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A renewal of science education in Europe

Views and Actions of National Academies

Analysis of surveys conducted in 2010 and 2011

A report of the ALLEA Working Group Science Education

(IAP Science Education Programme Regional European Council)

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The European Federation of National Academies of Sciences and Humanities

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Views and Actions of National Academies

A report of the ALLEA Working Group Science Education

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(IAP Science Education Programme regional European council)

«As citizens, science helps children develop the mental and moral predispositions to imagination, humility, rigour, curiosity, freedom and tolerance – all essential ingredients for peace and democracy » InterAcademy Panel (IAP), Mexico, 4 December 2003

Analysis of surveys conducted in 2010-2011

With the participation of Working Group members

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PRELIMINARIES

ALLEA (ALL European Academies) is the European Federation of 53 national academies of sciences and humanities from 40 countries. Its Working Group on science education, with delegates from currently some 25 academies, functions also as the regional European council of the science education programme of IAP (InterAcademy Panel), the global network of science academies. This science education programme is structured in four regional networks that gather member academies respectively located in Europe, Africa, the Americas and Asia. In this report, the European part of this structure is referred to as "ALLEA Working Group science education / IAP SEP regional European council", or simply as "the Working Group" (abbreviated: WG).

The present report provides a survey conducted by this WG of the activities of European National Academies and of some pilot projects by other parties, all aimed at advancing reform in science education. It describes different modes of intervention these actors have used to stimulate and advance debates and activities, typically involving leading scientists in support of this transformation. Seeking to establish measures of impact of such pilot projects in inquiry-based science education (IBSE) across Europe, examples are given for interactions between activities of National Academies and IBSE-related projects supported by the European Commission Framework Programme (which often also include mathematics and technology) as well as by others. Interventions include informal science events and specific offers attracting young people to science; support for teacher training; promotion of IBSE; writing analytical reports for the use of policy makers; interacting with their national and locally active educational authorities and with the corporate sector on possible improvements and new collaborations in the pursuit of better science education.

The report is distilled from three separate surveys conducted for different purposes in the course of 2010/11, one among all 53 Member Academies of ALLEA and the other two targeting primarily the members of the WG. The three surveys did not comprise questions that would yield data proper to quantitative analysis. Instead, questions solicited, to different degrees, short narratives about achievements and obstacles (both perceived and factual), networking and peer learning, as well as the role of leading scientists in supporting teachers and teacher trainers, thereby instilling or keeping (or simply providing an example for) the passion for science and technology as the IBSE approaches seek to kindle among the young. The material presented in this report has been compiled and re-arranged so that the short profiles give information about two points:

1. *Intentions:* views and interventions of national academies from across Europe in support of reforms in science education, with special attention being paid to efforts in the field of IBSE;
2. *Impact:* interactions with the national education system of such interventions of the academies (or, occasionally, of other actors at national level), including pilot projects financially supported by the European Commission.

The report should be helpful at the same time for *assessing past actions* of academies and for *building prospective actions* in each country and at European level concerning the role of European academies as a group. It ends with a number of conclusions and recommendations which aim at a better interaction between the leaders of the scientific community – represented by the national academies – and stakeholders in politics, society and business. The aim is to develop a joint roadmap for action combining intellectual, political and financial resources in order to renew science education through IBSE, both across Europe, by interventions at the level of the various national educational systems, and beyond, for example through external actions of the European Union as part of their neighbourhood and development policies.

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Abstract

ALLEA is the European Federation of 53 National Academies of Sciences and Humanities from 40 countries. Its Working Group on Science Education with delegates from, currently, some 25 Academies functions as the European Regional Council of the science education programme of IAP (InterAcademy Panel).

In 2010/2011, the WG conducted a survey that is presented in this report. The report describes some interventions of European National Academies to advance reform in science education, typically drawing on the support of leading scientists. The survey sought to identify the impact of pilot projects in inquiry-based science education (IBSE) across Europe; examples are given in this report for interactions between activities of National Academies and IBSE-related projects funded by the European Commission Framework Programme and by national and private funders.

The report also comprises a number of conclusions and recommendations which aim at a better interaction between the leaders of the scientific community – represented by the national academies – politics, society and business, both in the various national educational systems in Europe and as part of the external action of Europe through the neighbourhood and development policies.

A. EXTENDED SUMMARY

The task of transforming science education in Europe is daunting, with ca. 1 Million primary school teachers and some 100.000 secondary school teachers requiring additional in-service training. But the process has been launched, is making progress and will not likely be interrupted**.** Focusing on the activities of the national academies and their partners in addressing this challenge, the present report gives an overview of the perception of science and science education over the last fifteen years and the birth of the efforts at a renewal of science education. National Academies have a strong and long-standing commitment to promoting science literacy in their countries, and they have scaled up their efforts for a better formal and informal science education, especially by supporting inquiry-based approaches in schools, sometimes with the help of European Union co-funded programmes, and often in alliance with educational authorities and influential partners in the corporate sector.

A DECLINING APPETITE FOR SCIENCE –

SOON A SHORTAGE OF HIGHLY SKILLED SCIENTIFIC WORK FORCE?

The decline of interest in and the ambiguous attitudes towards science in their countries has become a concern for all Academies of sciences. Across Europe, they notice the painful mismatch of technologically advanced societies with often little, if any, understanding among the general public of much of the underlying science, and with often little or no desire to actively participate in or support the advancement of science and technology (S&T). While the S&T sector still offers career prospects that are attractive in terms of salaries, positions in public sector research organizations are growing scarcer. In many countries, scientists and engineers struggle with a problem of a skewed image and decreasing public recognition. All these factors let a career in science appear an uncertain choice for students: overall, we observe a stagnant or decreasing population of students taking graduate degrees in science. Worrying signs of a lack of Science Technology, Engineering and Mathematics (STEM) educated students have been identified by a variety of stakeholders in their respective domains, who warn of a possible shortage of highly-skilled scientific and technological staff in the labour market.

The fear that education systems might not produce sufficient S&T graduates, scientists, engineers and technicians, has led many academies - irrespective of the specificities of national situations - to demand that authorities take measures to reform science education and to make careers in science more appealing. This issue has been attracting the interest of leading scientists and political decision-makers. In some contexts, commentators have not shied away from speaking of a looming national crisis: the current trend - if not dealt with - risks imperilling the future of countries as full members of a European knowledge-based society.

Yet, the media echo to the ringing of alarm bells has been mitigated in many countries; the many in-depth reports and numerous round tables, often organised by the very academies or by educational authorities, have not yet been sufficient to fully sensitise the general public to this topic. As a consequence, decision makers in politics and public administration in some countries felt no need to heed the warning signals, even where the results of international assessment and benchmarking programmes leave much to be desired.

WHY INQUIRY-BASED SCIENCE EDUCATION?

The 2007 so-called 'Rocard report' entitled "Science Education NOW: A renewed Pedagogy for the Future of Europe", commissioned by the then Directorate General Research "Science, Economy, Society", described inquiry-based science education (IBSE) as a possible solution to the observed lack of interest for science. Yet, it must be recognised that the positive aspects of IBSE pilot experiences made by students, teachers, parents and communities do not easily translate into a general and systemic change of school pedagogy. But by the same token, a consensus is growing that such a profound change in teaching aimed at sustainable benefits in the long term, is worth the investment. In effect, one reason for this survey report was to explore where weak signals of systemic change could be observed that could be traced back to a shift to IBSE methodologies.

It is to be noticed that the success of IBSE approaches cannot be correlated with scores under PISA, TIMMS or similar exercises. Such benchmarking indices aim at measuring the overall performance of the educational system of a given country, while IBSE pilot projects are of a small scale and have barely started to effect systemic change. For the time being, no significant longitudinal study has followed students who had been exposed to a substantial amount of IBSE teaching. Most countries are as yet merely starting the process of rejuvenating science teaching. It is precisely at the outset of this process that national academies can play a critical role of advising stakeholders on the appropriate strategies, a role that will decrease once schools and their authorities have embarked on renewing science education.

Inquiry-based methods strengthen creativity and critical questioning. The socio-economic success of the vision underlying the "Europe 2020" agenda crucially depends on the ability of citizens to question existing solutions and creatively move towards and adopt scientific and social innovations. Against this background, it is paramount to acknowledge that education should foster among children creativity and critical questioning: this is precisely the core precept of IBSE approaches. An inquiry-based education appeals to the natural curiosity of children, and is conceived as a sound, early preparation for the personal benefit of tomorrow's citizens and, by extension, for the good of society. IBSE intervenes at the age when the child is eager to discover the surrounding world and to understand how it functions (say between four and twelve years, i.e. at pre-school, primary and lower secondary school level). The practice of inquiry in classroom exercises is similar to the process of scientific research and discovery: it involves, under the experienced guidance of a teacher, the elements of observing and collecting data, doing experiments, formulating questions and hypotheses, arguing rationally, searching – often jointly with others - for evidence and accepting the confrontation of ideas, while seeking to reach conclusions. In primary schools, unfortunately, there are as yet too few cases where science is taught through this exciting and challenging teaching mode, which is so much in line with the innate drive of the child to question. Instead, science is often taught in a mainly deductive pedagogy characterised by a low level of interaction, so that students risk losing their innate taste for science. Moreover science is sometimes not taught at all.

IBSE also has a number of other additional advantages: it typically transcends traditional disciplinary divisions, as IBSE teaching units are problem centred. It has also been largely demonstrated that inquiry-based approaches are beneficial for the cognitive and linguistic development of students. Moreover, they encourage work in small groups where children learn to cooperate with their peers in a constructive fashion. It has also been observed that in less homogeneous settings inquiry-based and traditional deductive approaches can be combined in the classroom to accommodate different stages of preparedness, mind-sets and age-groups. This is a particularly precious finding when it comes to moving from primary to secondary school.

Promoting inclusiveness through science education is facilitated by inquiry-based approaches. If on the one hand IBSE is fully compatible with the ambition of fostering excellence, it is just as appropriate to be used with weaker and less talented students. It does not enhance gender differences in learning practices, but is able to create in the science classroom the same level of achievement for boys and girls. It has been argued that more immediate links between science-related activities and daily life issues, as they are built under IBSE approaches, can contribute to enhancing the performance of girls in science classes. As the passion for inquiry and research is brought to the classroom, the atmosphere improves, so that IBSE is rewarding as pedagogical method also for the teacher.

In short, by improving interest of children in science, IBSE can help advance scientific literacy for future citizens and also increase the number of S&T students: for the future of Europe, the European academies united in this WG wish to play this winning card for the rejuvenation of the ways in which children are taught in science.

UNANIMITY AND DIVERSITY AMONG COUNTRIES

The present report shows a vast diversity of approaches towards renewing science education and at the same time a unanimous agreement among all academies about the need to reform and strengthen it. These different approaches observed cannot be correlated in any direct way to the size, wealth, or constitutional setup of the educational system (centralized or based on federal states or other administrative units). Nor does the type of member academy (with or without research institutes) directly influence their form and strength of intervention.

Evidently educational systems vary widely across Europe, reflecting social, regional, or political parameters, and educational authorities are structured differently as well. In certain countries policy efforts focus on low achievers and the political concern with the issue is primarily inclusiveness (minorities, gender etc.), while elsewhere there is an emphasis on identifying and nurturing talented students, either as part of a specific academy policy, or as a reflection of priorities of the national education system. Also the duration and intensity of participation in FP co-funded science education projects varies, as well as the degree to which academies have been involved in them and able to inject into the existing systems results from these projects. The actors, means and processes leading the development of IBSE (academies, national associations, foundations, seminars, workshops, etc.) also show a wide diversity. Finally, there seems to be no correlation between the performance of the national educational systems in benchmarking exercises such as PISA, and the ways academies are engaged in the reform of science education. As an inevitable consequence of this vast diversity the envisaged impact and form of the activities launched by academies at national or local level also vary considerably.

The report emphasizes three main factors that influence the renovation of science teaching.

The voice of national academies in favour of the reform: The report emphasizes that national academies are deeply involved in the issue of reforming science education. Since they are recognised by media and political decision-makers as institutions gathering the elite of the scientific community, their voice carries authority when they speak about science and science education and they also have a facility in accessing political environments on these issues. Throughout Europe they have helped spread the notion that science education must be reformed. Depending on the country, their advocacy for reform may be listened to in the education ministry and academies may also have a role to play in reforming the relevant school curricula. At the European level and globally a common sense of purpose has long been established between scientists and accordingly between academies: the shared objective of rejuvenating science education has easily federated the European academies in this ALLEA Working Group, the regional European council of the global IAP science education programme.

The lead of a few countries has been critical and the report will make reference, time and again, to the role played by certain academies in mobilising interest in the process of rejuvenating science also in neighbouring and partner countries. Their fine experiences rendered realistic the perspective of a reform in other countries that would go beyond pilot projects: a successful and innovative IBSE programme can be shown to spawn imitation across Europe, leading to multiple adaptations that adjust methods and interventions to the specific challenges of the respective local school systems. This process of peer learning often involves communities of scientists and education policy makers.

The competitively awarded projects co-funded under the European Commission's Framework Programme have proven an important help: while European initiatives in education cannot interfere directly in Member States policies (due to the principle of subsidiarity), the cross-border exchange of ideas and novel practices that has been facilitated by EU projects can be shown to have triggered continent-wide reflections and debates. Such projects proved to be eminently useful as a means of broadcasting innovation in the sector. European co-funded projects for reforming science education (such as SciEduc, Pollen, Fibonacci, to name but a few) advanced the appreciation for professional cross-border cooperation in the sector. These and other international networks and projects helped to convince and prepare national actors to take further local initiatives, e.g. for curricula, institutional structures or legislative rules. They stimulated experiments with imaginative and creative proposals for change against the background of ideas at national, regional or local level, and helped start the implementation of sustainable renewal in science education.

Teacher Training and the necessary systemic Reforms

Whatever the country, a sustained change in science teaching implies revisiting teachers training. Even in countries where the adoption of IBSE approaches in the classroom and changes in curricula have occurred under the pressure of the academies the way to a systemic change remains long. There is agreement that the fastest track towards a sustainable change is by providing appropriate in-service training to all science teachers through specific continuous professional development (CPD). To make this realistically possible further research in the field of didactics should also be supported. Moreover IBSE approaches must be included in teacher training programmes for initial and in-service training. This is a strong challenge in most countries, especially for in-service teachers training, not only because of the necessary revisiting of inspiring ideas beyond CPD, but also because of the financial means required to train the full set of already in-service teachers.

