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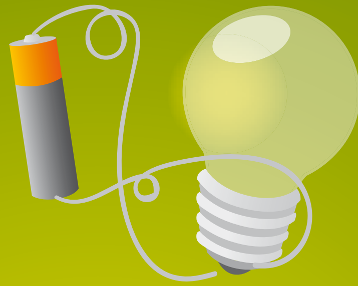

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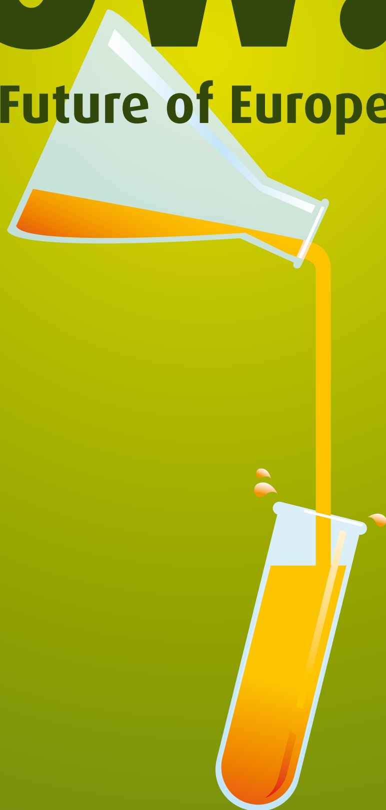
Science Education NOW:

A Renewed Pedagogy for the Future of Europe



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Science Education NOW:
A Renewed Pedagogy for the Future of Europe

High Level Group on Science Education
Michel Rocard (Chair), Peter Csermely, Doris Jorde, Dieter Lenzen, Harriet Walberg-Henriksson, Valerie Hemmo (rapporteur)

Directorate-General for Research
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\ Executive summary

In recent years, many studies have highlighted an alarming decline in young people's interest for key science studies and mathematics. Despite the numerous projects and actions that are being implemented to reverse this trend, the signs of improvement are still modest. Unless more effective action is taken, Europe's longer term capacity to innovate, and the quality of its research will also decline. Furthermore, among the population in general, the acquisition of skills that are becoming essential in all walks of life, in a society increasingly dependent on the use of knowledge, is also under increasing threat.

In consequence, the European Commission has tasked this group of experts to examine a cross-section of on-going initiatives and to draw from them elements of know-how and good practice that could bring about a radical change in young people's interest in science studies - and to identify the necessary pre-conditions.

Since the origins of the declining interest among young people for science studies are found largely in the way science is taught in schools, this will be the main focus.

In this context, whereas the science education community mostly agrees that pedagogical practices based on inquiry-based methods are more effective, the reality of classroom practice is that in the majority of European countries, these methods are simply not being implemented.

The current initiatives in Europe actively pursuing the renewal of science education through "inquiry based" methods show great promise but are not of the scale to bring about substantial impact, and are not able to exploit fully the potential European level support for dissemination and integration.

The findings and recommendations of the experts group are summarized below.

A reversal of school science-teaching pedagogy from mainly deductive to inquiry-based methods provides the means to increase interest in science.

Inquiry-based science education (IBSE) has proved its efficacy at both primary and secondary levels in increasing children's and students' interest and attainments levels while at the same time stimulating teacher motivation. IBSE is effective with all kinds of students from the weakest to the most able and is fully compatible with the ambition of excellence. Moreover IBSE is beneficial to promoting girls' interest and participation in science activities. Finally, IBSE and traditional deductive approaches are not mutually exclusive and they should be combined in any science classroom to accommodate different mindsets and age-group preferences.

Renewed school's science-teaching pedagogy based on IBSE provides increased opportunities for cooperation between actors in the formal and informal arenas.

Due to the nature of its practices, IBSE pedagogy is more likely to encourage relationships between the stakeholders of both formal and informal education. And it creates opportunities for involving firms, scientists, researchers, engineers, universities, local actors such as cities, associations, parents and other kinds of local resources.

Teachers are key players in the renewal of science education. Among other methods, being part of a network allows them to improve the quality of their teaching and supports their motivation.

Networks can be used as an effective component of teachers' professional development, are complementary to more traditional forms of in-service teacher training and stimulate morale and motivation.

In Europe, these crucial components of renewal of science teaching practices are being promoted by two innovative initiatives, "Pollen" and "Sinus-Transfer", that are proving themselves capable of increasing children's interest and attainments in science. With some adaptation these initiatives could be implemented effectively on a scale that would have the desired impact.

The level of funding required is in accordance with the scope of the funding instruments of the European Union.

Recommendation 1:

Because Europe's future is at stake decision-makers must demand action on improving science education from the bodies responsible for implementing change at local, regional, national and European Union level.

Recommendation 2:

Improvements in science education should be brought about through new forms of pedagogy: the introduction of inquiry-based approaches in schools, actions for teachers training to IBSE, and the development of teachers' networks should be actively promoted and supported.

Recommendation 3:

Specific attention should be given to raising the participation of girls in key school science subjects and to increasing their self-confidence in science.

