation of science among all young people. The budget essentially comes from the Science and Society action line of the "Sixth Framework Programmes for Research and Technological Development" and provides support for projects such as Scienceduc and Pollen, among many others.

The current framework programme is coming to an end in December 2006 and the seventh framework programme will commence in 2007. What lessons can we learn from our experience to date? And where should we focus our efforts over the next seven years?

Beyond Scienceduc : Pollen
A community approach for sustainable growth of science education in Europe

Raynald Belay
La main à la pâte, France

Pollen is a European research and development project supported by the DG RESEARCH of the European Commission (6th Framework Program – Science and Society), proposed by a group of pedagogical and scientific organizations from 12 European countries coordinated by *La main à la pâte* (*Ecole normale supérieure*). Pollen aims to stimulate and support science teaching and learning in primary schools, providing tools, training, coaching and assessment. The project will focus on the creation of 12 seed cities for science (Saint-Etienne - FRANCE, Bruxelles - BELGIUM, Tartu - ESTONIA, Berlin - GERMANY, Perugia - ITALY, Amsterdam - NETHERLANDS, Sacavém - PORTUGAL, Girona - SPAIN, Leicester - UNITED KINGDOM, Vác - HUNGARY, Ljubljana - SLOVENIA, Stockholm - SWEDEN).

Pollen will run for 3 and a half years and will involve a minimum of 1,600 classes. The 12 partner institutions each have a specific experience in science education, focused on an inquiry-based approach, combining a diversity of conditions, backgrounds, talents and activities (scientific research, training, resources and material production, European project management…) that makes cross-fertilization very fruitful. They are the following : École Normale Supérieure – France (coordination), Université Libre de Bruxelles – Belgium, Université of Tartu – Estonia, Freie Universität Berlin – Germany, Consortium Innovation Training Educational Inquiry – Italy, Universiteit van Amsterdam – Netherlands, Ciência Viva / Agencia Nacional para a Cultura Científica e Tecnológica – Portugal, P.A.U. Education – Spain (coordination), Royal Swedish Academy of Sciences – Sweden, University of Leicester – United Kingdom, Apor Vilmos Catholic College – Hungary, University of Ljubljana / Faculty of Education – Slovenia.

Pollen started on the 1st of January 2006, taking advantage of Scienceduc's network and results to launch large-scale experimentation about hands-on science teaching at the primary school level. Keeping inquiry-based science teaching as a principle, it is focused on the creation of 12 seed cities for science throughout the European Union. A seed city is an educative territory that supports primary science education through the commitment of the whole community (families, educative authorities, scientific and industrial partners, municipalities, museums and cultural centres, etc.). The major goal of Pollen is to show, empirically, how a reform of science teaching may be implemented locally, from the schools, but involving the whole community, in order to demonstrate the sustainability and efficiency of the seed city approach to stakeholders and national educative authorities, and to look for lever effects. At the same time that a local strategy is designed, tools are provided by the project to help this implementation. On the other hand, each partner will be in charge of experimenting and building tools for specific key issues, which are the following: low-income areas (Belgium), children with special needs (Estonia), involvement of the scientific community (France), gender issues (Germany), child participation (Italy), use of ICT in the learning process (Netherlands), family involvement (Portugal), immigrants (Spain), transition from primary to secondary school (Sweden), cross-disciplinary approaches (United Kingdom), and science education in new member States (Hungary and Slovenia). Guidelines will be elaborated on each of these topics by the partners and shared inside the Pollen network. Finally, in 2009 Pollen will release a European charter for Seed cities aiming at the development of science education in primary schools.

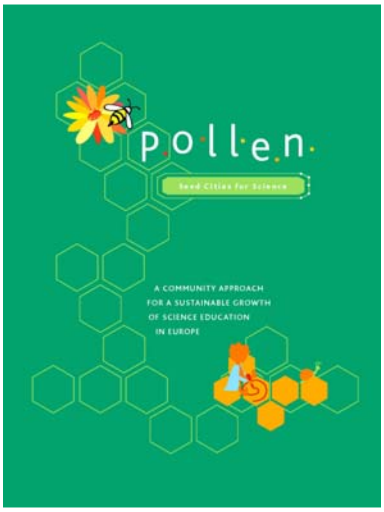
Pollen is built on a three-level network:
- European coordination (France and Spain).
- National coordination (usually an institution with nationwide acknowledgment).
- Local coordination in the Seed city.

The local team includes a coordinator, a trainer and a board of partners. In each Seed city, an average of 50 classes will participate for each school year. These classes will receive:

- basic scientific equipment and learning units.
- guides on how to implement hands-on activities in the classes.
- training and tutoring for the teachers.
- assessment and evaluation

Pollen partners agree on a unity of principles, inspiration and methodology: inquiry-based sciences at the primary school level, a similar approach guaranteed by common tools, guidelines and free learning units, evaluation protocols and questionnaires (on Community involvement and participation, Teachers' attitude towards science, Pupils' attitude towards science), coordination meetings, the seed city model. But the project also has to face the challenge of a great diversity of local situations: educative system norms and official instructions, curriculum, teacher status, receptivity for innovation, importance accorded to in-service training… This challenge of a grass root start must be used to the benefit of cross-fertilization of the seed cities.

All material produced inside Pollen, as well as further information about the project, its advances, achievements and outcomes, are freely accessible from the Pollen website: www.pollen-europa.net



Conference general report

Pierre Léna
Académie des Sciences, France

(Transcription of the presentation)

I am going to present my understanding of what I heard at this conference and I will try to develop it in some more personal points.