Everywhere, in order to make such a systemic and ambitious progress, an intervention at higher level and of politically respected format (such as the European one) is necessary in order to motivate action of political decision-makers. But there is also agreement that a substantial "machine" in the background is absolutely necessary in order to promote and to engage in a sustained reform of science education, at least at the primary school level.

B. THE RENOVATION OF SCIENCE EDUCATION IN EUROPE THROUGH IBSE

INTRODUCTION

Science and technology literacy will be among the key factors for socio-economic success or failure of societies, whether this success is measured in terms of material well-being or in terms of cultural development. For the rapidly ageing societies of Europe, with their declining percentage of economically active populations, such literacy alone – in the restricted sense of mastery of some basic skills - will not be sufficient. An ability to rationally challenge existing knowledge, a passion to boldly move beyond the known and towards the creative design of new solutions, a desire to discover as fresh and burning as it usually comes naturally to children needs to be nurtured throughout the school curriculum, and be kept alive in higher education and at workplaces. It has been argued that such critical thinking and analytical argumentation, both parts of a continuous quest to question, are among the key cultural contributions that IBSE can make to mature democracies. But also for democracies of today and tomorrow, where societies need to re-establish the mechanisms of evidence-based public debate, the IBSE approach can serve as a cultural tool to set-up viable consensus-building mechanisms around major critical choices.

Whether the Declaration of Lisbon of 2000 or the more recent vision "Europe 2020" with its emphasis on innovation and life-long learning - any politically set objective of a knowledge-based society will require a radical transformation of science education. As yet, we cannot help noticing with great concern the mismatch of a technologically advanced society with little if any understanding of the underlying science, or even, worse perhaps, without a desire to understand and advance that science and technology – the poor interest of school leavers for a career in science or technology is but one indicator.

"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."

Thus argued the so-called Rocard report "*Science Education NOW: A renewed Pedagogy for the Future of Europe*", commissioned by the then Directorate General Research "Science, Economy, Society" and produced by a high-level working group under the chairmanship of former French Prime Minister and Member of the European Parliament Michel Rocard. This lengthy quote seems justified: for the report that follows and its concluding recommendations, the Rocard report is a key reference. Its emphasis on IBSE as an important element of classroom teaching, its understanding of the need to promote inclusiveness and opportunities for all by reducing gender and minority biases, and its appreciation of informal teaching arenas that involve non-traditional communities and businesses alike, all will appear time and again as important elements for success among the academies' interventions in this field. There is evidence that IBSE, and variations on this methodology as they have been developed to suit conditions in different educational systems, is *the* main innovative pedagogical method for teaching S&T, and that, for certain age groups and fields, it could be the necessary remedy to many of the currently observed ills. Such, at least, has been the experience of the WG lead academy, the French Académie des sciences.

If Europe-wide action is by now gaining more and more acceptance for securing the continent's viability in financial and budgetary terms and, perhaps, very soon also in terms of security and foreign policies, Europe-wide action in dealing with education is limited by the principle of subsidiarity ("actions of coordination or complement", Art. III-282 of the European Treaty): constitutionally, the management of education systems is the domain of the Member States. Matters pertaining to labour law, curricula, funding issues, teacher training, etc. are all rooted in local institutional cultures and are better addressed at local or national level. So current projects and initiatives at European levels alone cannot do as much as would be required for the urgent, important and necessary task of reforming science education, which is what some view as unsatisfactory. This is why the collective authority of the national academies of sciences jointly with and supported by other partners (teaching professionals, industrialists, parents organisations etc.) can play a central role in creating a consensus at the various national or regional levels to ensure that reform measures are implemented in a coordinated fashion. A shared perspective on concepts and common goals among practitioners and those politically responsible for educational systems would allow for a transition towards a set of agreed new approaches. Paradoxically, the subsidiarity principle may even be helpful, as its underlying Westphalian philosophy may encourage an orderly competition among States, in accelerating the process towards the earliest and best possible uptake of the necessary measures.

Currently, however, we observe very diverse framework conditions and different stages of preparedness for the transition to a new, inquiry-based educational system. Thus it is important to sketch in some detail how IBSE approaches have already caught on, country by country, and to explain the past as well as potential future roles of academies, individually and as a group, in this process on transition, notably their role in mobilising the public and decision-makers in politics, society and business to understand and push ahead the transition Europe-wide in the near future.

This report, therefore, provides a selective overview over the intentions and actions of national academies of sciences in Europe to contribute to the reform and rejuvenation of science education in their respective countries. It sheds light on the ways by which national academies seek stimulate and advance national debates and actions on reforming science education, as well as on their own activities in the field; this includes the role and responsibility of leading scientists in supporting teachers and, more broadly speaking, providing a role model and instilling a passion for S&T among young students. It also highlights some examples of interactions between the activities carried forward by national academies (or, occasionally, other actors at national level) and the pilot projects financially supported by the European Commission's Framework Programme, seeking to win some insights into the impact of such projects;

Against this background, the report will make some recommendations for a better interaction between the leaders of the scientific community – represented as they are by the national academies – and leaders in politics, society and business in order to

- jointly reflect and act on the rejuvenation of science education across Europe, making full use of the consensus that is building across the continent for such a transition and the resulting desire to take action at European level,
- consider the means available under the subsidiarity principle that will allow implementing locally the most appropriate institutional solutions for this transition, as explored already partly under some of the pilot EU co-funded projects;
- combine intellectual, political and financial resources to also move ahead in the field of science education as part of the European neighbourhood and development policies (such as: Union for the Mediterranean [Arab spring]; emerging economies of Central Asia; EU-AU dialogue) and of Europe's global engagement for peace, sustainable prosperity, human security and human rights.

The report is largely based on a set of surveys conducted successively among all 53 ALLEA Member Academies, and then more specifically among the members of the ALLEA Working Group on science education throughout 2010 and the first half of 2011. Through questionnaires, interviews and oral reports, information was gathered about the engagement of academies in support of science education reform. In some cases also interventions in the fields of mathematics and technology were touched upon, but the focus was on IBSE approaches, and on the perceived or expected impact of experiments in FP-supported activities in this area

KEY CONCEPTS

Before providing a brief sketch of the movement to strengthen IBSE approaches that has led in Europe to a number of autonomous or more coordinated efforts, it may be useful to clarify a few key concepts that will be used in this report.

Science. In this report, unless defined differently, the word "science" refers to all sciences: physical, chemical, earth, life and environmental sciences. On occasion "science" may include also mathematics, computer science and technology (referring either to engineering or to hands-on applied science, or to more sociologically inspired S&T systems studies). From these descriptions it is evident that very substantial differences exist in the way these fields are packaged as subjects and in curricula taught at schools across Europe. Since this report is, however, written from the perspective of scientists and their academies, these institutional traditions are considered a secondary phenomenon if compared both to the universality of science, and to the common challenges school systems and societies face across the continent and beyond. This is also why comparatively little effort has been made in this text to differentiate "science", "science and technology" (S&T), or "science, technology, engineering and mathematics" (STEM or MINT, German for: "Mathematik, Informatik, Naturwissenschaften, Technik"). Yet evidently current national and FP-sponsored pilot projects are very consciously addressing these differences, the underlying institutional patterns, and the consequences of such patterns for any intended reforms.

IBSE (Inquiry-Based Science Education). Put simply, it is an approach that reproduces in the classroom the learning process practised by scientists: observing, formulating questions, doing experiments, collecting and comparing data, reaching conclusions, and extrapolating these findings to more general "theories". Recent projects have shown that it is not always easy to incorporate this approach across all fields of STEM education, while it has emerged that the method can be comparatively easy applied to the social sciences and the humanities.

Disciplines / subjects. As different IBSE approaches develop in different countries and schools of pedagogy, the key ambition remains unchanged: to keep alive the curiosity of young children throughout the curriculum. IBSE approaches take their cue from the fascination with natural phenomena, that is observed in children, whether these phenomena are daily and apparently familiar, or exceptional and spectacularly unusual; a similar interest is often stimulated by objects of human technologies that are used to harness the forces of nature. Against the background of an innate curiosity, it is critical - especially at primary schools - not to give too much weight to disciplinary distinctions between, say: biology, chemistry, physics, etc. Of course, such specialisation becomes more important and necessary during the later stages of the school curriculum.

Contributors to the report have commented that depending on the age group and on the science concerned, the central relationship with mathematics is resolved differently. When IBSE approaches were first introduced in primary schools, the real concern of adepts was with safeguarding science education as part of the curriculum: at the time it was argued that mathematics was under comparatively less of a threat, being part of the classic triad of reading-writing-arithmetic.

Schools / teachers. A number of excellent overviews over the different education systems in Europe, their diverging terminologies, hierarchies, etc., have been prepared over the years, funded by the European Commission or by national authorities. They often comprise significant quantitative information, which is not repeated here. Rather, the information requested from and provided by respondents for this report has been largely qualitative. No accurate translation of the terminology describing the administrative and hierarchical realities of national education systems was expected, and English terminology was used occasionally in a somewhat liberal fashion, where the relevant terminology had not yet become current in the national language. The report only resorts to additional explanations when it is strictly necessary.

Neuroscience / learning. In recent years, learning has become a core research interest of the rapidly expanding field of cognitive neurosciences: in particular, the study of learning processes during early childhood years of humans has fascinated scientists. The promise of a new pedagogy that might possibly be emerging from such studies has had repercussions beyond cognitive science itself, and gave a new spin to the nature/nurture debate. Advances in brain research and results from experimental psychology rapidly find their ways into public debates due to their possible impacts on educational questions. As some scientists, professionals, practitioners and, last but certainly not least, many parents engage in these debates, issues such as language acquisition, reading and dyslexia, numeracy, etc. tend to be at the heart of such discussions. Such is the appeal of cognitive science insights for possible advances in learning technologies that also intergovernmental organisations such as OECD have invested into understanding better the potential of what some have already called the new science of learning.

But even if children's brains in the "golden age of curiosity" (Pierre Léna) – the age between 4 to 12 years – will soon be widely scanned and scrutinised, we must not forget what we understood long ago, namely that the success of learning is intimately tied to teaching, hence to patterns of communication between ages, genders and classes, between and within cultures. The feedback loop between the science of learning and the art of teaching science is enriching. Some of this will be reflected in the academies' activities that are presented below. As IBSE approaches evolve from experimental and pilot projects to institutional implementation, the focus shifts to the art of teachin and to its practitioners: it becomes crucial that teachers of science hone their professional skills and scientific understanding so that they can remain creative and inquisitive themselves. This report argues that this can be achieved often through extended and systematic offers of continuous professional development.

Language. It needs to be emphasised that the "hands-on" approach duly acknowledges language as the key human tool for grasping the laws of nature and for conveying the notion of having grasped. IBSE approaches seek to advance the art of asking questions that are stimulated by careful and guided observation. While these methods involve a degree of curiosity-driven scientific experimentation, at the same time they aim at developing language and argumentation skills through questioning, hypothesising, and concluding.

Growth of a global Consensus among Academies on Reforming Science Education

The academies' interest in rejuvenation and strengthening of S&T education is not a matter of self-preservation of a rare species, "the scientist", even if the concern with emergence of the next generation of science leaders is not absent from the rationales provided for their commitment to reforms in science education. Overall, this commitment continues the responsibility for society at large that academies and their members – the leading scientists of all nations – have shown ever since they first started their cross-border exchanges in 17th war-torn century, developed the thinking behind the European enlightenment and the French revolution in the 18th century, supported the advances in medical research and in the basic sciences in the 19th century, and acted against the looming nuclear apocalypse in the 20th century. Now in the early 21st century, academies from around the world have gathered their intellectual and reputational resources to make governments understand the urgency in supplying sufficient resources and creativity in view of a thorough reform of the ways in which we teach our children and grandchildren the tools that will empower them to steer their world responsibly.

To the extent that academies have an advisory role at national and European level, they argue for a societally responsible development and use of science and technology in making major societal choices. They inform public debates on global challenges such as climate change and biodiversity, food crisis and biotechnologies, nuclear power and energy security, etc. Their commitment to support science teaching approaches that privilege critical reflection and an understanding of the way science, scientific discovery and technological applications work, must be seen in this context.

If included in the teaching of science, the notion that science and technology can contribute towards global justice can help make the field of S&T education appear closer both to real life concerns and to the ambitions of children and teenagers. Thus, academies see beyond the mere technical aspects of reforming S&T education: their ambition goes beyond transmitting skills and seeks to help shape the S&T-literate citizen of future democratic, inclusive, technologically advanced and ecologically sustainable societies in Europe and the world.

In the United States of America, it was such a vast ambition that led the National Academy of Sciences and the Smithsonian Institution support the creation of the *National Science Resources Center.* The NSRC went on to play an important role in eventually bringing IBSE to a fifth of the U.S. school districts. Different institutions under the leadership of exceptional individuals such as Nobel laureate Leo Lederman (Chicago), Karen Worth (Boston) and Bruce Alberts (then at the National Academies of Sciences) successfully drew attention to the benefit for inclusiveness of renewing the ways in which science was taught. Thus starting in the last 1980's, eminent scientists from around the world, supported by their national academies, took to heart the issue of reviving the passion for science among the young, and triggered a movement that has not stopped spreading and growing ever since.

In Europe, the French Académie des sciences was instrumental in generating ministerial support for the innovative IBSE programme "*La Main à la Pâte*", which by now reaches many primary schools in the country and has spawned imitators the world over. Also the Royal Swedish Academy of Sciences with its NTA programme ("*Naturvetenskap och teknik för alla*" or: Science and engineering/technology for all) adopted the IBSE approaches developed in the U.S.A. early on, and adapted them to respond to challenges in the Swedish school system.