Recommendation 4:

Measures should be introduced to promote the participation of cities and the local community in the renewal of science education in collaborative actions at the European level aimed at accelerating the pace of change through the sharing of know-how.

Recommendation 5:

The articulation between national activities and those funded at the European level must be improved and the opportunities for enhanced support through the instruments of the Framework Programme and the programmes in the area of education and culture to initiatives such as Pollen and Sinus-Transfer should be created. The necessary level of support offered under the Science in Society (SIS) part of the Seventh Framework Programme for Research and Technological Development is estimated to be around 60 million euros over the next 6 years.

Recommendation 6:

A European Science Education Advisory Board involving representatives of all stakeholders, should be established and supported by the European Commission within the Science in Society framework.

\ Introduction

In recent years, many studies have highlighted an alarming decline in young people's interest for key science studies and mathematics. Despite numerous projects and actions that are being implemented to reverse this trend, the signs of improvement are still modest. Unless more effective action is taken, Europe's longer term capacity to innovate, and the quality of its research will also decline. Furthermore, among the population in general, the acquisition of skills that are becoming essential *in all walks of life*, in a society increasingly dependent on the use of knowledge, is also under increasing threat.

In consequence, the European Commissioners responsible for Research and for Education and Culture have tasked this group of experts, chaired by Michel Rocard, to examine a cross-section of innovative on-going initiatives and to draw from them elements of know-how and good practice that could bring about a radical change in young people's interest in science studies - and to identify the necessary pre-conditions. Since the origins of the declining interest among young people for science studies are found largely in the way science is *taught* in primary and secondary schools, this is the main focus.

The group did not set out to "re-invent the wheel" nor to undertake a comprehensive evaluation of teaching practice nor even to conduct a comparative analysis across Member States. The substance of the group's mandate was succinct: can change be brought about, and can specific concrete examples be identified that show how effective action can be taken? The group recognises the possible shortcomings of this approach given the time constraints under which it was to complete its task; however, the group sought and received direct contact with the coordinators of a number of promising initiatives as well as meeting with representatives from several national ministries responsible for research and education policies (see Appendix1).

What is meant by "Science"?

Science, in the broadest sense, refers to any system of knowledge which attempts to model objective reality. In a more restricted sense, science refers to a system of acquiring knowledge based on the scientific method, as well as to the organized body of knowledge gained through such research.

In the context of this report the choice was made to use the word "science" to refer more precisely to all of physical sciences, life sciences, computer science and technology, and for the purposes of this report includes mathematics - subjects that are commonly taught at primary and secondary schools in most European countries.

\ 1. Background analysis

Observation 1
A major threat to the future of Europe: science education is far from attracting crowds and in many countries the trend is worsening.

Recent work by the OECD[1] indicates that over the last decade, in many European countries, the number of young people entering universities is increasing but they are choosing study fields other than science and in consequence the *proportion* of young people studying science is decreasing (see appendix 2). Moreover, in certain key areas such as mathematics and physical sciences - areas that are at the heart of sustainable socio-economic development – even the absolute number of students is falling in some countries. Indeed, some universities in Europe are reporting a halving in the number of students enrolled in physics since 1995.

When looked at from a gender perspective the problem is even worse as, in general, girls are less interested in science education than boys. As shown by the OECD Programme for International Student Assessment (PISA) study, at 15 years old, there is already a strongly gendered pattern and in most countries females are significantly less interested in mathematics than males. This pattern of gender differences continues with women choosing fewer academic studies in math, science and technology (MST). In fact, at the European level, girls account only for 31% of MST graduates (2004).

Observation 2
A general consensus on the crucial importance of science education.

With over 80% of Europeans (Eurobarometer 2005) considering that "young people's interest in science is essential to our future prosperity" it is surprising that fewer young people are taking up key science studies. This lack of interest shown by young people for science learning is truly an issue of great importance, as science education is vital for:

\ Providing all citizens with both science literacy and positive attitude towards science.
There is obviously a need to prepare young people for a future that will require good scientific knowledge and an understanding of technology. Science literacy is important for understanding environmental, medical, economic and other issues that confront modern societies, which rely heavily on technological and scientific advances of increasing complexity.

However, the key point is equipping every citizen with the skills needed to live and work in the knowledge society by giving them the opportunity to develop critical thinking and scientific reasoning that will enable them to make well informed choices. Science education helps fighting misjudgements and reinforcing our common culture based on rational thinking.

\ Ensuring that Europe is training and retaining sufficient numbers of high level scientists and engineers needed for its future economic and technological development.
Availability of highly qualified science and technology professionals is a key factor for the establishment, import and success of high-tech industry in the European Union. Europe should be in a position to anticipate

[1] *Evolution of Student Interest in Science and Technology Studies – Policy Report;* Global Science Forum, OECD, May 2006

rather than follow demand as it moves towards a knowledge based economy. Furthermore the link between the local availability of a highly skilled workforce and investment decisions as regards, for example, the location of R&D facilities is very apparent in global economic terms.

Against this background, European policy makers have not remained indifferent and have subscribed to numerous declarations as to the crucial importance of science education.