1. A global vision
We had a global vision of inquiry-based science education for children and teachers. This was presented essentially by our American colleagues as a set of interventions in a beautiful, well-organized, well-conveyed way and established on the basis of extensive work: How do children learn ideas? Are teaching scientific inquiry, inquiry evaluation and assessment progressively entering the classrooms? And finally, where does strategic implementation stand in the United States? These talks raise a question that was essentially the one Per-Olof Wickman mentioned a few minutes ago: Are these views suited to European conception(s) of science, to our school traditions, to the teachers' profiles and also to our philosophy(ies) of learning? In this respect, Europe has a long history, sometimes as far back as the middle age or the renaissance, which still leaves profound traces in our current visions of education. Thus, this meeting certainly helps us take full measure of the questions I summarize here, questions about the long process we are beginning, but it does not as yet give all the answers.

2. Children and science: a consensus – *A potential exists in all children (J. Moon, A. Jidesjö)*
Despite possible differences between Europe and the US, there are still two strong points of consensus: One is the children, the other the teachers. I took a few ideas presented at the conference to illustrate this consensus. It was well summarized by two approaches, one from Jean Moon, the other from Anders Jidesjö, about the potential existing in *all* children (here the important word is "all"). Once engaged, children have amazing capabilities that are to be trusted to move them forward.
The cognitive sciences may change our views on the science learning process. We heard a lot about constructivism, Piagetian and non-Piagetian visions, but there is more to come from the cognitive sciences through new investigative techniques and especially through the neurosciences. We must wait for these developments, trying neither to understate nor overstate the possibilities.
There is a profound common factor that reaches across cultural differences. This common potential exists. Yet it is clear, especially from what we have heard this morning and also from our experience, that cultural differences should not be glossed over in an attempt to find a universal model of education. Science education has to be deeply rooted in the local culture. We heard about Gypsies, for instance, which was very interesting in this respect.
Another point is the performance of "low achievers". Through the process of inquiry education, they gain in self-confidence and self-esteem. What better service could we give these young children than this particular one, if we are to promote their future development, regardless of whether or not they choose a career in science?

As mentioned by T. Tenno, children do not care about disciplines. At this stage of primary education, we don't want to teach science divided into a set of disciplines. I think this is a very important point, given that the organization of research in universities, of teacher training and very often of curricula is strongly based on this disciplinary structure. Such an organization is, of course, reasonable, but not if it causes us to forget about the learner's desire, endeavours and sensitivity, which were so well described again this morning.
There was consensus concerning the fact that (good) inquiry pedagogy is effective in revealing a taste for science. So, we have a serious question: How can such consensus be shared and reflected in educational policies and priorities? Work must be done on this in the future, and this involves many aspects: Curricula, teacher training, presentation of the teaching career to potential new teachers, etc… This is a key point, especially in the European countries, several of which are now saying that we have to return to the "good old days of schooling", when reading, writing and arithmetic were imposed as a quasi-exclusive goal in primary school and the rest was superfluous. Naturally, we would like to add something we can call *science literacy* or *reasoning*. We want this to be added to the curriculum and to the primary school objectives. This is not very easy to deal with, and there are many controversies around this point in current policy discussions all over Europe.
Another question addressed here, in the first talk and again, was: "Is evidence really lacking on the effectiveness of this pedagogy?" We have to think about what we call *evidence*. If evidence is a graph with a Gaussian distribution and a display of maxima by so many standard deviations, then we don't have much, and we would probably have a hard time interpreting it if we did. On the other hand, I think that we have so many convincing elements from children's interest, teachers' commitment, parents' commitment – all of which should be viewed as solid pieces of evidence. Indeed to gain future support, we have to provide better answers, and in as rigorous a way as possible. But our programs will always contain a certain element of the non-quantifiable, that is, our conviction.

3. Teachers and science: a consensus

There is consensus on a number of points: Primary school teachers are versatile and happy to deal with science, but some have difficulties with it. They need to better understand what science is, and not necessarily which aspect of science should be taught. Someone said "you do that by just doing, but you realize what it is and it's not what you thought it was". This would be easy if teachers were introduced through a personal contact with *real* – yet simple – science; they would certainly benefit from this.
As said this morning, this is a long process that takes months or years. The time constant (speaking as a physicist) of change in the system of science education is on the order of 5 to 10 years, but a change is possible. Tina Jarvis gave us several examples of such possibilities. One positive point is that formative assessment of teachers is possible and efficient. In fact, it is probably easier to accomplish for teachers than for children, because the criteria are probably easier to make explicit. One can count on one obvious fact: A good teacher leads to a good lesson and a good lesson to pupils' success. Thus, working for the improvement of teachers and the ability to evaluate these improvements is almost a guarantee for the success and support of the type of program we are discussing here.
Some questions have been raised. Should teacher training be organized and mutualized at the European level? How should we do that? Should we provide recommendations, should we establish standards? Another important question in my view, and one that was not brought up so much at this meeting, is: What role should active scientists play in this process? I don't think that the *Scienceduc* or *Pollen* projects would exist without the involvement of many prominent scientists in a number of countries, but this is not sufficient, there are too few. We can see that scientists have an extremely positive role to play and that this role has increased over the past 10 years; this should be kept in mind.

Another point very present at this meeting, with many positive experiments and suggestions, is *in-service training*. But vocational training was essentially not addressed at all, except in one comment at the round table – this may be unfortunate, but can be addressed at another meeting! What should we do for these future teachers, given that, in France (I don't have the exact number for Europe), nearly 15,000 primary school teaching students graduate every year? These young people, who are coming from faculties of education or from other university centres, will be in charge of education for several decades to come. So again, this raises the question of creating standards or contributing to them by associating the scientific community with development of such standards. This is a question we cannot ignore, given the magnitude of the problem. Indeed, in-service training is urgent, because we will soon have to demonstrate that what we do works well and is worthwhile.