The mid-1990's witnessed a mushrooming of international initiatives, all focussed on improving science education. The ICSU Committee on Capacity Building in Science, also led by Leo Lederman, helped to bring the issue to the agenda of the World Conference of Science held in Budapest in 1999 that was sponsored among others by UNESCO. The conference recognised "an urgent need to renew, expand and diversify basic science education for all…". The conference declaration states that *"access to scientific knowledge for peaceful purposes from a very early age is part of the right to education belonging to all men and women, and science education is essential for human development, for creating endogenous scientific capacity and for having active and informed citizens"* so that the following should be among the commitments and commandments of science and cultural organisations the world over:

"Science education, in the broad sense, without discrimination and encompassing all levels and modalities, is a fundamental prerequisite for democracy and for ensuring sustainable development. In recent years, worldwide measures have been undertaken to promote basic education for all. It is essential that the fundamental role played by women in the application of scientific development to food production and health care be fully recognized, and efforts made to strengthen their understanding of scientific advances in these areas. It is on this platform that science education, communication and popularization need to be built. Special attention still needs to be given to marginalized groups. It is more than ever necessary to develop and expand science literacy in all cultures and all sectors of society as well as reasoning ability and skills and an appreciation of ethical values, so as to improve public participation in decision-making related to the application of new knowledge. Progress in science makes the role of universities particularly important in the promotion and modernization of science teaching and its coordination at all levels of education. In all countries, and in particular the developing countries, there is a need to strengthen scientific research in higher education, including postgraduate programmes, taking into account national priorities."

Following in the footsteps of the World Conference, Science Council Japan hosted in 2000 the Conference on *"Transition to Sustainability in the 21st Century"* in Tokyo: one of the thematic foci in this collective forward looking exercise was on education. Also in 2000, the Chinese academy of sciences and partners – among them the above mentioned ICSU Committee – convened in Beijing an international conference which looked at advances and emerging new methodologies in science and mathematics education for primary schools. And in the first decade of the 21st century, the IAP, this worldwide group of science academies, adopted the principle and started supporting academies globally that sought to introduce similar approaches in their countries, and inter-academy networks in Africa, Asia, the Americas and then Europe that allowed for peer-learning.

THE ACADEMIES' MEXICO STATEMENT ON SCIENCE EDUCATION

In 2003 a statement on „*Science Education of Children*" was issued on occasion of an IAP plenary meeting in Mexico City, and was signed by 29 out of the 53 ALLEA Member Academies (see below).

Statement „Science Education of Children", Mexico City, 4 December 2003

« Must all children learn science at school? »

The answer is "Yes." Science opens young people's minds to the wonders of the natural world; introduces them to the elegance and honesty of scientific endeavours; and equips them with

- cognitive and problem-solving tools that will serve them well in the future.
Science brings children closer to the natural objects and phenomena that surround them; endows them with a rich understanding of our complex world; helps them practice an intelligent

- approach to dealing with the environment; and teaches them about the techniques and tools that societies have used to improve the human condition. As children become familiar with the universality of the laws of science, they also learn to recognize science's ability "to create and cement together a unity for humanity."
As citizens, science helps children develop the mental and moral predispositions to imagination, humility, rigour, curiosity, freedom and tolerance - all essential ingredients for peace and democracy. Therefore, the InterAcademy Panel on International Issues (IAP) recommends to all national leaders that:
1/. teaching of the sciences to both girls and boys begin in their primary and nursery schools. There is evidence that children, from the youngest age, are capable of building upon their natural and insatiable curiosity to develop logical and rational thought;
2/. this teaching should be closely tied to the realities with which the children are confronted locally, in their natural environment and their culture, in order to facilitate continuing exchange with their family and friends;
3/. this teaching should be based, to a large extent, upon models of inquiry-based pedagogy, assigning a major role to questioning by the students, leading them to develop hypotheses relating to the initial questions and, when possible, encouraging experimentation that, while simple in terms of the apparatus used, can be performed by children themselves;
4/. in this manner one should avoid, as far as possible, a teaching of the sciences which is handed down vertically by a teacher enunciating facts to be learnt by heart, in favour of one which is transformed for children into an acquisition of knowledge which is horizontal, that is, which connects them with nature - inert or living - directly, at the same time involving their senses and their intelligence;
5/. links should be established between teachers, via the internet, first within their own country, then internationally, taking advantage of the universal nature of the laws of science to establish a direct contact between classes in different countries on subjects of global interest (e.g. climate, ecology, geography);
6/. priority should be given to the networking of schools, and that support should be given …to efforts to develop shareable experiments and teaching tools (such as documents and experiment portfolios) to be placed in an electronic commons for all to modify and use."

The networking of international experiences facilitated accelerated learning process, and led to spectacular progress in some countries: in Chile, for example, with support from the U.S. and French Academies of Sciences, the Chilean Academy of Sciences and the University of Chile has been working since 2002 to set up and expand a national programme "*Educación en Ciencias Basada en la Indagación* (ECBI)". The programme had launched a pilot with the participation of six primary schools in a poor district near the capital Santiago de Chile; following the overwhelming success of the pilot project among students and parents alike, the programme was expanded and now reaches close to 300 schools with ca. 100,000 children all across the country. On the strength of an international evaluation, the parliament recommended to roll out the programme to all schools (see: Jorge E. Allende, *Science*, 321, 29 Aug 2008, 1133**).**

Regional inter-academy science education programmes are now functioning next to the Americas (16 Academies, since 2004) also in Africa (12 Academies, since 2005) and in Asia (18 Academies, since 2007). ALLEA was asked by IAP to coordinate the European network in 2009 (25 participating Academies). The participating national academies are committed to work towards improving the level and relevance of science education, to promote IBSE-related methodologies, to collaborate internationally at engaging governments, international organizations and private sponsors in the activities of science education.

In May 2011 a joint statement of the science academies from the G8+ countries was submitted to the Heads of State meeting in France, entitled "Education for a Science-Based Global Development". It comprised a number of recommendations that indicate that the Academies' engagement in science education is collocated in their wider support for measures that aim at building knowledge-based and science literate societies the world over. This statement is included verbatim at the end of the report in section 'D. Recommendations'

EUROPE: INDICATORS AND ATTITUDES GIVE RISE TO CONCERN

In recent years, educational policies in Europe are developed increasingly in response to international comparative performance assessments. They seem to suggest that in global comparison students in many European countries fare less well than expected. Since such assessments aim primarily at aggregate figures, it is far from certain that conventional text- and exam-based quantitative indicators that are collected for such global comparative studies (such as the OECD's "*Program for International Student Assessment*" PISA, TIMSS etc.) capture the parameters necessary for assessing the long-term and more comprehensive effects that IBSE approaches are supposed to have on students' abilities. For those schools and systems that have chosen a reform path with substantial elements borrowed from IBSE methodologies, some studies are now underway that will take a serious look at whether there are biases in assessment methodologies that can negatively affect the description of success of IBSE approaches. Beyond technical skills and problem-solving abilities, proponents of IBSE approaches claim that it would also foster more positive attitudes towards science and science careers, by creating an understanding of the very nature of doing science and relating it to society. Therefore it is equally important to develop robust assessment methodologies that allow teachers to reliably assess and compare achievements of individual students, and that, to some extent, would empower the students to take responsibility themselves for their advancement, Unfortunately as yet, we appear not to dispose of enough tools for a meaningful comparison between achievements under different teaching methods. It therefore seems appropriate to devote some research time on developing methodologies that are better suited to measure and compare the success, or otherwise, of IBSE approaches.

In the early 2000's, much of the impetus to make available resources and room for rejuvenating science education across Europe stemmed precisely from studies that indicated an ever decreasing interest in science among Europe's youths. Such studies saw a reflection of these attitudes in what were for most countries less than flattering results of the early PISA assessments. The sense of urgency to take action in the field of science education was therefore derived from the interpretation of these surveys, which predicted that such little interest in S&T education would be a problematic foreboding of a future lack of ambitions to enter careers in science, engineering and technology.

Some recent statistics suggest a growing number of graduates in S&T fields in parts of Europe, but the OECD's "Program for International Student Assessment" keeps pointing to an underperformance of sections of Europe, among others, in equipping its children with the appropriate understandings of critical issues in science and technology. It is certainly true that results from TIMMS 2007 and 2008 (advanced) and PISA 2009 do not give a consistent picture for the whole of Europe - those results are well known and need not be reviewed here.

Yet, the recent "*Special Eurobarometer Report*" of attitudes towards science and technology gives rise to concern: based on fieldwork in January / February 2010 and published in June 2010, the report suggests that few if any major changes occurred in attitudes towards science over the last few years. If anything, citizens are overall slightly less optimistic or knowledgeable about the effects of science and technology. The survey was conducted after the banking crisis was beginning to have its effects on European economies and just after the much publicised hackings into UK climate scientists' e-mails, but fell just before the tsunami-triggered nuclear catastrophe in Japan. It remains to be seen to what extent these factors will further influence attitudes. It is revealing, however, that in the words of the report Europeans "express interest in new scientific discoveries and technological developments where 30% are very interested and 49% are moderately interested", though only about one in ten feels well informed about the issues at stake. Not surprisingly, those more interested in S&T issues feel they are better informed and, more generally, have a more positive view of science and technology.

Interestingly, 70% of respondents also believe science education would add to the general culture of young people in a positive way (this conviction is slightly less pronounced among younger people themselves). Only 12% of respondents on average disagree with the statement that science (education) also prepares a new generation to act as well-informed citizen, with scepticism highest at 20% and 21% respectively in France and the Netherlands. Interestingly, agreement levels about positive effects of science education on job prospects are highest in those countries that otherwise are usually found in the group of innovation leaders, such as Finland, Sweden, Norway and Germany (73% each) and lowest in France (41%).

We observe a broad consensus among two thirds of respondents from the EU-27 countries who feel that governments are not doing enough to encourage young people to be involved with science (education, career choices etc.): such exposure to and understanding of science, it is believed, would help young people on the labour market. Looking at Eurobarometer that also covers some non EU-countries, disappointment with local government action in the domain is highest in Bulgaria, Croatia and Latvia and lowest in Luxembourg and Switzerland. It is encouraging to see that even among those who proclaim not to be interested in science themselves, 55% would like to see more efforts on the part of the government to encourage young people in science. Clearly, at least in the perception of citizens, measures to stem the critical shortfall of science graduates observed already in the 2005 survey have not been sufficient.

Since one key concern of the ALLEA Working Group as the regional European council of the IAP science education programme is to work towards making science education and S&T careers more attractive also to girls, it is interesting to see that ¾ of respondents at EU-27 level agree that women are underrepresented in top positions in research institutions and that governments should take steps to improve women's representation in the scientific professions. This, the majority of respondents think (63%), would lead to an overall improvement in the way research is conducted.

EUROPE: BIRTH OF A NEW NETWORK OF ACADEMIES IN SUPPORT OF SCIENCE EDUCATION

Following the publication of the so-called "Rocard report" and the initial successes of pilot projects and peer learning activities in IBSE-related approaches funded through different streams of European Commission support, a conference was held under the French EU presidency in Grenoble in October 2008 under the title "*Science Learning in the Europe of knowledge*". A convergence of analyses from different actors (including national and regional ministries, industry, Academies) pointed towards a desire to see a transformation in science education in Europe. Participants acknowledged that the task is daunting, with ca. 1 Mio. primary school teachers and some 100.000 secondary teachers requiring additional in-service training. Yet, it was felt that rolling out the necessary measures, which may need a sustained effort, should not take longer than 15 years. A crucial element was seen in the support to be given to this process by the scientific community: they could strengthen the creativity and scientific quality of teacher training (curriculum content; concepts, incl. ethics; unity of science across traditional disciplines or school subjects, etc.). Academies of sciences in particular pointed to the problematic constellation where the responsibility for the training of primary school teachers lies primarily with faculties of education or teacher colleges often removed from the cores of scientific progress and method. Also cross-border dissemination and peer learning (such as an "Erasmus" for teachers?) were considered among the elements that would contribute to overcoming the challenge of scale. Academies also pointed to the need to consider this issue not as being limited to Europe alone, but that science literacy is as much an issue that should underlie development and cooperation policies. Last but certainly not least, the conference acknowledged the need for appropriate assessment methodologies to be developed in order to better capture the contributions of IBSE approaches to the development of students.

It was against this background, and following some preliminary exchanges between Member Academies, that the extraordinary strategy meeting of all 53 ALLEA Member Academies in 2009 accepted the proposal submitted by the French Académie des sciences (lead academy) to establish an "*ALLEA Working Group on Science Education"* which would function as the European partner initiative to the IAP science education programme. Some 25 Academies are now actively participating in the WG. The appointed founding chair was Pierre Léna from Académie des sciences (he has meanwhile become coordinator of the global programme and has been succeeded in June 2011 by Odile Macchi, also from Académie des sciences.) Since mid-2011, the WG functions as the regional European council of the IAP programme.

The WG has established a fairly regular pattern of exchanges with the relevant actors in the European Commission, and, through the national academies, with relevant actors at national level. The focus is typically on issues to do with the linkages between national and European efforts leading towards new methods in science education and science communication; also the suggestion for this report stems from those exchanges.

This is not the place to review the flagship initiatives proposed since 2010 by the European Commission in view of the vision *"Europe 2020"*. As with all such major coordination actions, results and impact can be measured only in a few years time. Suffice it to say that with research and innovation as well as skills and life-long learning moving centre stage on an employment-oriented policy agenda, chances are that a cross-directorate alliance can be formed that will help, with the involvement of stakeholders at national and at corporate level, to make significant headway in the reform of science education. Whether or not financial resources will be available to continue pilot and deployment projects will be part of the negotiation process about the new framework programme "Horizon 2020".

It is important that the academies be seen as allies in this development, offering top-level scientific expertise not only in the educational sciences, but also by drawing on top scientists as role models for the ways of doing exciting and rewarding science, and by providing expert advisors on the ways of including emerging areas of science and societally relevant issues of S&T applications into school curricula.

In this role, ALLEA facilitated the exchanges of delegates from its European Member academies with some of the other international organisations that are active in the field: ICSU shared its preliminary reflections on possibly re-launching its own global science education programme at the ALLEA General Assembly in Stockholm in 2010, and WG founding chair Pierre Léna was invited to introduce the debate about the resulting report at the session convened on occasion of the ICSU General Assembly in Rome in September 2011.