- **The Lisbon summit placed the spotlight on the need for European countries to act together to turn Europe into the most competitive knowledge-based economy in the world. The summit recognised the need for action: action to foster a knowledge-based society and action to promote education and training.**
  At the Lisbon summit of 2000 Heads of State and Government of the European Union recognised that Europe's future prosperity is dependent on creating an environment in which the use of knowledge becomes the cornerstone of socio-economic development. A succession of European summits from Lisbon to Barcelona in March 2002 ended with the establishment of a European Strategic goal to increase the average European share of GDP dedicated to research up to 3% by 2010. This means increasing the number of researchers by half a million and the overall research personnel by 1.2 million.

- **In its report to the European Council on the concrete future objectives of education and training systems (2001), the Education Council stated the need to "increase the general levels of scientific culture within society".**
  Science was clearly promoted as a need for all citizens: "Expertise in science and technology is increasingly called upon to contribute to public debate, decision making and legislation. The citizen needs to have a basic understanding of mathematics and science if she/he is to understand the issues, and make informed - even if not technical – choices."

- **This affirmation of the crucial importance of science education was renewed and strengthened in the 18-months Programme of the German, Portuguese and Slovenian Presidencies.**
  Their programme states explicitly that "the presidencies will endeavour to foster a better environment and better conditions for research activities by addressing issues such as: (...) reinforcement of human resources in science and technology; promoting scientific and technological education and culture".

- **The Decision of the European Parliament and of the Council concerning the Seventh Framework Programme of the European Community for research, technological development and demonstration activities provides a basis for support for collaborative action.**
  Under the Science and Society part it calls for the "creation of an open environment which triggers curiosity for science in children and young people, *by reinforcing science education at all levels, including schools*, and promoting interest and full participation in science among people from all backgrounds".

Observation 3
The origins of this situation can be found, among other causes, in the way science is taught.

\ The reasons why young people do not develop interest for science are complex; however, there is firm evidence that indicates a connection between attitudes towards science and the way science is taught.

The 2005 Eurobarometer study on "***Europeans, Science and Technology***" reports that only 15% of Europeans are satisfied with the quality of science classes in school. In the 2001 survey, the sample population interviewed on the causes for declining interest in scientific studies and careers ranked foremost the fact that "science classes at school are not sufficiently appealing" (59.5%). In the same survey 60.3% of Europeans state that "the authorities should try to resolve this situation".

The report recently issued by the OECD "***Evolution of Student Interest in Science and Technology Studies***" identifies the crucial role of positive contacts with science at an early stage in the subsequent formation of attitudes towards science. However, the study also highlights that, while young children have a natural curiosity of these subjects, traditional formal science education can stifle this interest and therefore can have a negative impact on the development of attitudes towards learning science.

Among the causes identified, it is noted the uncomfortable situation of some primary school teachers that are requested to teach subjects in which they lack sufficient self-confidence and knowledge. They often choose a traditional 'chalk and talk' approach with which they feel more comfortable and avoid inquiry-based methods that require them to have deeper integrated science understanding. The focus is therefore on memorizing rather than on understanding; and furthermore, heavy workloads are reported to leave little time for meaningful experiments.

The report recommends that "teaching should concentrate more on scientific concepts and methods rather than on retaining information only" and that stronger support should be given to teacher training in science.

In its report "***Europe Needs More Scientists***", the High Level Group chaired by Prof. José Mariano Gago analyses problems found with science teaching. Again similar conclusions are offered: science subjects are often taught in a much too abstract way, "*It is abstract because it is trying to put forward fundamental ideas, most of which were developed in the 19th century, without sufficient experimental, observational and interpretational background*" and without "*showing sufficient understanding of their implications*". Science education also often fails to provide young people with "*the opportunity of a cumulative development of understanding and interest*" and is in strong danger of "*being excessively factual because of the explosion in scientific knowledge and the 'adding-on' of topics to an already excessive content base*". As a result, it comes of no surprise that "*students have a perception of science education as irrelevant and difficult*".

\ While most of the science education community agrees on the fact that pedagogical practices based on inquiry-based methods are more effective, the reality of classroom practice is that in most European countries, actual science teaching does not follow this approach.

What are Inquiry-Based Science Education (IBSE) and Problem-Based Learning (PBL)?

Historically, two pedagogical approaches in science teaching can be contrasted.

The first one, traditionally used at school, is the "Deductive Approach". In this approach, the teacher presents the concepts, their logical – deductive – implications and gives examples of applications. This method is also referred to as 'top-down transmission'. To be used, the children must be able to handle abstract notions, what makes it difficult to start teaching science before secondary education. In contrast, the second has long been referred to as the "Inductive Approach". This approach gives more space to observation, experimentation and the teacher-guided construction by the child of his/her own knowledge. This approach is also described as a 'bottom-up' approach.

The terminology evolved through the years and the concepts refined, and today the Inductive Approach is most often referred to as Inquiry-Based Science Education (IBSE), mostly applied to science of nature and technology.