4. Miscellaneous points (though important ones)

Below is a brief list of other important points addressed at the conference. I did not try to do justice to everybody, but merely provide this list of points to think about:

- Assessment of children after inquiry lessons: Is it difficult? Is it possible? Could it be quantitative? We heard an interesting paper addressing these questions (L.McKormak).
- Objects of science: from nature to kits … (A. Blagotinzek et al.). The objects of science, dealt with in class, can come from nature. Where is the balance between living nature, observation and experimentation and a nature "prepared" in kits? It was clear that there are different philosophies concerning this point. This area may be worthy of more exploration.
- Innovative resources: using cartoons, puppets etc., presentations (B. Keogh, A. Rodriguez…). We heard a number of interesting presentations on this topic.
- Science and technology: Inclusion or complete separation? This question was addressed by A. Ferro during the round table. Many of the items of interest for boys and girls, as said this morning, were science, technology or a relationship between the two, and it is sometimes difficult to explain this relationship exactly to teachers. In some European countries, the two are completely separated. In junior high school, there may be different teachers who seldom speak to each other, as is the case in France. I think such is the case in the UK too, so what should we do to solve this problem? Should we keep them separate or combine them? I am tempted by the second choice, but this has to be discussed.
- How is science (of nature), when taught, put in relation to other disciplines: language, history, maths… The experience we have in France is that, for teachers, closely connecting language acquisition and science acquisition is a big point.
- Is inquiry applicable to other fields? (P.O. Wickman)

Another question concerns the possible application of inquiry teaching to other fields of knowledge, and how this should be done. Is there an incentive to do so, with the risk of illusion and possibly even of confusion? Of course, in discussing with teachers, as well as with faculties of education and vocational teacher training programs, this is a question that recurs again and again.

- Transition from primary to secondary: how to make the latter benefit from innovation in the former (A. Jidesjö)? This is a very important point mentioned several times during the conference. From primary to secondary school, there has been a complete change in the profile of the teacher of science. In most European countries, science teachers have transitioned from being versatile to being specialists. Now, will specialists benefit from innovations taking place in seed cities for excellence, and how will they react to this? How are they tied to this process? Are they in a position to engage in dialog with primary school teachers? How will they receive children from the 1500 classes that were mentioned in the *Pollen* program? How will these children be treated; how will they react to more conventional teaching? In France, we are just beginning to introduce *La main à la pâte* into the junior high school (grades 6 and 7).

All the above questions seem to me to be very important.

5. European perspectives

- From Erice to Stockholm II

We had the Erice meeting (of which we have the proceedings) at the beginning of *Scienceduc*. I read again the conclusions last night, and it's obvious to me that we have already made a great step forward, which is very positive.

- The richness of diversity

We have come to realize, during this meeting, the richness of European diversity. If you look at the building of the CERN accelerator, the European Very Large Telescope in Chile, many other successes of science and technology, they are all a direct result of this diversity. We have had practical experience of this diversity here, and this is very important for the future. We have seen this explicitly through the descriptions of innovations, experiments and initiatives.

I think *Pollen* began on a good foundation. The final *Pollen* conference in 2009 promises to be a great event.

- European consciousness increases: Gago's Report, Figel's Report, Framework Program 7.

It's also clear from European policies that awareness of the importance of what has been done here is slowly increasing. We have a good demonstration of this with the intervention of Dr. Parker, we have the Gago's report, the Figel's Report, and as Raynald Belay quoted, we have the statements in the FP7, which were presented this morning. We also heard about the future Roccard report, which was officially announced this morning. Europe, which has achieved so many great things in research and technology, is progressively becoming aware of the challenges of education, not in a theoretical or proclamatory way, but in a practical way that concerns change. We still need, I believe, a deeper overview of what we call *science education*, a goal that has to be rooted in European visions of science. Now, how can we achieve this? Will the various science academies play a role here? Can we collaborate with the European Council of Science that has just been established, will it concern itself with this question of science education for all? What about subsidiarity? This point was underlined this morning; everything we did today was done with the EU research directorate, because the education directorate has no mandate to intervene in national systems, as Dr. Parker recalled. What we do here, what *Pollen* will do is really part of the national system, because we are ultimately dealing with children and teachers. This subsidiarity is in a sense an excuse for Europe to not act as it could. I look forward to seeing in more detail the project of the Rocard report, which reopens this question, not necessarily on the political or theoretical level, but on the practical level of action and support of efficient and proven actions.

Finally, the question of research was also central in the discussions. The need for research was recognized, but the issue was not developed.

What is next, after *Pollen*? We don't have much time to think about new projects, because we have the new calls for FP7, which may come during the coming year, and there is some time overlap between the existing program (*Pollen*) and future ones. We have this overlap between *Scienceduc* and *Pollen*, and we have to accept it.

About this next stage, should we call for a multiplication of seed cities? We have heard that such an extension process is already being considered in Italy. Anna Allerhand presented it. Should we plan for more countries to enter, as *Pollen* only includes half the countries of Europe? Some countries, especially from the East, are missing. Should we think about cooperation with the Balkans? There was a brilliant summer school last year in South East Europe that gathered 13 countries. There was great interest in what has been done, so how should we organize our collaboration with this part of Europe? Should we have more ambitious plans, such as to create a European teacher-training centre? Such as the great ICTP centre for research in Trieste, which was established by the Nobel Prize winner Abdus Salam

for fostering research in developing countries and which has had immense success for over 30 years now. Should we think of something like this for teachers? It would be a place where teachers would come, share, meet scientists, stay for 1 or 2 weeks and where they could train, engage in documentation…. This would be also one possibility, I'm sure there are many others. We have to demonstrate our imagination.
So, I will leave you with these questions, and my certainly biased comments on these excellent and fruitful days.