UNESCO's decade-long programme "Education for sustainable development" (ESD) was also presented and discussed at the ALLEA General Assembly in 2010. ESD is understood as
"education that allows learners to acquire the skills, capacities, values and knowledge required to ensure sustainable development; ...at all levels and in all social contexts (family, school, workplace, community); ... fostering responsible citizens and promoting democracy by allowing individuals and communities to enjoy their rights and fulfil their responsibilities" (see: UNESCO ESD Information sheet).
In addition, IAP and ALLEA with support from Royal Society and Welcome Trust, organised the global conference on "*Taking IBSE into Secondary Schools*" convened at the UK's National Science Learning Centre in York in October 2010. If during its first years, the IAP programme had focused on introducing IBSE in primary schools, a Euro-Latin-American workshop held in Santiago de Chile in January 2010 shifted gears: it revealed that with a view to sustaining interest, among the school population, for S&T, insights into possibilities of adapting IBSE methodologies to secondary schools should be explored. The conference reviewed experiences of projects that experimented with IBSE approaches in secondary schools in different regions of the world, and considered the possible role for science academies in such contexts. As had also been suggested above, speakers confirmed that the issue of implementing appropriate assessment methodologies has lost nothing of its urgency, comparative measures becoming more and more important in steering policies, as the age cohorts approach the moment of career choices. The conference proceedings is currently being published in a number of languages.
The growing engagement of academies in activities aimed at reforming science education, as will appear clearly from the following overview, is perhaps the strongest signal yet that points to holistic education as a foundation stone for building a knowledge-based society:

"Proposing a unified vision of knowledge, where science – including mathematics – is integrated with language, history, geography to answer the curiosity of children, develop their creativity and critical mind, must succeed since it is an urgent need of our times." (Pierre Léna, Erasmus Lecture...)

C. ACTIVITIES OF THE NATIONAL ACADEMIES AND OTHER PILOT PROJECTS: VIEWS AND ACTIONS

OVERVIEW

This section presents results of a survey about the views of national academies in Europe on reforming science education, the different modes of intervention they have used to stimulate and advance national debates and their action at national level. The survey shows that academies often function as transmitters of best practices and of ambitions for better practices in the educational system. The surveys did not comprise questions that would yield quantitative data. Instead, questions solicited, to different degrees, short narratives about achievements and obstacles, both perceived and factual, networking and peer learning; another focus was on the role and responsibility of leading scientists in supporting teachers and teacher trainers, thereby instilling or keeping alive the passion for S&T or simply providing an example for it.

Not surprisingly, the feedback received from academies was as uneven as is the level of engagement and commitment of Academies to these new approaches in STEM education. The overview is certainly incomplete as it relies on voluntary fact gathering conducted largely by WG members in the different European countries. No field work was conducted, and no direct contact with other actors in this domain was sought for this report. The text therefore does not mean to rival larger-scale and potentially comprehensive exercises done by Eurydice or other such agents on more generic aspects of national education systems. Rather it serves to create the backdrop against which those institutions that played a central role in introducing IBSE approaches in Europe (the Academies) can reflect on their next steps, be it peer learning, collective action at regional, European or global level, or collaboration with other actors in European consortia.

After a portrait of the activities of the French Académie des sciences and its pioneering activities in the field of inquiry-based science education, the overview proceeds in alphabetical order by country, presenting insights from the reports academies provided. Many of the submissions of evidence from academies do not restrict themselves to their own activities, but offer more far-reaching reflections of the general state of society and of the economy which help explain the need for a reform of science education in a variety of settings and educational systems across Europe.

FRANCE: ACADEMIE DES SCIENCES – «LA MAIN A LA PATE»

Transatlantic inspirations

Carried out in France ever since 1996, the project «*La main à la pâte*», lead by the French Académie des sciences, has proven to be remarkably effective in terms of transformations of science education all across the country and by triggering policy debates and initiatives.

In 1995, the Franco-Polish scientist Georges Charpak, Nobel prize winner for physics in 1992, had been impressed by the example of his colleague Leon Lederman in Chicago, where primary schools in deprived neighbourhoods and in downtown ghettos and characterised by high drop-out rates had led Lederman to launch a programme based on the new approach of inquiry-based “hands-on” science education. As we shall see, “hands-on” science education does not refer to purely manual activities.

In the U.S., the National Science Resources Center (NSRC), created in 1985 by the Smithsonian Institution and the U.S. National Academies, had been given the mission to improve the learning and teaching of science for all children in the United States and throughout the world. This, the NSRC does by scaling up and sustaining effective science education programs, by supporting the professional growth of teachers of science and by providing research-based inquiry-centred science instructional materials. The NSRC has two curriculum programs that provide teaching materials for classrooms (kindergarten to Grade 9), covering the life, earth, and physical sciences and technology. All of these materials were subjected to rigorous scientific review prior to initial field testing in classrooms, which in turn was subjected to rigorous evaluations. All tools include embedded assessments to help teachers and students determine progress. Consistent use of these materials over time show improvements of student results in socially very diverse places across the U.S.

Impressed by the U.S. experiences, the French project was launched in the following year (1996) by Georges Charpak himself, jointly with Pierre Léna and Yves Quéré from the French Académie des sciences, benefitting from support of the French Ministry of Education. Building on these experiences observed in the U.S., the French academicians hoped to revive science education in France, where the teaching of science had nearly disappeared from the five years of elementary school teaching (although in principle it remained part of the curricula).

Shortcomings of science education in France

Next to support from the Ministry of Education, the Academy could soon rely on the partnership of the National Institute for Pedagogical Research (Institut National de Recherche Pédagogique, INRP) and the École normale supérieure of Paris. By now, the work-plan of *La main à la pâte* is determined chiefly through an annual agreement between Academy and Ministry. Despite these strong partnerships, the project remains the main testimony to the commitment of the French Académie des sciences to the rejuvenation of science teaching.

A number of observations had led the academy to privilege this novel approach: a main obstacle to any rejuvenation of science teaching lay in fact in the relationship of teachers with science itself: how could teachers be confident in teaching inquiry, if they themselves had never practised it, starting by questioning their own observations and by challenging the categorisations imposed by the academic disciplines? How could they appreciate, sustain and develop the curiosity of children vis-à-vis the scientific phenomena of the natural world, if they themselves had never experienced the excitement of discovery and guided analysis? Profound changes, it was concluded, were needed in teachers' attitudes and preparations, overcoming their experiences of "a vertical method of teaching" where questioning and experimenting were not considered essential, perhaps even subversive. Only such additional teacher education in the new methods would enable them to make the best of inquiry-based learning.

The IBSE methodology suggests that teachers are guides in a process of exploration of the world, involving both scientific experimentation and the development of language and argumentation skills: questions, hypothesis, and conclusions. In many ways, the most important element of this new pedagogy is the discovery, or re-discovery, by teachers and teacher educators, that science *can* (or even: *must*) be taught in a horizontal, co-exploratory way. This ran counter to the tenets that many teachers had absorbed and made their own from their initial education onwards. In order to achieve this transition it was considered crucial that they must be offered specifically designed professional development courses while in-service, which would ideally include coaching by professional scientists, for example with the help of academicians. Such exchanges with cutting-edge science would remind teachers that the practice of scientific inquiry involves a great deal of uncertainty, and mental as much as physical experimentation. It is of prime importance for such in-service training units that a vision of the nature of science and of its unity is proposed that breaks with the traditional division into academic disciplines that many teachers have inherited from their own training.

An equally important element of teacher training would be to fully appreciate the close link between science learning and mastery of language, especially since language acquisition is at the forefront of concerns in official statements on the objectives of school instruction and a constant arena for parental pressure to be exercised.

By the same token, the societal value of science education can be stressed by insisting on the relationship between science and technological progress. Probably a more complex challenge, just as it is for most scientists, even if critical for the success of an inclusive education, will be the in-depth appreciation of the historical and cultural perspectives that should be conveyed during such training, relating scientific notions and the social practice and profession of "doing science" to other cultural domains.

The Ten Principles of La Main à la Pâte

As the intellectual and pedagogical programme *La main à la pâte* developed, it became structured around the "ten principles", some basic rules initially developed for the specific French educational and institutional context, but applicable and adaptable to other national educational systems: the fundamental point of departure for the IBSE methodology is to:

(1) Encourage children to observe an object or phenomenon in the real world that surrounds them and, if appropriate, experiment with it.
(2) In the course of seeking to understand their observations, they use arguments, share and discuss their ideas and interpretations and build their knowledge; a purely manual activity is therefore insufficient and is not what is meant by "hands-on" science education.
(3) Teachers propose activities that are organised within a teaching module, preferably related to official school programmes, while, at the same time, affording pupils ample independence for their autonomous pursuit of understanding.
(4) It is considered important that sufficient time is spent on any given thematic, a minimum of two hours per week for several weeks; by the same token, it is considered critical that continuity of activities and pedagogical methods is ensured, ideally throughout the school programme, at least from kindergarten to early secondary schools.
(5) Pupils are required to keep a science notebook or book of experiments, written and updated in their own words, and recording the work they performed in the science classroom, or related activities carried out at home (importance given to language).
(6) An objective is the gradual appropriation by pupils of scientific concepts and techniques, and working methods, including the notion of uncertainty and a proper understanding of discovery, also through a consolidated grasp of oral and written expression.
(7) Families and local communities are expected to be closely associated with the process of structured acquisition of knowledge.
(8) Local scientific partners would be envisaged as accompanying the work as well (for example: universities, engineering schools, etc.) supporting classroom work and offering access to their specialized skills and facilities.
(9) Teacher training colleges are expected to make their pedagogical and didactic experience available to teachers, and to offer in-service professional development.
(10) Teachers can obtain teaching modules, ideas for activities, and answers to questions at the website. They can take part in collaborative work with colleagues, trainers and scientists; the contact to the most advanced scientists as role models is a central element.

Towards a national programme in inquiry-based science education

Based on these principles, many actions were implemented to counteract the negative dynamics in science education. In 1996, an experimental programme was launched in a small sample of 350 classes. Established as an additional tool to help teachers, the internet site with resources for classroom work enjoys continued popularity (over 200,000 connections per month in 2004, with c. 320,000 primary school teachers employed across France); a sustained dialogue with scientists acting as consultants could be opened and exchanges of good practices between teachers encouraged.

An evaluation conducted by the Ministry of Education acknowledged the merits of the experimental approach and a nationwide roll-out of the programme was initiated by the Ministry for the last three grades of elementary schools (2000–2003). The "Plan de Rénovation de l'Enseignement des Sciences et des Technologies à l'Ecole" (PRESTE: Science and Technology Teaching Renovation Plan for Primary Schools) was thus launched. This far-reaching implementation included providing teachers with new material for experiments in the classroom, and developing in-service training sessions for teachers, with the participation of active scientists seeking to modify the teacher's perception of science. After a second evaluation, 2002 saw moves towards the publication of a new curriculum, which explicitly referred to the inquiry method and introduced learning of science and technology from kindergarten level onwards.

Meanwhile, the Académie des sciences, with support from a wide range of diverse local stakeholders undertook to develop a network of pilot centres in various socio-economic and geographical contexts all across France, rural or urban, deprived or less disadvantaged settings, where the results of innovative learning methods could be compared. Altogether the programme reached some 3,000 classes. *La main à la pâte* began to enjoy popularity in the media and among parents, which by itself demonstrated the interest of society for an action that placed the reduction of the gap between science and citizenry at the very heart of education.

Fifteen years after the launch of the action, science teaching in French schools has undergone significant changes, both in terms of quality (more horizontal, less vertical teaching) and in terms of quantity. By 2005, inquiry-based approaches had become part of the national curriculum. In 2011 it is estimated that about 35% of classes have by now introduced science teaching incorporating the basic ingredients of inquiry-based approaches: an experiment notebook, experiments being carried out in the classroom, etc. Some 30-40% of primary school teachers are engaged in some form of science teaching, compared to less than 5% in 1996. Kindergarden classes also joined the process, building on their traditional strengths in terms interactive teaching.

A study of teaching practices carried out by *La main à la pâte* has shown that the most successful initiatives for bringing scientific inquiry and active pedagogy into the classroom were those that provided teachers with long-term, continuous, in-class support, familiarising them progressively with IBSE practices. According to this study, in order for training to be truly effective, it must be around 80 hours long. While in-service teacher training sessions were few in number and often suffering from poor attendance before the launch of the project, by 2006–2007 up to 10% of all opportunities for continuous professional development offered to teachers have some bearing on IBSE methodologies. An evaluation conducted in France as part of the FP-6 supported project "Pollen" showed some impact of the project on teachers' attitudes towards science. In particular, the confidence of those teachers who were involved in the project in applying inquiry-based science teaching methods increased to a significant level in the second year of the project. Just as in many other countries, it was observed also in France that the in-service upskilling programme boosted teachers' confidence to teach science. Based on these findings, the evaluation report recommended that high-quality in-service training as an essential element of any transition process, providing teachers with a first-hand experience of the IBSE approaches.

It is the intention to engage universities more heavily in the rejuvenation of early science education. As a dedicated vehicle, the ASTEP programme was set up ("*Accompagnement Scientifique et Technologique à l'Ecole Primaire*" / Scientific and Technological Support for Teachers in Primary Schools). The programme encourages university-based active scientists to offer support to teachers in classroom activities. It has been running since 1996 and has come to involve 27 French universities and 19 engineering schools, with as many as 870 scientists taking part in the programme in 2010. It must be admitted, however, that 805 of these are de facto science students, whereas no reliable figures appear to exist, on the other hand, on the involvement of professional and fully fledged scientists in early education programmes: training, participation in steering committees, production of teaching material, etc.

Also in pre-service training for teachers universities are acquiring a new mission with changes under way since September 2010.

Despite the active participation of scientists in pioneering or routine IBSE-based classroom activities, it remains an undisputable fact that at universities and in teacher training colleges much progress still needs to be made to advance research into science education, in parallel to what can be observed in many other European countries.