By definition, inquiry is the intentional process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments (Linn, Davis, & Bell, 2004).

In mathematics teaching, the education community often refers to "Problem-Based Learning" (PBL) rather than to IBSE. In fact, mathematics education may easily use a problem-based approach while, in many cases, the use of experiments is more difficult. Problem-Based Learning describes a learning environment where problems drive the learning. That is, learning begins with a problem to be solved, and the problem is posed in such a way that children need to gain new knowledge before they can solve the problem. Rather than seeking a single correct answer, children interpret the problem, gather needed

information, identify possible solutions, evaluate options and present conclusions. Inquiry-Based Science Education is a problem-based approach but goes beyond it with the importance given to the experimental approach.

In this report, it will be referred to IBSE as inquiry-based and problem-based science education.

In most European countries, science teaching methods are essentially deductive. The presentation of concepts and intellectual frameworks come first and are followed by the search for operational consequences, while experiments are mainly used as illustrations. A change is under process in some countries towards more extensive use of inquiry-based methods however, the mainstream still remains mainly deductive.

Observation 4
Many on-going initiatives in Europe actively contribute to the renewal of science education. Nevertheless, they are often small-scale and do not actively take advantage of European support measures for dissemination and integration.

\ Many initiatives may be found with the science education community.

First of all, many **dynamic teachers**, both at primary and secondary levels of education have developed multiple innovative practices. These projects often involve and are supported by the local community: parents, companies, scientists, researchers, university students. Funding, when available, is sourced from various sources with local authorities – cities and regions – often providing a large part of the necessary resources.

Other very significant actors are the **out-of-school science education organisations** with a particular role played by cultural partners, science centres, science museums and associations for the promotion of sciences, often organising fairs and events.

However, these initiatives often **rely on the motivation and goodwill of a few individuals**, resulting in budgetary pressures, limited ability to scale-up projects, and putting at risk their permanence and sustainability.

Furthermore, due to budget and time constraints, the evaluation of initiatives is often limited. The interconnections between initiatives are very rare which effectively eliminates the possibilities for scaling-up and for the dissemination of the new ideas: the dynamics of "economy of scale" and the huge potential for real impact are simply not being exploited.

\ In this insufficiently organized context, Europe has a major role to play in the identification, integration and dissemination of good practices.

\ 2. Mandate/work carried out

There is a clear rationale to take action, but what specific concrete action can be taken in Europe to improve the way science teaching is approached in primary and secondary schools? Fortunately there are many in-depth studies that have already been carried out to understand the causes of the problem and to suggest potential leads for action. The objectives of this report are, therefore, specifically to:

\ **Analyse a selection of the ongoing collaborative science education initiatives within the EU in order to identify effective and innovative techniques that show potential for increasing interest towards science and which could be used as models for future policies;**

\ **Draw from this analysis a reduced set of concrete policy recommendations that would ensure that their experience is used, valorised and disseminated across Europe.**

As a basis for the analysis of initiatives, the following criteria were adopted:

\ ***The earlier the better:*** **science teaching at primary school has a strong long-term impact. Primary school corresponds to the time of construction of intrinsic motivation, associated with long-lasting effects, it is the time when children have a strong sense of natural curiosity and it is the right time to tackle gendered patterns.**

\ **Priority given to *actions focused on schools*, as this allows each child to benefit from a longer exposure to the action and has a more systematic effect on large groups and takes a better care of the most deprived children.**

\ **Reduced need of specific materials for *cost sustainability*.**

\ **Priority given to initiatives designed to reach a *critical mass* of young people and at the same time *respect diversity*.**

\ ***Teachers are the cornerstone of any renewal of science education.*** **Teachers' skills (pedagogy and content), self confidence, motivation and integration in a larger community are crucial.**

\ **Priority given to initiatives that include a large *diversity of practices in science teaching* to respond to the diverse needs of children: problem based inquiry process; hands-on/minds-on activities; teamwork; independent work on open-ended questions; trans-disciplinary activities; showing relevance of science content.**

\ 3. Findings

Finding 1
A reversal of school's science-teaching pedagogy from mainly deductive to inquiry-based methods provides the means to increase interest in science.

\ Inquiry-based methods proved their efficacy in science learning at primary level with increasing both children's interest and teachers' willingness to teach sciences.

IBSE emphasizes curiosity and observations followed by problem solving and experimentation. Through the use of critical thinking and reflection, students are able to make meaning out of gathered evidence.

Moreover, IBSE is perfectly adapted to the younger audience of primary schools. This is a key advantage as starting science education at this age allows making the best use of this 'curiosity golden age'.

In addition, inquiry-based methods provide children with opportunities to develop a large range of complementary skills such as working in groups, written and verbal expression, experience of open-ended problems solving and other cross-disciplinary abilities.

\ IBSE methods are also effective in secondary education.

However, this approach faces more reluctance from teachers as they often consider it as time-consuming leading to conflict with the requirement to deliver curricula content.

\ IBSE techniques are effective on students groups for which traditional deductive methods are ineffective.