6- Thanks to …
Before giving the floor to Sven Olof for conclusions, I wish to sum up by expressing my thanks. I would really like to thank our hosts: the Royal Swedish Academy, Sven-Olof, Kerstin, Karin, the Swedish Committee… for doing such a good job of organizing this meeting. To Pamela Lucas, who is the very modest and efficient leader of *Scienceduc* and who will now move to *Pollen*, and to Raynald Belay. Thanks of course to all the speakers, especially to the puppets and their parents… *Scienceduc* is over, let us succeed with *Pollen*, and prepare for the post-*Pollen* future.

Program

Sunday, October 15

Session chaired by: Sven-Olof Holmgren, *The Royal Swedish Academy of Sciences Sweden*

12:30 Registration
(Display of posters starts at 12:00)

13:00 **Welcoming Speech**
Gunnar Öqvist, Permanent Secretary - The Royal Swedish Academy of Sciences

13.15 **Conference introduction**
Sven-Olof Holmgren, Chairman of the conference - Member of The Royal Swedish Academy of Sciences, Sweden

13: 30 **Science education : a priority to build the future**
Edouard Brézin, President of the *Académie des sciences*, France

13:45 **European overview of primary science education and scientific career perspectives**
José Mariano Gago, Minister for Science, Technology and Higher Education, Portugal

14:30 **Coffee break**

15:00 **Defining and Teaching Scienctific Inquiry: Past and Future**
Norman G. Lederman - Professor, Illinois Institute of Technology, Chicago, The U. S.

16:00 **Scienceduc[1]: Status reports of seven ongoing national EU initiatives – perspectives on inquiry and curriculum**
- France: Pamela Lucas, ENS- La main à la pâte
- Estonia: Toomas Tenno, Tartu University
- Germany: Petra Skiebe-Corette, Free University of Berlin
- Hungary: Zsuzsanna Gajdóczky / Bernadett Kkohegyi, Apor Vilmos Catholic College

16:45 **Break**

17:15 **Scienceduc: Status reports of seven ongoing national EU initiatives – perspectives on inquiry and curriculum**
- Italy: Anna Allerhand, LUMSA
- Portugal: M. da Luz Carvalho de Figueiredo, Ciencia Viva/ Agrup.Esc. de Buarcos
- Sweden: Per-Olof Wickman, Stockholm Institute of Education and NTA
  Britt Lindahl, Senior Lecturer, Kristianstad University

18:15 **Instructional materials, Assessment and Accountability: Lessons learned from two decades of science Education Reform**
Sally Goetz Shuler, Executive Director, National Science Resources Center, Washington DC, The U. S.

19:00 **Adjournment**

Monday, October 16

Session chaired by: Sven-Olof Holmgren, ***The Royal Swedish Academy of Sciences Sweden***

8:30 **Summary of previous day and expectations for second day.**

8:45 **Inquiry, evaluation and assessment in a primary class room**
Judith Sweeney Lederman, Ph. D.
Director, Teacher Education, Illinois Institute of Technology, Chicago, The U.S.

9:45 **Poster Session 1: *"Inquiry, evaluation and assessment in a primary class room"***
Session chaired by Dr. Judith Sweeney Lederman
- Ed van den Berg, AMSTEL Institute, Amsterdam, Netherlands
- Nada Razpet, Faculty of Education Koper and Ljubljana, Slovenia
- Sally Goetz Shuler, National Science Resources Center, Washington DC, The U. S.
- Questions and concluding remarks

10:25 **Coffee break**

11:00 **Teacher support and training**
Tina Jarvis, Ph. D., Director, Science Learning Centre, East Midlands, The U.K.

12:00 **Poster Session 2: *"Teacher support and training"***
Session chaired by Dr. Tina Jarvis
- John CRIPPS CLARK, Deakin University/Hazlehead Academy, Australia, The UK
- Ana Alexandra Valente Rodrigues, Rui Marques Vieira & Patrícia da Conceição Gomes do Nascimento, Departament of Didactics and Educational Technology of University of Aveiro, Portugal
- Sally Goetz Shuler, Executive Director, National Science Resources Center, Washington DC, The U. S.

- Questions and concluding remarks

12:40 **Lunch**

14: 00 **Engaging the new generation**
Brenda Keogh, Ph. D. and Stuart Naylor, Ph. D.
Millgate House Publishing and Consultancy Ltd, Sandbach, the U.K.

15:00 **Poster Session 3: *"Engaging the new generation"***
Session chaired by Drs. Brenda Keogh and Stuart Naylor
- Alberto Eduardo Morão Cabral Ferro, IST - Departamento de Engenharia de Materiais, Lisboa, Portugal
- Sonja Stuchtey, Fenita Dyckerhoff & Shadi Mueller-Menrad, Science-Lab, Germany
- Ana Gostincar Blagotinsek, Faculty of Education, University of Ljubljana, Slovenia
- Lorraine McCormack, CASTeL, Centre for Advancement of Science Teaching and Learning, Dublin, Ireland
- Questions and concluding remarks

15:40 **Coffee break**

16:10 **Reports:**
IAP Working Group on Evaluation of Inquiry-Based Science Education Programmes
Glenn Hultman, Ph. D., Professor, Linköping University, Linköping, Sweden

Pupil´s learning in science teaching
Jan Schoultz, Ph. D., Professor, Linköping University, Linköping, Sweden

Taking Science to School – How Children in K-8 Learn Science Ideas
A Report by the National Research Council, The National Academies, The U.S.
Jean Moon, Ph.D., Director, Board on Science Education, The National Academies, Washington, The U. S.