Wider societal impact of the programme

The commitment of educational authorities and the full support by Académie des sciences ensured that the programme could survive successive political changes over 15 years, and has led to a profound transformation of early science education. Some preliminary assessments have provided indications of a systematic positive effect of IBSE approaches being introduced to classroom work, such as improvement in language acquisition and use, a better integration of students from diverse cultural backgrounds (minorities) in classroom activities, and advances in civic behaviour and ability to debate among students.

Certain characteristics of the programme prepare for structural changes as well: *La main à la pâte* pays particular attention to the need to retrain teachers, preparing them to develop ownership of the method of inquiry. In partnership with diverse stakeholders, it disseminated knowledge through an array of co-sponsored conferences, symposia, stakeholder involvement, training modules and printed and online publications, and peer-learning. A key element is the involvement of the scientific community - not in a one-off format or ex cathedra, but through active classroom support for teachers. Every year, the *La main à la pâte* prize is awarded, under the aegis of Académie des sciences, in recognition of the work done in primary school classrooms. It also rewards two theses on the teaching of science, submitted by future teachers during their training.

All in all, this has lead in France, ever since 2000, to a change in the perception of the importance of early science education among decision makers, whether politicians or civil servants. This change of mindset has subsequently translated into several national science education plans by the French Ministry of Education (see also below). The endorsement of the IBSE approach by the academy and its support for the key initiatives has played a critical role in this recognition: the intervention of Académie des sciences has succeeded in drawing the attention of the highest levels of government to the importance of renovating early science teaching. Georges Charpak's charisma and media personality contributed greatly to the success of this strategy, as did the tireless lobbying efforts of education authorities by outstanding scientists such as Pierre Léna and Yves Quéré, so as to keep early science education high on the agendas of the relevant ministries.

The interest of the political class and of academia in reforming early science education is reflected in the *media interest*, whether in the written press (newspapers, magazines) or audio-visual and digital media. Between 2003 and 2005, the national news radio broadcaster (France Info) transmitted a weekly chronicle on *La main à la pâte*, which contributed greatly to the visibility of the programme among the general public. The national cultural radio, France Culture, also continues with a number of features. In September 2010, the death of Nobel Prize winner Georges Charpak, one of the three founders of *La Main à la Pâte*, reawakened media interest in the topic.

In societal debates, the questioning of traditional pedagogical methods by teachers and parents alike, and more generally, the increased involvement of parents in schools, open the road to educational and pedagogical innovations. What used to be an exclusively professional debate, confined to schools and educational inspectorates, has by now widened to a subject of public debate, with political stakes to match. Science and technology has become a social concern, because of its repercussions on economic growth and societal goals; against this backdrop, the teaching of science now appears among the priorities for society. Against this background, the declining interest of students in taking science degrees and science careers is being taken more seriously by decision-makers: as a consequence, many are now convinced of raising learners' interest and curiosity in science from an early age on, by using more active ways of teaching along the lines of the IBSE approach.

IBSE into secondary schools

Starting in 2006, initial forays were made under the aegis of the academy to introduce IBSE methodologies into secondary schools, in an effort to sustain the renewed interest of children for science throughout their school careers. Under a programme named EIST, or "*Enseignement Integré de Sciences et Technologie*" (Integrated Education in Science and Technology), a pilot was launched in 400 classrooms.

The initiative to launch this pilot also helped to bring about, as a new element in the national science education plan developed by the French Ministry of Education, the *Socle commun de connaissances et de compétences* ("Common Base of Knowledge and Competencies") which was implemented since 2007 and which put a strong emphasis on inquiry-based teaching in both primary and junior secondary schools.

Numerous parliamentary reports were submitted to both the National Assembly and the Senate (second chamber), such as "*Les jeunes et la science*" (2005; Youth and science), or the report by the Commission on cultural and educational affairs presented by Jacques Grosperrin in 2010 on secondary schools and on the "Common Base of Knowledge and Competencies". The year 2010 also saw the announcement by the Minister of Education of a „*Plan Sciences*" (Science Plan), followed by new funding opportunities offered under the Calls of the programme "*Investissement d'avenir*" (National Investment for the Future). It was prepared by the so-called Commission Juppé / Rocard, emphasising the evolution of science education. It is currently supporting the creation of a network of centers, including a national coordinating centre and several regional science centres, with the purpose of training science teachers in the IBSE approach as part of a continued professional development along the lines pioneered in the UK with the National Science Learning Centre (NSLC) in York, and its network of Regional Science Learning Centres.

Promoting IBSE throughout the world

Ever since 1998, and increasingly in the new millenium, *La main à la pâte* has been active also internationally, collaborating with the major inter-academy, science and cultural organisations and mobilising the scientific community, sharing experiences, expertise and best practices through meetings that would typically involve teachers and policy makers alike, offering specialised teacher training, often in partnership with teacher training colleges and universities, offering to exchange and translate pedagogical resources, including websites and other online material, international networking, and through collaborative projects for the world's classrooms (such as *In the steps of Eratosthenes*, *Hygiene and Beauty*, *Europe - Land of Discoveries*, *Learning to find your way around*), which could often rely on the use of the latest IT technologies.

By 2005, bilateral collaborations had been established with over 30 countries aimed at developing and advancing IBSE. In these bilateral exchanges, some of the key structural problems were rediscovered that had been found in the French context a decade or so before, such as: primary education focusing on the triad 'reading–writing–arithmetic', with little or no science learning, and teacher training being under the responsibility of faculties of education, which have their strengths typically in psychological or sociological visions of education, but have little if any connection with the realm of the sciences and its actors.

Since 2010 an annual week-long training workshop is proposed by *'La Main à la pâte'.* Language of instruction is English, and while the organisers can accommodate some 50 foreign teachers and education stakeholders each year, the workshop has been oversubscribed since its inception.

The conclusions reached and recommendations made as a result of the analysis conducted in numerous countries, showed strong convergences with those reached in France: no matter what the state of overall societal development, and despite the often adverse conditions in teacher's training, levels of salaries and recognition of the profession, there is an increasing perception of the urgency to add science education to the classical triad. It can be safely assumed that the universality of science, uniting scientists of various cultures around this concept, will be likely to help along the sharing of classroom protocols, the exchanges on difficulties teachers may face and training elements of particular usefulness. While Internet is nowadays providing a powerful tool also for the autonomous, professional self-improvement of teachers, a structured approach with the involvement of the educational authorities may overall be more appropriate. Successful use of Internet resources are the partial translations and selective adaptations of the French-language website of *La main à la pâte* in Germany, Serbia, China (in Chinese), Egypt (in Arabic) and South-America (in Spanish). The Internet also offers the possibility for distant twinning of classes on joint projects, as has been tested out successfully in the *Eratosthenes* project, which measures the earth's diameter using the shadow of a stick.

Advancing IBSE approach across Europe

There has been a close interaction between the French national programme, especially *La main à la pate,* and the European Commission's efforts to promote the rejuvenation of science education across Europe through Calls under the "*Science in Society*" programmes in FP6 and FP7. What started out as a pioneering action in France was well received and enjoyed rapid success at European level: for example, the virtues of the IBSE approaches developed in France featured prominently in the Rocard report of 2007. Since 2004, under the auspices of the academy of sciences, *La main à la Pâte* had co-designed and coordinated as lead partner the FP-6 project "*SciencEduc*" with partners from five countries. It was followed by *"Pollen"* (2006-2009) with partners in France and in 11 other European which created a network of 12 European "seed cities", one per country, in order to test avenues for the advancement of IBSE approaches in different local contexts. A set of 100 primary school classes were selected to become, in the course of four years, prototypes for a new form of comprehensively renewed science teaching in primary schools. *Pollen* built on the existing experiences in France, the UK, Sweden and elsewhere, to help less-advanced partners establish a common set of data and resources, evaluation concepts, teacher training protocols and a framework of comparisons and informal benchmarks. The goal of the project was to identify in each country a pioneering pilot centre as prototype that could integrate all the country-specific aspects of a given educational system, institutionally as well as culturally. In a few of these countries, science academies as well as civil servants joined the efforts, as did the relevant educational authorities, in order to create models for a *school–society–science community*, which would be expected to lead to profound and sustained changes. *Pollen* produced a number of tools for teachers, coordinators and trainers. These documents initially were produced in English, but were then translated into French and into other languages, and have remained useful for implementing IBSE pilot centers across France, especially the *"Support Handbook for establishing a Seed City to develop Science and Technology in Primary School".* Among other helpful educational materials for teachers operating under national curricula is the guide on *"Designing and Implementing Inquiry-Based Science Units".* These resources remain freely available on the Pollen website.

Under FP7, *La Main à la Pâte* is now the leading partner of *"Fibonacci",* which involves 24 countries and 38 centers, plus another 24 new centers added in early 2012. It aims at setting up a cascading network of pioneering pilot centers of different maturity and, in doing so, seeks to establish a self-perpetuating peer-learning environment. Fibonacci, as the name indicates, also has as one of its objectives to include mathematics education into the inquiry-based approach, by combining two earlier successful FP-funded pilots – focusing respectively on science education and on mathematics education for sciences. Fibonacci will complete its activities at the end of 2012.
It is worth mentioning that in May 2011 a general presentation of the current national and international activities of the *La Main à la Pâte* programme was given by Odile Macchi from the French Académie des sciences and chair of the ALLEA Working Group on science education (regional European council of the IAP science education programme), at the invitation of the dedicated and recently established expert working group on MST. She presented also the French 'common base of knowledge' recently introduced in connection with new curricula.

While these European projects were often inspired by French experiences and led by French partners, the national French programme *La Main à la pate* has benefitted from European projects and cross-border exchanges. They reinforced the position of the programme in France, adding to its reputation and contributing to securing continued support: close and formal contacts with relevant authorities and a framework agreement was reached between Académie des sciences and the French Ministries responsible for education. Beyond FP6 and FP7, the French academy of sciences, jointly with its *La main à la Pâte* programme also used the opportunities of the other relevant European Call stream – under the Directorates Education And Culture (EAC) - to further advance IBSE approaches in Europe. For instance, through the so-called "*Maths, Science and Technology (MST) clusters*" set up by the EAC Directory in 2006, IBSE projects have progressed in several European countries. The MST clusters aimed at following the European MST benchmarks, improving participation in MST studies and careers. The emphasis was on the gender imbalance and low achievers and raising the level of scientific culture of citizens, with the ultimate objective of reaching the Barcelona target of 3% of GDP spent on research. In a wider context, the MST clusters referred to one of the eight key competencies for lifelong learning, improving also the scientific culture of citizens. Overall priorities included to *'modernise pedagogical methods; enhance professional profile of teachers; ensure transitions from secondary to tertiary sector; promote partnerships between schools, universities and industry'*. The follow-up of the work under the cluster would include reflections on improved didactics, on the necessary professional profile of MST teachers, on school curricula, partnerships, and specific support to be given to girls and other identified groups such as high and low achievers. The five initial peer-learning activities of the clusters were closely linked to policy priorities on MST-related matters at the respective national levels[3]. The third one was co-convened by the academy in France under the title 'Renovation in science teaching: an inquiry-based approach'. On this occasion representatives from ten European countries met in 2007 with a large group of French experts and practitioners; sessions and visits focused on the institutional dimensions of rolling-out a "hands-on" approach, addressing also the role of varied stakeholders such as the school inspectorate for monitoring and evaluation; graduate engineering schools for coaching teachers in the classroom; municipalities, scientific research centers, active citizen groups for mentoring schemes; science museums for a possible support (e.g. Cité de la Science et de l'Industrie at La Villette) and other partners.

All these pilot and peer-learning projects aimed at comparing across Europe a variety of methods, activities and programmes that serve the common purpose of fostering an awareness of the importance, opportunities and challenges of renewing science teaching for pupils and young students. Their main goal was to spread methods and good practices in science education through the creation of a European network of partners who would take pilot initiatives to directly support teachers' practices in the classroom. Contacts were also established with a number of other FP coordinated projects that neither the academy nor *La main à la pâte* are directly involved in, as for example the S-TEAM project creating useful links between project coordinators (*Proco-Net*). The *Scientix* platform has also been found useful in this regard.

In an environment that goes beyond the FP-funded projects, the WG has proven a useful platform for preparing, across all those countries in which pilot projects have been supported in the past, the political interaction necessary to effect, eventually, a system change. If the French experience is anything to go by, the next step at European level will be to ensure that lessons can be drawn from pilot projects and that systemic change (curriculum; teacher training; etc) can be triggered, that would anchor IBSE firmly in the respective national educational systems.

[3] e.g. the 'Delta Plan' in the Netherlands, the 'Focus on mathematics education' in Sweden, the promotion of MST in Norway, of scientific culture in Portugal, and of science and maths reform in Latvia.

1. Austria: Austrian Academy of Sciences (ÖAW)

The Austrian Academy of Sciences (ÖAW) fulfils three functions in the Austrian science system: as a Learned Society, it assembles the leading Austrian scientists and scholars and provides competitive and prestigious funding for young researchers in a number of programmes. As a research performing organisation it is the largest group of basic research institutes in all fields of sciences, social sciences and humanities outside the country's universities. With the "Junge Kurie", ÖAW has created an early career section that further links the Academy to the research environment in the country.
As a research organisation, the Academy has less contacts to the Ministry for Education than to the ministry in charge of research and innovation, and did not – at the time of reporting – recognise major contributions to any debates about science education, or "science literacy" or attempts to introduce also the teaching of mathematics in the context of reforms as are envisaged under IBSE programmes.
The Academy-affiliated Institute of Technology Assessment in Vienna published a study, in 2009, entitled "Technical Education for Sustainability. An Analysis of Needs in the 21st Century", which examined the implication of the United Nations Decade of Education for Sustainable Development (2005-2014) for technical education, which focuses, however, on higher education.

ÖAW as an institution is not involved, otherwise, in pilot projects on inquiry-based science education in Austria. Its local outreach activities in Viennese schools are rather focused on approaches that seek to promote understanding for science and research among young people. There are, however, also exchange visits with secondary schools in the Vienna region, where the Academy invites school classes to join its lecture series, and speakers from those lecture series then pay a visit to secondary schools ("Junior Academy"). Also, since 2006, ÖAW's cooperation with "NÖ-Bildungsgesellschaft" includes lectures to be given by Academy researchers at schools of the federal state of Lower Austria.
Austrian institutions participating in IBSE and related pilot and seed-money projects funded under FP6 and FP7 show a wide variety of diverse institutions (from ministries, over professional societies to individual research institutes). Here, as has happened in many other countries, the Academy could in effect play a key role in providing a platform for these various entities and their projects to interact and to develop common positions for future interaction with government in view of greater impact (on curricula and legislation) of these pilot projects which otherwise risk remaining dispersed and fleeting in impact.