Using IBSE methods has been shown to have a positive impact on students' attainments, with an even stronger impact on the students with lower levels of self-confidence and those from disadvantaged backgrounds. This allows science education to be inclusive, which is of utmost importance in a knowledge society where being scientifically illiterate is of such high cost for both the individual and the society in general.

\ Science Teaching based on inquiry-based methods does not mean giving up the ambition of excellence.

Indeed, these practices may be used to create the most favourable conditions and attitudes (interest, self-confidence) to reach the deepest levels of knowledge for the most talented, creative and motivated students.
Moreover, IBSE allows for the development of crucial intellectual skills in addition to knowledge acquisition, the basis for all types of higher level of education.

\ Finally, the two approaches are not mutually exclusive and can and should be combined in any science classroom to accommodate for different kinds of scientific topics, different mindsets and age groups preferences.

An example of what is meant by IBSE (source: Pollen)

Experimentation does not mean complicated experiments involving sophisticated and costly equipment. Most experiments carried on at schools, under the POLLEN project, for example, are in fact very simple and require nothing more than ordinary, inexpensive equipment.

Imagine that a teacher wants children to work on the "hourglass" (a well known and simple timing device) by trying to identify the parameters that determine how long the sand will take to fall. Several different options exist:

- A. The teacher shows the students an hourglass and states that the time required for the sand to run out depends on [...] and that the students are going to be able to see this for themselves. This method is akin to the traditional, so-called lecture-type format, in which the teacher is content to pronounce results, and it *is worlds away from an inquiry-based approach*.
- B. The students observe, draw and describe an hourglass set on the teacher's desk, then the teacher asks them what factors determine how long it takes for the sand to run out. This question is meaningful to most of the students, but not to all of them.
- C. After having observed an hourglass, the teacher asks the students how to increase or decrease the time required for the sand to run out. Here, the child starts to come up with questions as he or she looks for a way to make something happen.
- D. The teacher sets out at least three hourglasses, one of which takes much more time than the others to run out of sand. The students, divided into groups, observe, draw and describe the hourglass they have in front of them. Considering the distinctive features of the hourglasses set before them, one will continue to have sand running, while the others will have stopped. The children will take notice of this and instinctively wonder what makes that hourglass run longer. This is one way (though not the only one) to have children take ownership of a problem and *demonstrates why IBSE can be so effective*.

Children have very good recollection of the experiments they conduct themselves but to be effective they need to reach this realisation themselves through experiments they have come up with themselves. In the hourglass example, the children might consider the amount of sand, the width of the glass, the size of the sand particles, the size of the hourglass, the presence of certain colour additives, etc. There is nothing quite like leaving the children to carry out the experiments themselves so that they realise they can achieve useable results only if they adjust one parameter at a time (keeping the others constant) and that, taking that into consideration, the size of the hourglass does not play an important part.

\ A renewal of pedagogy based on an increased use of the IBSE approach may be an effective way to increase girls' interest, self-confidence and participation in science activities.

The group found that in initiatives in which the IBSE approach is being used, girls participate more enthusiastically in the activities and develop a better level of self-confidence than with the traditional approaches to teaching science.

Finding 2
Renewed school's science-teaching pedagogy based on IBSE provides increased opportunities for cooperation between various actors in the formal and informal arenas.

Due to the nature of its practices, IBSE and problem-based pedagogy are more likely to encourage relationships between the stakeholders of both formal and informal education. And it creates opportunities to involve firms, researchers, universities, local actors such as cities, associations, parents and other kinds of local resources.

The initiatives this group identified as successfully promoting IBSE are often organized and supported at the local level, especially at cities level, even when they are also part of a broader organisation.

Finding 3
Teachers are key players in the renewal of science education. Among other methods, being part of a network allows them to improve the quality of their teaching and supports their motivation.

Teachers report that isolation is often one of the main negative elements of their professional practice and is clearly very bad for morale and motivation. Being part of a professional network, however, can provide them with opportunities to enrich their practices and professional context through cooperation within and between schools, collaborative reflection, development and evaluation of instruction, exchange of ideas, materials and experiences, quality development, cooperation between teachers and researchers and support and stimulation from research.

In consequence, networks can be used as an effective component of teachers' professional development, and are complementary to more traditional forms of teacher training.

Finding 4
In Europe, these crucial components of renewal of science teaching practices are being promoted by two innovative initiatives, "Pollen" and "Sinus-Transfer", that are proving themselves capable of increasing children's interest and achievements in science. With some adaptation, these initiatives could be implemented effectively on a scale that would have the desired impact.

\ Pollen is already international and includes 12 European countries.

Pollen operates in 12 cities in 12 countries[2] of the European Union, targeting schools in cities to promote inquiry-based teaching

[2] Belgium, Estonia, France, Germany, Hungary, Italy, the Netherlands, Portugal, Slovenia, Spain, Sweden, and the United Kingdom.

techniques that have been demonstrated to work both in France ("la main à la pâte") and, originally, in the United States. The initiative, originally focusing mainly on primary schools, is now expanding into the secondary level. Pollen is supported through a Community grant of 1.75 million euro under the Science and Society part of the Sixth Framework programme for research, technological development and demonstration activities.