18:00 **Adjournment**

18:15 **A tour of the Nobel Museum**
All the participants are invited to a tour of the Nobel Museum where a buffet dinner will be served.
The buses to the Museum will leave the Royal Swedish Academy of Sciences at 18:15

Tuesday, October 17

Session chaired by : Pierre Léna, *Académie des sciences, France*

8:30 **ROSE, The Relevance of Science Education:**
"Students' interest in science and technology - A comparison between primary and secondary schools in Sweden."
Anders Jidesjö,
Graduate student, The National Graduate School for Research in Science and Technology Education, Linköping University, Linköping, Sweden

9:30 **Support for European collaborative projects on science education**
Stephen D.Parker, Ph. D.,Head of Sector: Education and Science, Research Directorate General European Commission, Brussels, Belgium

10:15 **Coffee break**

10:45 **Beyond Scienceduc: POLLEN^2 initiative and its perspectives in Europe**
Raynald Belay, Vice-director La main à la pâte, France

11:00 **Discussion about European perspectives**
Pierre Léna, Ph. D.
Académie des sciences, France
- What could we learn from the results from Scienceduc? Common elements?
- How to disseminate the process to other countries?
- How to implement networks?
- What can we learn from each other?
- What transfer can we expect?
- Could we implement European development strategies?

11:45 **Conference general report**
Pierre Léna, Ph. D.
Académie des sciences, France

12:15 **Closing remarks**
Sven-Olof Holmgren, Ph. D.
The Royal Swedish Academy of Sciences, Sweden

12:30 **End of the conference**

The international Scientific Committee

- **Per-Olof Wickman**, *The Stockholm Institute of Education, Stockholm, Sweden* ***(Chairman)***
- **Bruce Alberts**, *University of California, San Francisco, USA*
- **Björn Andersson***, Gothenburg University, Gothenburg, Sweden.*
- **Saouma BouJaoude**, *American University of Beirut, Beirut, Lebanon*
- **A.L.(Ton) Ellermeijer**, *AMSTEL Instituut, Universiteit van Amsterdam, Amsterdam, The Netherlands.*
- **Peter Fensham**, *Monash University, Melbourne, Australia*
- **Guillermo Fernández de la Garza**, *US-Mexico Foundation for Science, Mexico City, Mexico*
- **Wynne Harlen**, *University of Bristol, Bristol, UK*
- Chistine Harrison, *University of London, UK*
- **Ryszard M. Janiuk**, *Maria Curie-Sklodowska University, Lublin, Poland.*
- **Tina Jarvis**, *Science Learning Centre East Midlands,University of Leicester, Leicester, UK.*
- **Norman G. Lederman**, *Illinois Institute of Technology, Chicago, USA*
- **Jean Moon**, *National Academies, Washington DC, USA*
- **Yves Quéré,** *Académie des sciences, Paris, France*
- **Elwira Samonek-Miciuk**, *Maria Curie-Sklodowska University, Lublin, Poland*
- **Dennis Schatz**, *Pacific Science Center, Seattle WA, USA*
- **Sally G. Shuler,** *National Sciences Resources Center, Washington DC, USA*
- **Russell Tytler**, *Deakin University, Australia*
- **Karen Worth,** *Education Development Center, Inc., Newton , USA*

The Swedish Organizing Committee

Sven-Olof Holmgren – *The NTA Program/ Royal Swedish Academy of Sciences* ***(Chairman)***

Anders Jidesjö, *Linköping University*

Britt Lindahl, *Kristianstad University*

Per-Olof Wickman *The Stockholm Institute of Education*

Glenn Hultman, *Linköping University*

Kerstin Reimstad, *The NTA Program*

Jan Schoultz, *Linköping University*

Helge Strömdahl, *Linköping University*

Pamela Lucas, *La main à la pâte - ENS, France*

Participants

ALBERTO EDUARDO MORÃO CABRAL FERRO
Instituto Superior Técnico - Professor/Lecturer
IST - Departamento de Engenharia de Materiais
Av. Rovisco Pais, nº1 1049-001 Lisboa, Portugal
alberto.ferro@ist.utl.pt
Tel: 351218418119

ANNA ALLERHAND
Lumsa University Rome - Italy and Headteacher of a primary school, Rome - contract professor
LUMSA Facoltà di scienze della formazione, Piazza delle Vaschette 101 00193
Or
51° Circolo Didattico, via Lovanio 13 00198 Roma, Italy
a.allerhand@katamail.com
Tel: 39068553209

PROF. PIERLUIGI MINGARELLI
Laboratorio di Scienze Sperimentali di Foligno –Director
Via Isolabella - 06034 FOLIGNO (PG), Italy
direttore@labscienze.org
Tel: ++(39) 0742342598

JOHN CRIPPS CLARK
Deakin University/Hazlehead Academy
Fulwood 8 Grampian Terrace Torphins AB31 4JS UK
crippscl@deakin.edu.au
Tel: 1339882384

DR TINA JARVIS
Science Learning Centre East Midlands University of Leicester -Director
21 University Road Leicester LE1 7RF UK
jar@le.ac.uk
Tel: +44(0)116 252 3771

DR BARBARA BUZZARD
School of Education University of Leicester - Lecturer
21 University Road Leicester LE1 7RF UK
bjb8@le.ac.uk
Tel: 44 + (0)116 2523707

ANA GOSTINCAR BLAFOTINSEK
Faculty of Education, University of Ljubljana - lecturer
Kardeljeva pl. 16, SI-1000 Ljubljana, Slovenia
ana.gostincar@guest.arnes.si
Tel: +386 1 589 22 18

RAYNALD BELAY
La main à la pâte - Assistant director
La main à la pâte - ENS - Diffusion des savoirs 1 rue Maurice arnoux 92120 Montrouge, France
raynald.belay@inrp.fr
Tel: 33157016597

PAMELA LUCAS
ENS - La main à la pâte - Scienceduc coordinator
La main à la pâte / ENS / Diffusion des savoirs 1 rue Maurice Arnoux 92120 Montrouge, France
pamela.lucas@inrp.fr
Tel: 331 58 07 65 97