2. Belgium: Académie Royale de Belgique and Koninklijke Vlaamse Academië voor Wetenschappen en Kunsten

In Belgium, education – as apprenticeship of citizenry - is strictly separated along the lines of the linguistically defined communities, as is incidentally the world of Academies, even if the Flemish- and French-speaking science academies have created an umbrella organisation to represent Belgium internationally in inter-academy setting, the Royal Academies for Sciences and the Arts of Belgium (the German-speaking community having their own educational system but no separate Academy).
Thus, the three community governments are responsible for issues related to science and mathematics education: The "Vlaamse Overheid" in Flanders (ca. 6 Mio. inhabitants), the

"Gouvernement de la Communauté française de Belgique" for the French-language teaching in Brussels and in Wallonie (ca. 4 Mio. inhabitants) and the "Belgische Deutschsprachige Gemeinschafts Präsidium" for the Eupen-and-Malmedy counties (80.000 inhabitants).

The Classes of Sciences of the two Belgian Academies of Arts and Sciences (Académie Royale de Belgique and Koninklijke Vlaamse Academië voor Wetenschappen en Kunsten) have been involved in nation-wide activities for encouraging science teaching, but primarily in secondary schools (Athénées and Lycées). Some of the 25 intermediate "National Committees“ organise competitions in different disciplinary fields (cristallography, astronomy, etc.)

The Academies have contacts with the Federal Ministry of Scientific Policy (responsible for the Belgian representation to inter-governmental science establishments such as CERN, ESA, ESO, as well as direct authority for the Federal research institutes in fields such as meteorology, space aeronomy, astronomical observatory, physics of the earth, Royal Natural Sciences Institute etc. for outreach activities.

However, with regard to inquiry-based science education, there has not yet been any official Academy involvement in pilot projects. It has been only after the establishment of the ALLEA Working Group on Science Education in 2009 that the Academies have taken the initiative to consult with well-informed colleagues about the exact situation in the different parts of the country. With the linguistically divided educational system, it appears as if approaches vary in the different parts of the country, depending on cultural affinities: science teaching in Flanders seems to take much of its inspiration from UK and from the Netherlands, while in the German-speaking cantons there is a certain affinity to the German system. Brussels and Wallonie, on the other hand, follow more closely the developments in France. For instance it keeps contacts with the CLEA (Comité de Liaison Enseignants et Astronomes) and the schools' general supervisors for physics and chemistry.

In public debates, the issue of "science literacy" is frequently referred to across the various media supports, whether in the press, on the radio and in TV debates. A long line of activities has been launched by successive Belgian governments to stimulate the study of science in school and at university, but it is difficult or outright impossible to assess the success of these measures (nor, it is fair to admit, has such an assessment been tried). Yet, a simplistic interpretation of the perhaps surprisingly strong economic performance of Belgian Hi-Tech industry even in times of crisis at the end of the 2000's seems to suggest that something must have been done right.

The academies' assessment, on the other hand, chooses a tone of greater urgency, notably with the recent report by Académie Royale de Belgique's Class of Technology and Society on the "de-industrialisation in (Western) Europe“: the report („manifesto“) stresses the need for a better integration of scientific, technological and entrepreneurial education. The report also explicitly identifies the need to cultivate local talent for the future of science and engineering positions in academia and industry because, unlike the U.S. – the report argues – Europe cannot count on a culture of immigration to make up for the shortfall. In this context the current reluctance of pupils to choose a career in science and technology is, in the view of the authors, a mirror-image of a society lacking the necessary level of S&T literacy and hence unable to knowledgably make choices about science-related matters (energy; food; climate etc.).

Even though the academies themselves do not have, currently, any specific action in the field of IBSE, they were involved in the wider debates in the 1970's and 1980's about the programme for mathematics in secondary schools, notably in the French-speaking part of Belgium. At the time, ministries favoured a very abstract teaching without any graphical support (even in geometry); but after severe criticisms on the part of the professional associations of engineers, physicists and mathematics teachers, the program reverted to what it was around 1965, except for some simplifications (no demonstrations in 2 or 3 dimensions geometry, for instance). In Flanders and in the German speaking region, programmes generally remained of a more conservative type.

3. Bosnia-Herzegovina: Academy of Sciences and Arts of Bosnia and Herzegovina (ANUBiH)

The Academy of Sciences and Arts of Bosnia and Herzegovina (*Akademija nauka i umjetnosti Bosne i Hercegovine ANUBiH*) was established as the national academy in 1966. Its history goes back to the Scientific Society, founded in 1951. The Academy, as an independent body, has by law a responsibility for promoting the development of science and the arts in the country. This task it fulfils by giving support for scientific research and arts-related events and through publications. The academy has six departments (social sciences; medical sciences; technical sciences; natural sciences and mathematics; literature and arts). Among the working committees there is currently no committee for science education, though policy aspects of education could be dealt with under the remit of the committee for scientific, technological and social development. The academy has not been involved, as an institution, in efforts to introduce inquiry-based science education or related approaches in the country.

Any action in the field of education is rendered immeasurably complicated by the constitutional design that had emerged from years of civil war: Bosnia and Herzegovina is divided in two entities, the Federation of Bosnia and Herzegovina and Republika Srpska, with the Federation being further divided into ten cantons – with the district of Brčko under a separate administration. If educational matters are regulated by the respective Ministries of Education of the Federation and of Republika Srpska, each canton in the Federation also has its respective Ministry of Education. In terms of the potential influence of the National Academy on education, matters risk taking a turn for the worse, with the establishment of new regional academies, which are also constituted along community lines: the first step in the direction of further fragmentation and mutual isolation was made when several years ago, Bosnian Serbs set up the Academy of Arts and Sciences of the Republika Srpska in Banja Luka; recently, a Bosniak (Muslim) Academy of Sciences and Arts was set up in Serbia, triggering an announcement of the imminent establishment of a Croatian Academy of Arts and Sciences in the Southern Bosnian town of Mostar.

Such fragmentation may hinder the deployment of progressive teaching resources and the upgrading of teachers' skills. Neglect for modern teaching methods and tools in the sciences may also bring to an end a remarkable heritage from socialist times, namely that the wide-spread pattern of reluctance among girls to embark on a course of studies in the sciences (the example studies was physics) is reported not to be found among Bosnians (residents and emigrées alike) to the same degree as in other countries. As was argued in the FP6 funded project PROMISE ("*Promotion of Migrants in Science Education*") which involved a team from the University of Sarajevo, this phenomenon and the resulting higher than EU average percent of female science graduates appears to be linked to the existence of socialist-educated and professionally–trained female role models in the mother generation. The project found that this diverging pattern of attitudes and aspirations is maintained also in at least the first generation of emigrants.

4. Croatia: Croatian Academy of Sciences and Arts

The Academy, which became the Croatian national academy in 1991, had been founded in Zagreb in the mid-19th century and soon evolved into a formidable cultural force in the revival of the Southern Slavs inside (Croatia, Slovenia, Bosnia and Herzegovina) and outside the Austro-Hungarian empire (Serbia, Bulgaria etc). Its original name „Yugoslav Academy of Sciences and Arts" hints at this wider irradiation of influence. In the independent Republic of Croatia, the Academy counts among its responsibilities to make proposals and advise on the promotion of the sciences and the arts in areas of special importance to the Republic.

In the field of science education, the Croatian Academy of Sciences and Arts has played an active role in a variety of formats in the work leading up to the new National Curriculum for primary and secondary schools, which had been initiated in 2008 by the Ministry of Science, Education and Sports. The strong engagement of the academy stemmed from a concern about a possible weakening of teaching in mathematics, physics and chemistry in curricula for both primary and secondary schools. As a result, a wide-ranging societal discussion evolved about the importance of science education. The Academy has been active in these debates through the participation of several members in the commissions preparing the national curriculum, but also through the Committee for Cooperation with Croatian Universities and Scientific Institutions, and – in a very pronounced fashion – through the Department of Mathematical, Physical and Chemical Sciences.

It is to be noted that these discussions - within the Academy and beyond – had seen, for a long time, two diverging positions being upheld with regard to reforming science education. The first position was advocated by those involved in pedagogy and proposes an interdisciplinary approach in the teaching of science, somewhat akin to the philosophy underlying IBSE approaches, notably for primary schools. The second position was represented mostly by natural scientists in the Academy and argued in favour of the time-honoured approach of teaching science as divided into individual disciplines. The core of the debate was a disagreement about the level up to which science should be taught in an interdisciplinary fashion, and from what level onwards the disciplinary approach should be followed. Most experts in pedagogy suggested to follow the interdisciplinary approach for the full first ten years of education, so that disciplinary teaching – say, of physics, chemistry etc. - would be introduced only during the final two years of school education. Active natural scientists believe that disciplinary education in the various branches of the natural sciences should start significantly earlier, i.e. after the first six years of the school education. Several meetings and discussions were held about the strategy in education and the development of the national curriculum, but a common ground was difficult to find. In the Croatian Academy of Sciences and Arts, the Department of Mathematical, Physical and Chemical Sciences took an active role. Its position is summarized in the table at the end of this subsection.

The majority position of the Academy is that natural sciences should be taught disciplinarily by professors/teachers who themselves would have benefitted from formal education in the corresponding disciplines. Interdisciplinary subjects are important and should be included in certain disciplinary courses like physics, chemistry, biology etc. The underlying philosophy is that one learns in a disciplinary fashion, but once educated one needs to be able to solve interdisciplinary problems by working in groups that are typically composed by experts in different disciplines. The Academy is organizing discussion meetings on this subject starting in June 2011.

(1) Science education in schools is important for all citizens as part of general culture and scientific literacy is fundamental for an appropriate understanding of major social issues, enabling citizens to make well-founded choices in issues such as energy, ecology, health, use of chemical products, etc.
(2) Science education in schools should be seen as the foundation for any course in higher education in the natural sciences, pharmacy, medicine, and the various fields of technology.
(3) Science education in schools should be organized according to traditional disciplines (mathematics, physics, chemistry etc.). Important and interesting interdisciplinary topics should be incorporated into the courses of the relevant disciplines.
(4) Mathematics is a subject by itself, which is the basis for all other sciences; by the same token, physics is required by those studying chemistry, just as future biologists and earth scientists need a sound knowledge of both physics and chemistry.
(5). Mathematics, physics and chemistry are fundamental disciplines and should be taught from an early stage on.
(6) Success in science education depends crucially on knowledge, attitude and educational skills of the teacher; their understanding of the discipline they teach should therefore be of the highest possible level; in addition to having a formal education in those scientific disciplines, teachers should also participate in continuous professional development and on-the-job training (seminars etc.).
(7) Further in-service education for teachers should include both scientific aspects and pedagogical methodologies.

5. Czech Republic: Academy of Sciences of the Czech Republic

The Academy of Sciences of the Czech Republic (ASCR) is a public, non-university, scientific research institution with its own system of research institutes that are primarily engaged in conducting basic research. ASCR also participates in the formulation of the country's S&T policy. The Academy and its institutes participate in national and international research programmes, promote knowledge transfer from basic to applied technology and innovation, and, more generally see it as their mission to foster education, scholarship and culture. Part of this mission is to engage in the strengthening of the science base of education.
The Academy actively promotes science literacy across the country in order to enable citizens to participate, in an informed fashion, in science and technology related societal debates. As part of its science outreach to a wider public, ASCR subsidises selected science and popular-science publications (2009: forty-four books).

A total of 117 lectures, 12 exhibitions, 6 science cafes, 7 presentations, 4 seminars and 2 conferences were organised as part of the 9th Annual Science and Technology Week and of the Open Houses throughout the institutes of the ASCR system in 2009; these annual Open House events are regularly organised in several Czech cities. The total number of participants does not cease to rise (2008: 25,600 participants, 2009: 31,550; 2010: 33,555; 2011: 42,506 counted attendees). The year-round cycle of lectures for the public known as Academic Prague, which is organised jointly with Charles University, also reaches a wide public, along with the cycle of lectures specifically tailored for secondary-school pupils.

The ASCR is a member of the „*European Science Events Association*", which associates European institutions that organise science festivals and similar events. Coordinating educational events for the general public through this association helps building new international contacts. As an example, the ASCR took part in the ceremonial launch of the International Year of Astronomy on Old Town Square in Prague in the presence of leading personalities from abroad and the Institute of Astronomy organised the *„100 hours of Astronomy"* project. In a similar fashion, the Institute of Geology is participating in the preparatory group for the activities of the International Year of Planet Earth.

As part of a more general commitment to science communication, ASCR researchers regularly appear as experts in the national and regional media, commenting on events at home and abroad. A growing number of diverse science education activities are also organised in informal (non-class room) environments.

While ASCR actively seeks to provide information about science as to as universal a public as possible, one of the outspoken aims of such activities is also to attract promising novices for a science career already from an early age on. An example for such activities is given by the Institute of Astronomy, whose researchers involve not only the public and schools, but also children at nursery schools, as part of their programme to mark the International Year of Astronomy.

Overall, employees of the ASCR gave more than 2,000 hours of lectures at secondary schools in 2009. Almost a hundred competitions for secondary-school pupils were organised to motivate them to take an interest in science. As part of its outreach activities, the by now traditional programme "*No Fear of Science*" consists of cycles of public lectures by Academy scientists for secondary school students and teachers on topics in the natural and technical sciences. The main aim of this year-long activity is to show real current scientific advances to the next generation of potentially aspiring researchers and to foster their interest in science and research. The project thus intensifies the communication and cooperation between high schools and research institutions at the Academy and universities. Average attendance has been more than 100 students. Within the cycle, the *„Day with Astronomy"* was especially successful, linking-up as it did with a series of spectacular events organised in the context of the International Year of Astronomy.