Participating cities are provided with teacher training, specific resources for the classroom (learning units, teachers' guides, material and resources database, information booklets...), as well as a web support resource. Exchanges between teachers, scientists and pedagogical experts are strongly encouraged and the scientific community engagement provides support to teachers.

The positive results arising from Pollen are many. The methods used by Pollen have proven to raise primary teachers' interest, self-confidence and skills in science teaching and therefore the quality and quantity of science teaching sessions. Pollen also increases children's interest in science learning activities. The gender gap is reduced as a higher share of girls tends to actively participate in science-related activities. The increased interest and participation is even stronger with weaker children and those from disadvantaged backgrounds.

Furthermore, Pollen has proved itself capable of obtaining strong support from both community and scientific institutions (Academies of Sciences, higher education institutions).

In addition, Pollen has already showed potential for scaling up. Indeed, after having been tried at local levels, it has already been scaled up twice (at the national French level first, then at the European level), with federating national and local pre-existing initiatives (in United Kingdom, Portugal and Sweden).

The specificity and strongest point of Pollen is probably its ability to disseminate usable techniques while at the same time respecting the diversity of local contexts: indeed, its methods are particularly adapted and effective in this context.

\ Sinus-Transfer has already been extensively tested in Germany

Sinus-Transfer provides secondary school teachers with tools to change their pedagogical approach on science teaching. It includes and emphasizes the importance of using scientific inquiry and experimental approaches. The focus is put on teachers' professional development: Sinus-Transfer is characterized by a long-term, school-based and collaborative approach that is focused on students' learning. It relates to didactical problems in science classrooms and stimulates teachers to evaluate and reflect their teaching in a process of continuous quality development. During the process a strong cooperation is established between teachers within and between schools as well as between researchers and practitioners.

The impact of Sinus-Transfer is very positive. The evaluations conducted show significant positive impact on student attainment, especially for weaker students. Large numbers of teachers have shown strong support and enthusiasm for this initiative.

\ Two initiatives: common key points

Both projects propose an ***innovative pedagogical approach***, while not having any intention of changing curricula or content, as defined by the relevant authorities.

Moreover, both promote ***a pedagogy using an inquiry-based approach*** that succeeds to develop excitement around science. They both present the processes and methods of science together with its products and promote a wide range of practices including inquiry based activities, hands-on/minds-on and group projects.

In their organisation too, they show strong similarities. Their action is based on the training, support and motivation of teachers, providing them with pedagogical materials and opportunities to be part of a network while respecting their independence. Moreover, both initiatives promote rich and long-term links with the different stakeholders (students, teachers, parents, scientists, engineers, entrepreneurs, R&D firms).

Finally, ***they both focus on dissemination***, as exemplified by their names "Pollen" & "Transfer".

\ Pollen and Sinus-Transfer: How might the EU assist them in scaling up and disseminating throughout Europe?

Pollen could easily be scaled-up to increase the number of participating cities and countries. There is also a crucial need for a stronger input in teacher training requiring a greater commitment from local education authorities. Other high priority actions aimed at dissemination would include the adaptation of the existing materials to national languages and contexts, the organisation of a more systematic evaluation of impact, improving the adaptation of the IBSE method to secondary education and developing stronger international student and teacher networks.

As regards Sinus-Transfer, priority should be given to developing the concept outside of Germany in collaboration with other national programmes. The first steps towards internationalisation would be to translate and adapt its methods and contents as well as to develop networks on a European level. An important aim of these networks would be to foster exchange and collaboration between crucial subgroups that are concerned with science teaching and science teacher professional development in Europe: science teachers (schools), students, members of support systems (e.g. teacher training institutions, Universities, administration), international experts for science education (e.g. educational researcher, science educators).

\ 4. Recommendations

The importance for Europe of having a well science-educated population is beyond doubt. Given that innovative pedagogy has been developed and tested at a relatively large scale, and that it has proved to be successful, there is equally no doubt that specific and urgent actions can be taken. The following recommendations outline a set of such actions.

Recommendation 1
Because Europe's future is at stake decision-makers must demand action on improving science education from the bodies responsible for implementing change at local, regional, national and European level.

This issue should be given a central place in the Lisbon Strategy Renewal and be considered as an imperative priority. Member States should more actively promote and fund initiatives that contribute towards the renewal of pedagogy in science education.

Recommendation 2
Improvements in science education should be brought about through the new forms of pedagogy: The introduction of the inquiry-based approaches in schools and the development of teachers' networks should actively be promoted and supported.

Teachers must remain the key players in the process of reform, but need better support that complements professional training and stimulates morale and motivation.

Recommendation 3
Specific attention should be given to raising the participation of girls in key school science subject, and to increasing their self-confidence in science.

Priority should be given to initiatives that specifically include gender issue among their objectives including the presentation of role-models for girls in the form of successful women scientists, engineers and business-women in the R&D field.

Recommendation 4
Measures should be introduced to promote the participation of cities and the local community in the renewal of science education through collaborative actions at the European level aimed at accelerating the pace of change through the sharing of know-how.