PIA NORRTHON
Danderyds kommun - Teacher and NTA-coordinator
Pia Norrthon Vasaskolan Box 124 182 05 Djursholm, Sweden
pia.norrthon@personal.danderyd.se
Tel: 08-568 914 70

NADA RAZPET
Faculty of Education Koper and Ljubljana - assistant
Faculty of Education Kardeljeva plošèad 16, SI – 1000 Ljubljana, Slovenia +386 1 589 22 00
nada,razpet@guest.arnes.si
+386 1 589 22 00

ED VAN DEN BERG
AMSTEL Institute - Lecturer
AMSTEL Institute Kruislaan 404 1098 SM Amsterdam, The Netherlands
eberg@science.uva.nl
Tel: 31-20-5257985

ANA ALEXANDRA VALENTE RODRIGUES
Departament of Didactics and Educational Technology of University of Aveiro - Teacher and researcher on Primary Science Education
Universidade de Aveiro Departamento de Didáctica e Tecnologia Educativa Campus Universitário de Santiago 3810-193 Aveiro, Portugal
arodrigues@dte.ua.pt
Tel: 351234378128

RUI MARQUES VIEIRA
Departament of Didactics and Educational Technology of University of Aveiro - Teacher and researcher on Primary Science Education
Universidade de Aveiro Departamento de Didáctica e Tecnologia Educativa Campus Universitário de Santiago 3810-193 Aveiro, Portugal
rvieira@dte.ua.pt
Tel: 351234372408

PATRÍCIA DA CONCEIÇÃO GOMES DO NASCIMENTO
Departament of Didactics and Educational Technology of University of Aveiro - Candidate to a doctor's degree on Primary Science Education
Universidade de Aveiro Departamento de Didáctica e Tecnologia Educativa Campus Universitário de Santiago 3810-193 Aveiro, Portugal
pnascimento@dte.ua.pt
Tel: 351234370810

LORRAINE MCCORMACK
CASTeL, Centre for Advancement of Science Teaching and Learning - Postgraduate Researcher
CASTeL, X149, School of Chemical Sciences, Dublin City University, Dublin 9, Ireland
lorraine.mccormack2@mail.dcu.ie
Tel: 00353 (0)1 700 5375

HELGE STRÖMDAHL
National Graduate School of Science and Technology Education Research Department of Social and Welfare studies Linköping University - Professor
Linköping University FontD, ISV 601 74 Norrköping, Sweden
helst@isv.liu.se
Tel: 4611363365

FRANKIE MCKEON
University of Leicester - Science tutor
School of Education 21 University Road Leicester LE1 7RF, UK
fm10@le.ac.uk
Tel: 441162523709

JANIS GEDROVICS
Riga Teacher Training and Educational Management Academy - Assoc. professor
RTTEMA, Imantas 7 line No 1, Riga, LV 1083, Latvia
janis.gedrovics@rpiva.lv
Tel: 3717808120

KARIN HELLAT
University of Tartu - lecturer
Jakobi 2, 51014 Tartu, Estonia
Karin.Hellat@ut.ee
Tel: +372 7 375 179

TOOMAS TENNO
University of Tartu - professor
Jakobi 2, 51014 Tartu, Estonia
Toomas.Tenno@ut.ee
Tel: +372 7 375180

PER-OLOF WICKMAN
Stockholm Institute of Education and NTA - Professor
Dept UKL Box 34103 10026 Stockholm, Sweden
pow@lhs.se
Tel: -7379785

BRITT JAKOBSON
Department of Curriculum Studies and Communication, Stockholm Institute of Education - graduate student
Lärarhögskolan i Stockholm, Box 34103, 100 26 Stockholm, Sweden
britt.jakobson@lhs.se
Tel: 070-561 00 66

LILLEMOR BIRGITTA STERNER
Stockholm Institute of Education Science Department - Lecturer
Stockholm Institute og Education, Science Department Box 34103, 10026 Stockholm, Sweden
lillemor.sterner@lhs.se
Tel: 4687379873

MARGARETA EKBORG
Malmö University, School of teacher Education - Senior lecturer
Malmö University School of Teacher Education SE 205 06 Malmö, Sweden
margareta.ekborg@lut.mah.se
Tel: 46406658020

BRITT LINDAHL
kristianstad University - Senior lecturer
Kristianstad University SE-291 88 Kristianstad, Sweden
britt.lindahl@mna.hkr.se
Tel: +46 44 203447

DR. ODILLA FINLAYSON
CASTeL, Dublin City University - Senior LEcturer in Science Education
CASTeL, School of Chemical Sciences, Dublin City University, Dublin 9, Ireland
odilla.finlayson@dcu.ie
Tel: 353-1-7005409

JEMIMA ANN ROBISON
Epping West Primary School - Class Teacher
69 Carlingford Road, Epping West, 2121 NSW Australia
jemimaann@hotmail.com
Tel: (02) 9876-8255

ELA AYSE KÖKSAL
Middle East Technical University (on behalf of Nigde University) - Research Assistant
Secondary Science and Mathematics Education Department Faculty of Education Middle East Technical University 06531 Ankara Türkiye
ela@metu.edu.tr
Tel: 903122104049

PETRA SKIEBE-CORRETTE
Freie Universität Berlin NatLab Fabeckstr. 34-36 D-14195 Berlin, Germany
skiebe@zedat.fu-berlin.de
Tel: 49-30-8385-4905

DR. KARIN ELISABETH BECKER
Berlin-Brandenburgsche Akademie der Wissenschaften - International Relations and Science Policy
Berlin-Brandenburgsche Akademie der Wissenschaften Jägerstr. 22/23 D-10117 Berlin, Germnay
becker@bbaw.de
Tel: 49-30 203 70 583