The Institute of Astronomy has been an active participant in the FP-supported project EU-HOU (*„Hands-on Universe*"), which had started in 2004 and is now in its third funding phase (2010-2012: „Connecting classrooms to the Milky Way"). EU-HOU is a collaboration of hundreds of teachers and scientists from 14 countries and develops exercises that promote active learning on the basis of real astronomical data. The observational data can be acquired by the pupils and further processed in the classroom with the help of pupil-friendly software. Data capture occurs with didactical tools (Webcam system, radio telescope) that had been developed in earlier phases within the project, or, more recently, through a European and global network of automatic telescopes operated via Internet. At the heart of the most recent project phase is the establishment of such a European network of radio telescopes for education. The results and experiences of the pilot project will be integrated into innovative and up-to-date educational resources that will arise from this close collaboration between researchers and teachers.

In a similar mode, *„Earth Day"* on 22 April 2010 brought together more than 100 people who watched simulations of natural phenomena such as earthquakes and volcanoes at Geopark in Prague, following a series of introductory lectures by Academy based geoscientists. The event was part of the FP-7 supported CASC project (*Cities and Science Communication: Innovative Approaches to Engaging the Public in Science").*

Summer schools supported by Academy institutes are also increasing in numbers and have become an increasingly significant tool in bringing science closer to potential new adepts. The Institute of Physics organises weeklong study residences with excursions for secondary schools and their teachers, as well as all-day seminars for physics teachers at secondary schools. It has also recently organised a visit to CERN for secondary school teachers. The Institute of Computer Science, together with the Ministry of Education, Youth and Sports prepared a day of lectures and a workshop as part of a camp for students who are preparing for international competitions. The Institute of Microbiology and the Institute of Experimental Botany arrange excursions for pupils from secondary schools throughout the school year. Also their photo exhibition of the winners from the competition *"Plants with a Story"* was a great success with the general public.

A pilot project on IBSE was implemented by the Ministry of Education, Youth and Sports (Division of European Programmes) under the name *„Support for Technology and Science Fields"* (2009-2011). It offers structured support for the study of technology and science, including professional and research activities and targets potential university students in those fields. Project activities rest on three major pillars: (1) motivational activities, (2) science communication and (3) teaching support. The project has developed a methodology of support for technology and science education, background material, analyses and case studies to be presented in conferences, seminars, workshops, popularization lectures, and particularly through pilot activities across all regions. Three studies were produced during the analytic phase of the project (published in Czech only) on reasons for the lack of interest in S&T among school children, on employers' perceptions of the required qualifications of graduates in technical and scientific studies and a wide-ranging overview over online and hands-on, national and institutional projects worldwide and FP-funded science education and science communication pilot projects elsewhere. The Academy of Sciences is not a formal contracting partner in this project, but offers, through close collaboration with the coordinators, the capacities of its research institutes for the project implementation phase.

Also in the debate about reforming mathematics education, the Academy is very visible, notably through the Institute of Mathematics. The Department of Didactics of Mathematics of this institute addresses problems of mathematics education of pupils aged 5-15 years and cooperates with universities on the project design of mathematics education in elementary and secondary schools. The department also participates in preparing and organizing the Mathematics Olympiad. The goal of the research conducted at the department is to better understand the processes of learning and teaching mathematics, and the application of such knowledge to optimising mathematics education. Attention is also paid to identifying the contribution of mathematics to the development of both mathematical and general literacy, as well as to ways of how to improve mathematics classroom culture and how to enhance the professional competences of teachers.

Next to the Academy's promotion of IBSE-related approaches through various projects at national and regional level, other Europe-wide efforts or those co-funded by the European Social Fund and the national budget provide practical training and courses tailor-made for high-school science teachers to improve their professional skills. Also multidisciplinary seminars organized by the Academy help to create links between the different branches of science. As a research performing organisation, the Academy takes a keen interest in seeking to develop and to support new ways of stimulating a passion for scientific inquiry among young students; after all, its future performance as one of the nation's key research institutions depends critically on the continuous inflow of talented and ambitious young researchers. A focus of the programmes proposed is therefore on secondary-school students and on teacher training.

As part of an education programme for secondary schools, the *„Open Science II"* project was launched in 2009 (Operational Programme Education for Competitiveness, Support Area 2.3, co-financed from the state budget of the Czech Republic and the European Social Funds). Building on a similar, earlier project that offered secondary-school students in Prague an internship in the natural sciences and technical disciplines at one of the ASCR laboratories, OS-II offers talented pupils from outside the capital an internship in a laboratory of one of the participating 20 ASCR research institutes or at one of the cooperating seven institutions of higher education. A total of 150 researchers employed by ASCR and HE partner institutions devote part of their time to mentoring the selected students. The student internships are held for up to 12 hours per month for a period of two school years. The best results of these scientific internships will be published after student scientific conferences (2011 and 2012).

An open Call was distributed to all eligible secondary schools, and students could choose from over 330 internship topics. Some 450 students applied, and more than 200 were selected by the scientists, who have been leading the internship programmes at research institutes since early 2010. The strongest appeal was exercised by biology, mathematics and computer science, but also specialised topics from chemistry, physics, geology and geography found takers. The students that were selected have a unique opportunity to become acquainted with the practical side of the everyday real scientific research; they can also participate actively in top-class research projects of scientific leaders or carry out their own plans under expert supervision. This project is part of the Academy's continuous quest to win over talented students for a career in science. Important elements of the IBSE philosophy – exchange with and learning from the practice of active scientists – form the cornerstones of the programme implementation, all the way to acquiring the skills necessary to be able to present one's research results effectively and convincingly.

A similar project has been running in cooperation with the Centre for International Mobility of the Region of Southern Moravia in Brno. While also focusing on talented secondary-school pupils, it offered a wide range of other measures, including support for the self-education of gifted students from the 1st year of high-school all the way up to the bachelor’s degree, high-school research projects, and diverse activities for high-school students such as internships at research institutes, e-learning courses and IT-excursions and interdisciplinary competitions.

In a series of events supported as part of the FP-7 CASC project (“*Cities and Science Communication: Innovative Approaches to Engaging the Public in Science”)*, high-school students in Southern Moravia could learn about the impact of human activities on the environment through a series of lectures and laboratory exercises. “*Learn to understand the environmental context and begin to behave differently”* (May 2010) took place at Masaryk University campus in Brno, and targeted 60 students from South Moravian secondary schools who had shown particular interest in biology and chemistry. Students learnt about techniques in environmental research, tested their newly acquired skills in laboratory exercises, participated actively in discussions with experts about environmental issues, and shared their new expertise and communication skills with their peers upon returning to their schools.

The *Open Science to Regions* programme is an extension of this project. Three practical courses in biology, chemistry and physics for secondary-school teachers were prepared as a possible in-service further education pathway for secondary-school teachers. Their aim was to contribute to the improvement of the quality of the teaching of natural-science subjects. Improvement in communication between high-school teachers and students was particularly emphasized. A total of 79 teachers were trained during the summer months. This „*Open Science for Secondary School Teachers*” programme component seeks to familiarise teachers who already have a teaching approbation in biology, chemistry and physics, with the latest advances in science by creating opportunities for exchanges with leading Czech scientists. The programme also seeks to introduce them to new educational approaches, mainly “hands-on education” in scientific laboratories. The programme rests on the assumption that better prepared teachers can serve as role models for students to choose a course of study in the natural and technical sciences.

Pilot projects on science education in primary and middle schools have had considerable impact at national level, whether funded from European or from national resources. Consequently, there has been a remarkable change in public and political perception of the importance of early science education in the Czech Republic since 2000. The main factors influencing this change are the growing awareness of initially lower than expected performance of the Czech education system in international benchmarking exercises such as PISA (though by 2006 Czech children scored above average in science literacy), the envisaged consequences of the demographic trend which shows a pronounced birth rate decline in the early 1990s, and the growing need of the national economy for qualified staff educated in S&T disciplines. The shift in attitudes was felt, obviously, first and foremost among the professional community of teachers, in schools and universities, but was soon reflected also in the media. While the increased recognition of the issue was acknowledged also among political decision makers and within national policy, no significant legislative or conceptual changes were introduced; support provided was given mainly to specific programmes that were often of the nature of pilot projects.

Against the background of a less than completely articulated national policy and with the resulting mushrooming of many uncoordinated initiatives, there is in the Academy some scepticism about the systemic effectiveness and impact of the FP-funded SiS-pilot programmes or their equivalents at national level. Partly this concern stems from the fact that pilot projects are often taken forward without being linked to overall national policy aims. As a consequence, the quantitative impact of these pilots is also limited. In terms of FP-co-sponsored projects, institutions from the Czech Republic only participated in six projects during the last decade; this occurred largely without direct participation of the Academy of Sciences. The successful projects all had different orientations, targeting, for example, specific areas in the popularization of science (movies; internet), conveying advanced methods of teacher education, networking of primary science education, building links with industry, or coordination of education in maths, science and technology. All of these are worthwhile goals and initiatives, and the participation of Czech institutions in these projects must have had some positive impact on the development of teachers' perception of science and their training; it can also be observed that a variety of new educational resources appeared in the Czech language. In effect, one may even surmise that to some extent, these actions may also have affected debates about national policies with regard to school curricula and gender issues. However, given the very limited (often: local) extent of the SiS-supported projects in particular, their impact risks to remain within a restricted regional context, particular areas of education or specific target groups. The same concern about stand-alone activities can be articulated in view of the many projects supported under the Socrates/Comenius scheme, as for examples the recent "*Improving Quality of Science Teacher Training*" project, with participating teams from Bulgaria, the Czech Republic, Cyprus, Lithuania and Turkey. The project aimed at implementing constructivism as a pedagogical theory into initial science teacher training and proposed the setting up of e-learning and training modules etc. On the other hand, it is believed that programmes under the Operational Programme EU "Education for Competitiveness" (e.g.: projects such as Support for Technology and Science Fields, Open Science) have produced more significant effects at national levels. Nonetheless it has to be noted that so far, formal teacher training in the Czech Republic only includes few elements of introduction to IBSE approaches; this reluctance towards the new methodologies is mirrored, by and large, in average classroom experiences.

On the other hand, it is beyond doubt that the national and European pilot projects have helped to stimulate the interest of the scientific community in advancing science education, both in the Academy of Sciences and outside. Examples of the significant involvement of several hundreds of researchers from the Academy of Sciences and other institutions of higher education in such activities have been given above. The closer link between senior scientists and teachers may also be an encouraging experience for some among the teachers, notably the senior ones, to revise their scepticism vis-à-vis exploring IBSE-style approaches. It can be expected that the Czech government will be further interested in continuation of programmes of science education funded by EU. The optimal channel for this message would be the Ministry of Education, Youth and Sports of the Czech Republic and the Academy of Sciences has established close contacts with the Ministry, hoping for a better overall coordination in the application and the uptake of results from pilot projects, and that its future involvement with FP-funded projects will bear fruit also at the level of national educational policy.

6. **Estonia: Estonian Academy of Sciences**

The Estonian Academy of Sciences, founded in 1938 as an association of top-level scientists and scholars, has as its primary mission to foster new knowledge that can contribute to the economic growth and a better quality of life in Estonia. Once its research institutes were restructured or transferred to the universities, the Academy was instrumental in launching the national science foundation ETF. Today, its remit also includes the enhancement of public understanding and appreciation of science and scientific methods of thought. The former President and current vice-president of the Academy, Professor Jüri Engelbrecht, has been President of ALLEA since 2006 and has emphasised on many occasions the central role of education, and science education in particular, for the building of knowledge-based societies in Europe. It must be emphasised, however, that the main mission of the Academy with regard to science education remains to improve communication about the world of science and the achievements of Estonian scientists, encouraging talented young people in the process to choose science as a subject for their tertiary studies, and ultimately to aspire to a career in science.

In Estonia, the forms and content of education, including matters of education in the natural sciences and in mathematics as well as the related curricula are defined by legislative acts. In the run-up to the recent amendment of the "*Basic Schools and Upper Secondary Schools Act*" (in June 2010), EAS debated the issue of science education and school curricula at different times: internally, the topic was taken up during seminars and at Board meetings, and was also discussed during the General Assembly. As a consequence of these deliberations, EAS submitted recommendations to the lawmakers. In addition, the Academy contributed to the compilation and publication of textbooks for higher education here. It also sent delegates to participate in expert panels and in commissions created to contribute to science education matters within national programmes, and is a partner to the relevant decision-making bodies and to institutions of higher education.

Science education is seen by the Academy as the backbone for a knowledge-based society in Estonia and beyond and is believed to have an immediate impact on the functioning of society. A well-balanced, quality-oriented and effective science education system is also a prerequisite to excellence in research and to the growth of capabilities in knowledge application and innovation. Political decision-making that is based on scientific evidence is a must at every level of 21st century societies, whatever the topic in question, but can be sustained only if society as a whole is science literate. Therefore, debates about "science literacy" are a constant feature in debates in all sectors societal discourse, also in the mass media, and the Academy and its members are regular participants in these debates, whether as experts or as citizens.

Projects on IBSE fall into remit of the Faculty of Social Sciences and Education of the University of Tartu and Tallinn University. A number of Members of EAS are affiliated to the University of Tartu. When a new national curriculum for basic and high school education was introduced in 2002, it included for science education what, at the surface, looked like very modern elements. Yet, it was soon found that a main stumbling block for hands-on inquiry in the study of science were the traditional teacher training methods and the available teaching and learning materials. On the other hand, with the subject plan of the national curriculum being quite general, listing terms and concepts ("solids, liquids, weather, plants, animals, senses, comparison, measurement, organisms and their habitats"), there was certainly scope for innovation. The Estonian working group of the FP-6 co-sponsored project "*Scienceduc*" supported the development of teacher guides and other teaching materials based on IBSE methods, adapting materials for pre-school and primary school level from the STC program (USA). Trials were made in a number of schools and kindergarten in Pärnu, Tartu and Türi, and the materials were revised after valuable feedback was received from teachers. At the 2nd European Conference on Primary Science and Technology Education *"Science is Primary II"* which was held in 2006 in Stockholm, project participants from the University of Tartu reported on "a comparative research program to measure students' emotional and mental development at the primary level using psychological tests", that aimed at proving the effectiveness of IBSE-approaches. The sample remained small – "due to the low interest of our educationalists and lack of resources" - but the study, published in a medical journal, demonstrated positive differences in the development of those students who had experienced IBSE methods at school. As in the case of similar evaluations elsewhere, the reform of teacher training and in-service professional development appears to be a crucial element.