Collaborative pilot actions conducted at the European level demonstrate that Community support can be instrumental, not only in accelerating the pace of change, but also in enriching the newly developed techniques. The participation of all stakeholders, including experts of science education, teachers, students, parents, scientists, engineers and their organisations, including schools, teacher and parent organisations, universities, research institutes, science museums, science centres, firms and local authorities is a key factor for the success.

Some initiatives were promoted by organisations that work on informal science education. Cities should use these initiatives in order to foster and strengthen the links between formal and informal (curricular and extracurricular) science education. It would be useful if resources, including human resources, were dedicated to these links at local level.

Recommendation 5
The articulation between national activities and those funded at the European level must be improved and the opportunities for enhanced support through the instruments of the Framework Programme and the EAC programmes to initiatives such as Pollen and Sinus-Transfer should be created.

The group is not in a position to quantify exactly how much extra funding should be allocated to this area, but notes that on the basis of the budgets of the activities that were examined, a budget of 60 million euros over six years is not an unreasonable estimation as regards a Community contribution.

Recommendation 6
A European Science Education Advisory Board involving representatives of all stakeholders, including experts of science education, teachers, students, parent organisations, scientists, engineers and firms, should be established and funded by the European Commission within the framework of the above instruments.

- **The Advisory Board should suggest ways and means to encourage the development of cross-disciplinary and multi-national self-organization of science-interested students in Europe.**
- **The Advisory Board should monitor the development of new initiatives aiming at developing the use of inquiry-based methods in science teaching and support their cooperation and integration at a European level, so as to avoid replication of multiple small scale projects, allowing them to benefit from synergies and knowledge sharing.**
- **The Advisory Board should continue to support research and development of projects that bring innovation to science teaching throughout Europe. It should monitor innovative teaching practices and other new developments in science education, including connections to the science education community.**
- **The Advisory Board should organise the evaluation of initiatives.**

\ 5. Conclusion

Although setting curricula remains the prerogative of the relevant bodies and ministries within each Member State, much could be done at the European level that would have a substantive impact on the way that science is taught: actions to promote the adoption of new teaching techniques; actions aimed at helping teachers present the subject in an exciting and relevant manner; and actions that stimulate inquiry-based learning among young people.

The revision and repositioning of science teaching in Europe must become a priority area for European policy makers. Not only is it essential for the development of individual European countries but it is also essential if European Union Members States are to collectively make clear inroads towards meeting the Lisbon objectives.

The group has had the opportunity to study many high quality initiatives which actively contribute to the development of interest in science and the involvement of young people in these fields of study. The specificity of both Pollen and Sinus-Transfer is that they promote **a change in the pedagogical approach used to teach science**. Additionally these initiatives provide opportunities for the establishment of a European network of science education teachers, which appears to be a key factor in promoting excellence.

Pollen and Sinus-Transfer are significant and adequate initiatives. For instance, Pollen demonstrated how its approach can be applied in different national settings. Pollen partners while following the same philosophical approach (inquiry based learning) have nonetheless implemented it in different ways as a function of local conditions, thus demonstrating good flexibility.

\ 6. Appendices:

Appendix 1:

List of interviewees from national ministries responsible for research and education policies

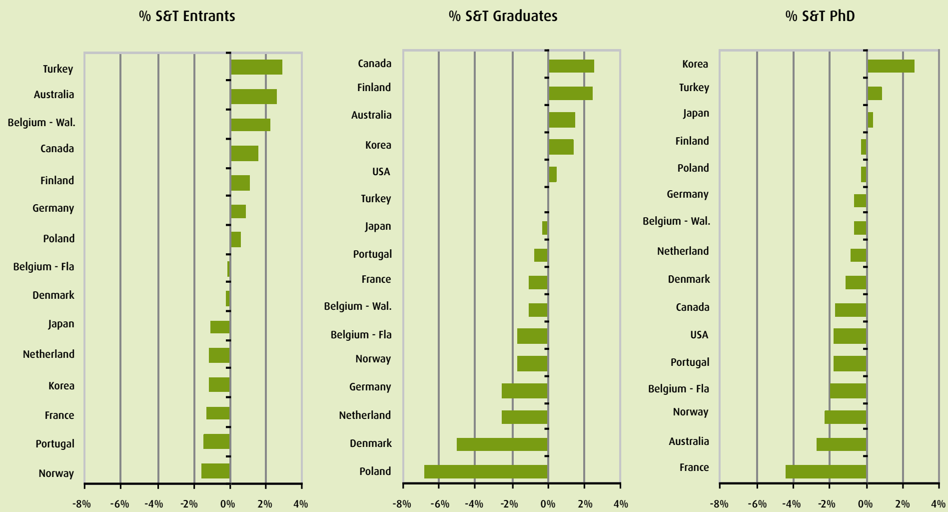
\ Ms Elles Rinkel, Ministry of Education, Culture and Science (The Netherlands)
\ Mrs Kornelia Haugg, Ministry of Education (Germany)
\ Mr Werner Klein, Ministry for Education and Women of the Land Schleswig-Holstein (Germany)
\ Mme Florence Robine, Ministère de l'Education Nationale, de l'Enseignement Supérieur et de la Recherche (France)
\ Mr Max Kesselberg, Ministry of Education and Research (Sweden)
\ Mr Thomas Overgaard Jensen, Head of Section at the Danish Ministry of Science (Denmark)
\ Ms Ana Noronha, National Agency for Scientific and Technological Culture (Portugal)