DR. BERND RICHTER
Freie Universität Berlin - Teacher Trainer
Freie Universität Berlin NatLab Dept. of Biology, Chemistry, Pharmancy Fabeckstr.34-36, D-14195 Berlin, Germany
brichter@chemie.fu-berlin.de
Tel: 49-30-8385-4905

ANNA MARBÀ TALLADA
Universitat Autònoma de Barcelona. SPAIN - Teacher
Facultat d Educació. Universitat Autònoma de Barcelona. Campus Bellaterra. 08193 Barcelona, Spain.
anna.marba@uab.es
Tel: 34935812642

CONXITA MÁRQUEZ BARGALLÓ
Universitat Autònoma de Barcelona. SPAIN - Teacher
Facultat d Educació. Universitat Autònoma de Barcelona. Campus Bellaterra. 08193 Cerdanyola del Vallès. Spain
conxita.marquez@uab.es
Tel: 34935812642

JESÚS PIQUERAS
Stockholm Institute of Education - Assistant Professor
Lärarhögskolan i Stockholm UKL BOX 34103 10026 Stockholm, Sweden
jesus.piqueras@lhs.se
Tel: +46 8 7375921

BODIL NILSSON
Stockholm Institute of Education - lecturer
Lärarhögskolan i Stockholm; UKL/Nv-avd.; Box 34103; 100 26 Stockholm, Sweden
bodil.nilsson@lhs.se
Tel: 08-7379722

HANS PERSSON
Institute of Education - assistant professor
Lärarhögskolan i Stockholm Box 34103 10026 Stockholm, Sweden
hans.persson@lhs.se
Tel: 87164448

PERNILLA NILSSON
Enheten för Lärarutbildning, Högskolan i Halmstad - Teacher trainer/Ph D student
Enheten för lärarutbildning Högskolan i Halmstad Box 823 301 18 Halmstad, Sweden
pernilla.nilsson@elu.hh.se
Tel: 035-167768

CHRISTINA OTTANDER
Dep of mathematics, technology and science education Faculty of Teacher Education Umeå university - Senior lecturer
Dep of mathematics, technology and science education Umeå university 901 87 Umeå, Sweden
christina.ottander@educ.umu.se
Tel: +46 90 786 7124

DUSAN KRNEL
Faculty of Education, University in Ljubljana - lecturer
Faculty of Education, University in Ljubljana Kardeljeva plošèad 16 1000 Ljubljana, Slovenia
dusan.Krnel@guest.arnes.si
Tel: 38615892341

TRANSETTI CLEMENTINE
La Rotonde - Ecole Nationale Supérieure des Mines de Saint-Etienne - Pollen local coordinator
www.emse.fr/larotonde
transetti@emse.fr
Tel: 33477420205

LARS FORSBERG
Lärarhögskolan i Stockholm - Univ. Adjunkt, Sweden
lars.forsberg@lhs.se
Tel: 08-737 97 33

CAROLINA SVENSSON HULDT
Stockholm Institute of Education, Dep of Curriculum Studies and Communication -Lecturer
Stockholm Institute of Education, Dep of Curriculum Studies and Communication, Box 34 103, SE-100 26 Stockholm, Sweden
carsve@lhs.se
Tel: +468 737 57 59

DR KEITH BISHOP
University of Bath - Senior Lecturer
Department of Education University of Bath BA2 7AY UK
k.n.bishop@bath.ac.uk
Tel: 441225385027

PROFESSOR JOSÉ MARIANO GAGO
Minister for Science, Technology and Higher Education
Estrada das Laranjeiras, 197-205, 1649-018 Lisboa, Portugal
gago@mctes.gov.pt
Tel: +351-217231016

EDOUARD BREZIN
Académie des sciences - President
Académie des sciences - 23, quai de Conti - 75006 PARIS – France
edouard.brezin@physique.ens.fr
Tél.: 33+ (0)1.44.41.43.67

PIERRE LÉNA
Académie des sciences – Academician and Education and training delegate
Académie des sciences Délégation à l éducation et la formation 23, quai de Conti 75006 PARIS
pierre.lena@obspm.fr
Tel: 33+ (0)1 44 41 43 89

KERSTIN REIMSTAD
The City of Linköping, Department of Education The Royal Swedish Academy of Sciences - Project Manager
Linköpings kommun S-581 81 Linköping, Sweden
kerstin.reimstad@linkoping.se
Tel: +46 13 26 31 02

FULYA ONER ARMAGAN
Gazi Universitesi Gazi Faculty of Education Primary Science Education Department - Research Assistant
Gazi Universitesi Gazi Faculty of Education Primary Science Education Department Teknikokullar Ankara Turkey
armaganf@gazi.edu.tr
Tel: 242970709

LENA LÖFGREN
Kristianstad University - Lecturer
Kristianstad University 291 88 Kristianstad, Sweden
lena.lofgren@mna.hkr.se
Tel: +46 44-20 34 31

ÅSA JULIN-TEGELMAN
UKL LHS - Senoir Lektor
Inst UKL LHS Box 34103 10026 Stockholm, Sweden
asa.julin-tegelman@lhs.se
Tel: 87379872

DR. HEIKE SCHETTLER
Science-Lab - Cofounder/Pedagogical Direction
Rodelbahnstr. 4 82223 Eichenau, Germany
heike.schettler@science-lab.de
Tel: +49 8157 99 67 83

EVA RIESBECK
Institutionen för utbildningsvetenskap Department of Educational Science Linkoping University - Lecturer
evari@iuv.liu.se
Tel: 013-282718

LARS WILZÉN
IFM, Linköping University - Lecturer
IFM Linköping University SE 581 83 Linköping, Sweden
ldw@ifm.liu.se
Tel: +46 13 281875

SALLY GOETZ SHULER
National Science Resources Center - Executive Director
901 D Street, SW, Suite 704-B Washington, DC 20024 USA
shulers@si.edu
Tel: 202-633-2972

SZATLÓCZKYNÉ DR. ZSUZSANNA GAJDÓCZKY
Apor Vilmos Catholic College - professor
HU-2900 Vác, Konstantin tér 1-5, Hungary
go@avkf.hu
Tel: 003627-814-240

KÕHEGYI TAMÁSNÉ (BERNADETT MIKULAI)
Apor Vilmos Catholic College - coordinator
HU-2600 Vác, Konstantin tér 1-5, Hungary
kohegyi@avkf.hu
Tel: 0036-27-814-240

MARIA DA LUZ CARVALHO DE FIGUEIREDO
Agrupamento de Escolas de Buarcos, Figueira da Foz - Teacher
info@eb1-figueira-foz-n5.rcts.pt
luzul@sapo.pt
Tel: 351233433064

LENA RENSTRÖM
Lärarhögskolan i Stockholm - uni.lekt.
Lärarhögskolan i Stockholm Box 34103 10026 Stockholm, Sweden
lena.renstrom@lhs.se
Tel: 08 - 737 96 90

PAULINA MATA
Faculdade de Ciências e Tecnologia Universidade Nova de Lisboa - Assistant Professor
Departamento de Química Campus FCT-UNL, Quinta da Torre 2829-516 Monte de Caparica, Portugal
paulina.mata@dq.fct.unl.pt
Tel: +351 21 2948354

GLENN HULTMAN
Inst för utbildningsvetenskap (IUV), Linköpings universitet - Professor i Pedagogiskt arbete
glehu@iuv.liu.se
Tel: +46 13 282071

JAN SCHOULTZ
Department of educational science - professor
IUV Linköping University 58183 Linköping, Sweden
jansc@iuv.liu.se
Tel: 4613281832

SZILVIA GOLYÁN
Apor Vilmos Katolikus College - assistant lecturer
2600 Vác, Konstantin tér 1-5.
szilvia_golyan@freemail.hu
Tel: 0036-27-814-240

C. JEAN MOON
The National Academies - Director, Board on Science Education
500 Fifth Street, NW Washington, DC USA 20001
jmoon@nas.edu
202 334 3055

ERIK SANNER
NTA Stockholm - Coordinator
erik.sanner@spanga-tensta.stockholm.se
Tel: 08-508 03 390

PERNILLA LÖVENHAMN SEGER
NTA Stockholm - Coordinator
pernilla.lovenhamn@spanga-tensta.stockholm.se
Tel: 08-508 03 389

DR. NORMAN G. LEDERMAN
Illinois Institute of Technology - Professor and Chair
Illinois Institute of Technology 3424 S. State St., Rm 4007 Chicago, IL 60616 USA
ledermann@iit.edu
Tel: 312-567-3658

FENITA DYCKERHOFF
Science-Lab - International Manager
Rodelbahnstr. 4 82223 Eichenau Germany
fenita.dyckerhoff@science-lab.de
Tel: 498141536642

COSTAS P CONSTANTINOU
University of Cyprus - Associate Professor
Learning in Science Group, 19 Ledas Str, No. 101, CY2115 Nicosia, CYPRUS
c.p.constantniou@ucy.ac.cy
Tel: 35722753758

JONTE BERNHARD
ITN, Linköpings universitet (samt FND- Svensk förening forskning i naturvetenskapernas didaktik)
Associate professor (ordförande i FND)
ITN, Campus Norrköping, S-60174 Norrköping, Sweden
jonbe@itn.liu.se
Tel: 011-363318

ANDERS JIDESJÖ
Linköping university - PhD student
Linköpings universitet: Tema vatten 581 83 Linköping Sweden
andji@tema.liu.se
Tel: +46 13 28 89 02

KARIN BÅRMAN
KVA - Development manager
karin.barman@kva.se
Tel: +46 8 6739740

SVEN-OLOF HOLMGREN
RSAS and Fysikum, Stockholm University - Professor
Stockholm University Fysikum AlbaNova University Centre SE-106 91 Stockholm
soh@physto.se
Tel: +46 8 55378622

STEPHEN PARKER
European Commission
European Commission SDME 7/83 B-1049 Brussels, Belgium
stephen.parker@ec.europa.eu
Tel: +3222958551

STUART NAYLOR
Millgate House Publishing & Consultancy - Director
30 Mill Hill Lane Sandbach Cheshire CW11 4PN, UK
stuartnaylor@millgatehouse.co.uk
Tel:+44 1270 764314

BRENDA KEOGH
Millgate House Publishing & Consultancy - Director
30 Mill Hill Lane Sandbach Cheshire CW11 4PN, UK
brendakeogh@millgatehouse.co.uk
Tel: +44 1270 764314

JUDITH SWEENEY LEDERMAN
Illinois Institute of Technology - Director of Teacher Education
3424 South State Street Chicago, Illinois 60616, USA
ledermanj@iit.edu
Tel: 312-567-3662

XIA ZHU
Linköping University / Southwest University, Chongqing, P.R.China - Professor
ITN, Linköping University, S-60174 Norrköping, Sweden
zhuxia114@yahoo.com
Tel: 013-281000

AGNETA WALLIN LEVINOVITZ
Nobel Web AB -Executive Editor
Nobel Web AB, Nobelprize.org, Box 5232, SE-102 45 Stockholm, Sweden
agneta.wallin.levinovitz@nobel.se
Tel: +46-8-6638335

NESE YILMAZ
Freie Universität Berlin – NatLab - Student
http://www.natlab.de/
nese.yilmaz@web.de
Tel: 04930 / 838 54 295