List of interviewees responsible for coordinating selected actions supporting science education in schools

\ Prof. Dr. Manfred Prenzel representing the project SINUS
\ Mr Cyrille Raymond and Mr Philippe LECLERE representing the project GRID
\ Ms Catherine Franche representing the ECSITE
\ Professors G. Charpak, Pierre Léna and Dr David JASMIN representing the project Pollen
\ Mr Claus Madsen and Ms Silke Schumacher representing EIROFORUM
\ Mr Marc Durando respresenting EU Schoolnet

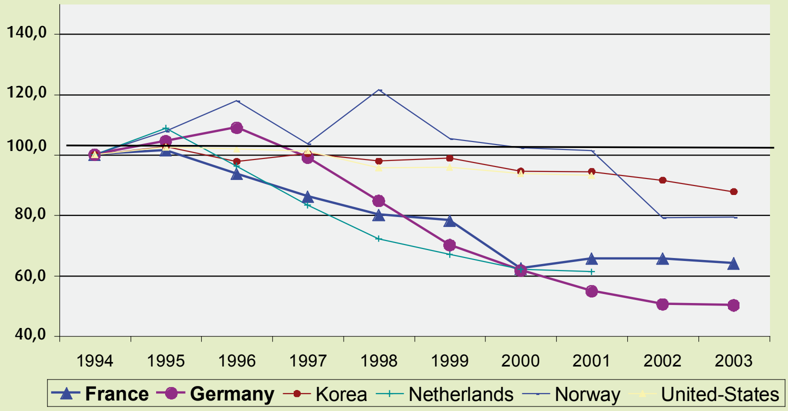
Appendix 2:

Figures from *Evolution of Student Interest in Science and Technology Studies – Policy Report*; Global Science Forum, OECD, May 2006

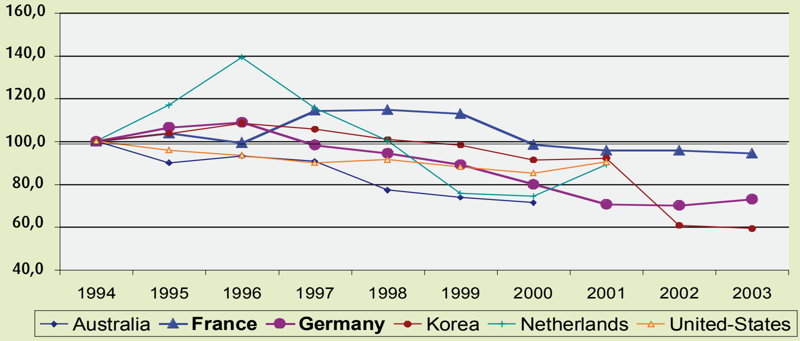


Average annual change in the share of ST students as a percentage of the total number of students (1993-2003)

Total number of physical science graduates in selected countries index 100: 1994



Total number of graduates in mathematics and statistics in selected countries index 100: 1994



Appendix 3:

Females as a proportion of all MST graduates and students (source: DG EAC)

Females as a proportion of all MST graduates	
	2004
EU27	31.2
Belgium	25.3
Bulgaria	41.7
Czech Republic	29.4
Denmark	32.3
Germany	23.8
Estonia	40.6
Ireland	31.3
Greece	40.5
Spain	30.3
France	:
Italy	36.8
Cyprus	37
Latvia	32.7
Lithuania	35.6
Luxembourg	:
Hungary	28.4
Malta	:
Netherlands	19.5
Austria	22.6
Poland	33.3
Portugal	41
Romania	38.5
Slovenia	25
Slovakia	35.3
Finland	:
Sweden	33.9
United Kingdom	31.2
Croatia	33.2
Macedonia	45.2
Turkey	30.4
Iceland	38.1
Liechtenstein	50
Norway	24.5
Japan	14.6
United States	30.8

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In recent years, many studies have highlighted an alarming decline in young people's interest for key science studies and mathematics. Despite the numerous projects and actions that are being implemented to reverse this trend, the signs of improvement are still modest. Unless more effective action is taken, Europe's longer term capacity to innovate, and the quality of its research will also decline. Furthermore, among the population in general, the acquisition of skills that are becoming essential in all walks of life, in a society increasing dependent on the use of knowledge, is also under increasing threat.

In consequence, the European Commission has tasked this group of experts to examine a cross-section of on-going initiatives and to draw from them elements of know-how and good practice that could bring about a radical change in young people's interest in science studies - and to identify the necessary pre-conditions.

Since the origins of the declining interest among young people for science studies are found largely in the way science is taught in schools, this is the main focus of this report.

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