For its activities in support of science education (with elements of inquiry-based education), the Academy acts through a number of affiliated societies and through partnering with other civil society institutions.

As part of the FP-sponsored "*European Researchers' Night*", coordinated by the Science Centre AHHAA, EAS was responsible for activities in the capital Tallinn. The event presented to a wider public and in particular to schoolchildren of every age, science-related issues and, more generally, the professional world of researchers. EAS has been involved with Researchers' Nights since 2006. 9-10 year olds enjoyed in particular the experience offered by the Estonian Children's Literature Centre with cooperation from researchers of the Institute of Cybernetics at Tallinn University of Technology: children learnt about the research of computer scientists and were given an opportunity to programme an animated cartoon or a computer game and to operate a cube robot. Next to many other activities in the capital, six other cities are involved, with the Estonian National Broadcasting service contributing to the project as partner.
EAS also initiated and supported since 2008 a science programme "The Falling Apple" on Radio Kuku, dedicated to essential issues in Estonian science, which has become popular among teenagers for its practice of targeting topical issues.

The Academy supported within the current schemes the *Estonian Physical Society* in their science education activities. One of the EPS initiatives is a "*Science Bus Ursa Major*" that travels from school to school as a sort of mobile laboratory, introducing experiments in physics, chemistry as well as mathematics and giving also science theatre performances, all in order to enliven the usual school science curricula and to attract children to discover for themselves the world of science. The Estonian Physical Society also supports the Physics Olympiad of Estonian schools and awards an annual special prize (annual subscription to "Scientific American") to a student from secondary schools. Together with the Science School of University of Tartu, the Society organises science camps which, in 2009, attracted some 132 students of forms 5-9. Topics treated under scientific supervision were robotics, physics, chemistry, materials science, biology, and rocket science. Jointly with the Department of Natural Sciences of the University of Tartu and the University's Science School a programme of workshops was launched for selected students of forms 7-12 in the fields of physics, chemistry and biology. Every programme comprised 32 hours; by the end of 2010, 1699 people (students and teachers) had registered in working groups. Within three months, 192 working groups were convened in 25 support schools across Estonia with the help of 38 supervisors. Next to these activities among student, the Society also organises meetings with physics teachers in different locations across the country – promoting, to give an example of 2010, the integration of different disciplines, such as chemistry and physics through measurements and experiments. Efforts are also made to convince political authorities to recognise the need for continuous professional training of physics teachers. EPS is also helping to support the implementation of new syllabi by issuing a competitively awarded grant for writing gymnasium physics textbooks, which would be published both as hard copy and in electronic format with the help of Tiger Leap Foundation and Webmedia. Recently, the EPS also has been employing European Social Fund support to organise, as an activity of GLOBE Estonia, a summer camp with participation 150 teachers and students, including a student conference and a teachers' seminar.

7. Finland: Delegation of the Finnish Academies of Science and Letters

The Delegation is the umbrella organisation of four academies of sciences, letters and technology in Finland. It operates nationally and internationally to promote high quality research in all sciences and in the humanities, produces expert reports and statements issued as part of its commitment to science communication with society at large, and awards prizes. The Delegation itself is not involved in science education activities, but the Technology Academy Finland organises the world-renowned international millennium youth camp (see below).

Due to its excellent performance in international benchmarking exercises (science, mathematics, reading), interest has been growing in the reasons behind the successes of the Finnish education system ever since 2000. The teaching profession – despite salaries that certainly do not exceed the international average – has a good reputation in Finland; teacher training positions enjoy oversubscriptions of 1:10, which may have to do with the relative job security, most teachers being full civil servants. The strong political and societal commitment to equal opportunities – also in terms of regional distribution of and access to resources – and a comparatively homogenous population are matched by a teacher training philosophy that actively transmits skills for dealing with problematic students early on: as a consequence, PISA data of 2006 show that in Finland only 5% of the overall performance variation can be linked to school differences (compared to, for example, Germany's 33%). Furthermore, there is a good uptake of in-service training opportunities by teachers, and strong support for such measures by trade unions, which together have developed a professional ethics of high achievement. Within the conditions set by the Ministry, school authorities have a large degree of autonomy when striving for the best of their schools, students and staff. Some have argued that this decentralisation also carries risks of vulnerability for the system as a whole in times of economic crisis. So far, however, the system has proven resilient, and the efforts at instilling and maintaining a culture and work ethics where education is valued at schools are successfully matched by a policy that makes Finland rank top in terms of overall affordability and accessibility of higher education as well (one more factor to push the tertiary education enrolment rate to close to 43%, compared to an OECD average of just under 25% in 2010).

In some contexts it was even argued that Finland's real concern should be with how best to foster the best of the well-educated and highly-talented youngsters in science education, rather than focusing on the very small percentage of its low-achievers, as would be required to be in line with the declared priority of current European efforts.

Compared to the turn of the century, the importance of early science education has therefore been fully recognised by now, both among decision makers and in the general public. An important sign for and, at the same time, a factor for that change in attitude is the establishment, in 2004, of the national science education centre, the *LUMA Centre* (http://www.helsinki.fi/luma/english).

The aim of the Centre is to deliver positive experiences in learning, studying and teaching natural sciences, mathematics, computer science and technology at all levels of students. Support for young pupils comes in various forms, for example through the mathematics-club for primary school children which attracted 500 regular participants in the Greater Helsinki area in 2007; in the same year, 11 summer camps were organised that focused on the sciences. There is the webzine „Jippo" (online since 2003) which introduces children to the wonders of nature and natural science; the key objective of this free Internet club is to encourage the pleasure of curiosity and of asking questions. The material on the website can also be repackaged for classroom activities. With the recent addition of the webzine „Luova", LUMA now also targets teenagers; next to adapting and pursuing the approach of keeping the passion for scientific discovery and creativity alive, the site also addresses scientific issues of current affairs and offers a scientific look at matters of everyday life. It is part of LUMA's holistic approach that the "*Science Day for families*" makes a strong case for also involving parents in the learning experience. In keeping with the policy of creating equal opportunities across the country, LUMA has developed into a network of science centres across a number of cities and regions and continues to expand year after year.

If camps and clubs are lead by students in teacher training, interaction with research-active scientific staff from the university is an integral part of the LUMA concept.

One of the science education projects with the strongest involvement of scientists has become, especially during the International Year of Chemistry, the *ChemistryLab Gadolin* - organized by the Unit of Chemistry Teacher Education at University of Helsinki and supported by the Finnish Chemical Industry Federation. This new learning environment supports and develops the teaching and learning of chemistry, and encourages educational choices in this field. The project (2008-2011) is named after Johan Gadolin (1760–1852), the founder of Finnish chemistry research and discoverer of the element Ytrium. Its activities centre on active study visits of pupils aged from 7 to 20 years; short two-hours to much longer study courses include experimental laboratory work, computer modelling and visits to research laboratories and discussions with scientists. Teachers select contents that best fit the study objectives and curricula and lay the foundations for the visits through classroom study. New content is developed all the time, and during the school year 2010/11 topics offered include everyday chemistry, energy, renewable natural resources, material chemistry and green chemistry. The purpose of involving the corporate sector was also to offer access to new technologies that would not otherwise be in reach of schools. Besides the visits, briefcases with equipment, chemicals, protection gear, and instructions for a chemistry experiment for 30 pupils can be borrowed by schools for free (loan period: two weeks). For high school students, the Gadolin Club events, held either at the university or at collaborating companies, propose visits and lectures by top researchers from the chemical industry.

Chemistry Lab Gadolin participates actively in the continuous professional development of teachers, and disseminates up-to-date information on new experiments, practices and research in chemistry teaching. For example, the project offers tutoring for teachers in mastering the experiments and in the development of new, own experiments.

Cooperating companies see the project as an easy conduit for interacting with students, pupils, and teachers. Companies can co-organize experiments, present their field of activity, and while supporting the project through corporate philanthropy also give potential future professionals a glimpse of chemistry at work.

By now, the merits of the domestic educational system are receiving full attention and recognition and are seen as an asset in an international and comparative perspective: in June 2009 the Ministry of Education and Culture appointed a working group to prepare a national strategy for exploring the possibilities of exporting Finnish educational expertise.

A very successful new international initiative was jointly launched in 2009 by the LUMA Centre and the Technology Academy Finland**.** Technology Academy Finland (TAF) incorporates the Finnish Academy of Technology (TTA), the Swedish Academy of Engineering in Finland (STV) and the Industry Council, whose members represent leading Finnish industrial companies. Following a tough international selection process, the International *Millennium Youth Camp* (MY Camp) brings to Finland every June some thirty 16-19 year olds from all over the world who have demonstrated their interest and talent in mathematics, science and technology. For the first MY Camp in June 2010 almost one thousand applications were received from 62 countries. During a week-long science camp in mid-June they can present some of their work and attend group-work sessions which give them an opportunity to discuss with leading scientists from academia and industry. Group sessions are challenged to tackle complex issues, where scientific expertise alone is not sufficient; for example the following table is the task of the group working on water management systems (see Table below). The results of group projects are presented at a Gala in the Museum of Technology. For instance in 2010 effectiveness of carbon sequestration methods; sustainable methods of hydrogen production; *s*ustainable water purification methods and consumption patterns in rural habitats; biofuels from waste; social media and the ethical challenges of pervasive computing; and: applied mathematics. It is also part of the concept of the summer school that “MY Campers” are introduced to a number of Finnish companies and higher educational institutions which also are ready to give them a hand in starting up a career in these fields. Further reading for both challenge levels is made available online.

Finnish institutions – including some among those featured before – participate actively in European projects. A recent example of close cooperation between industry and schools is in the FP-7 supported project “*MaterialsScience*: University-school partnerships for the design and implementation of research-based ICT-enhanced modules on Material Properties”. Next to Helsinki, universities in Naples, Thessaloniki, Barcelona and the University of Western Macedonia participate in the project. Aiming to integrate results of science education research into practice, researchers and science teachers design teaching modules in Materials Sciences for a target student population of 10-15 year olds. The modules utilize existing modelling and simulation tools and strive to adhere to the IBSE objective of generating of active student engagement and collaborative learning.

***International Millennium Youth Camp*: Example of project task "Water management systems"**

Your task is to develop a sustainable water management system for a rural village community located in a drought stricken area. The village has 500 people. There is no existing infrastructure for clean water or waste treatment. The availability and quality of water from nearby river and the village well are poor. Some villagers grow vegetables and grain on small fields and raise some cattle.

Challenge level 1: Describe and visualize sustainable systems for:
a) waste water treatment including toilet systems and/or
b) drinking water purification systems and/or
c) grey water use or treatments systems (Grey water is water from the kitchen, shower, body and cloth washing)

How would the systems be different for a small community of 5 – 100 persons?
Also consider educational aspects for using the described systems. How do you want to solve these? Do you think the some of the side streams can be used for something beneficial, e.g. energy production or as fertilizer? If so describe how you would like the small community to use these assets. Also consider economical aspects of your solutions. How do you suggest that the small community shall pay for the investment and operations costs of the solutions you propose?

Challenge level 2: Innovate and develop integrated solutions for:
a) Provision of appropriate sanitation services;
b) Use of organic wastes including wastewater and/or composted manure to produce biogas for energy supply;
c) Practical uses to apply the produced organic fertilizer/grey waters for the improvement of agricultural soils and at the same time;
d) Reducing environmental problems and
e) Improving public health.

The improvement of public health would imply the disinfection of grey waters (if being used as fertilizers) and keeping the other components of the system such that they would not spread water-borne diseases such as diarrhea, scistosomiasis and malaria.
An additional component to be developed, which can be considered as optional, would consist of a system to purify drinking water with locally produced energy, such as photovoltaic energy. The generated electrical energy would also allow the charging of mobile phones, computers and even a village-scale mobile phone link station.

The combination and integration of all these services would make the system highly attractive for the local communities, and the following aspects should be considered in the assignment:
a) Institutionalization of the management;
b) operation and maintenance of the system at villages.
c) Would the system be marketable to NGOs and donors?
d) Who else could finance the systems at village level and provide the needed capacity building and training?
The market interest of industries to produce components for such systems would be due to the largely untapped markets in rural communities which would not easily obtain:
a)Electrification and/or
b) Biogas supply,
c) Services for clean water and sanitation , and
d)Agricultural fertilizers from conventional, centralized systems.
For instance, for the mobile phone industry, the largest untapped market (perhaps 40 per cent of the mankind) lives in such conditions and the competition for this market is important for many enterprises. The same could apply for environmental industries, which could benefit from joint undertakings with some other fields of industry.
The baseline is to search for sustainable solutions with appropriate level of technologies to improve the livelihoods of a large number of rural communities, and keep the villages appealing places to live also for the younger generation.

The University's Department of Applied Sciences of Education also participates in the more recent FP-7 supported 25-partners consortium S-TEAM (*Science – Teacher Education Advanced Methods*) which aims at disseminating the best methods of science teaching, specifically those based in IBSE methodologies.

As part of the FP-7 co-funded project "*Fibonacci*", the university's Department of Teacher Education offered, for example, a two-day course for 200 aspiring teachers (still in the training phase) on IBSE based „Integrative science education in open learning environments", but also as a combination of hands-on learning and ICT an in-service course that targets 25 teachers.

These and other European projects have certainly further raised the appreciation in government of the value of professional cross-border cooperation on science education, which has also been articulated through the appointment of a delegate deeply involved in the national reform initiatives to the Working Group on Mathematics, Science and Technology teaching of the European Commission's Directorate for Education and Culture. However, with the freedom given to municipalities in drawing up their school curricula (within the framework of the national curriculum), any highly-centralised approaches of imposing new structures would be met with some cultural and institutional resistance.

For the visibility of the EU dimension it is significant that the *EU contest for Young Scientists* (14-21 years of age) was held in 2011 in Helsinki. The week-long event featured the work of the winners of prestigious science awards at national level, who competed for prizes in front of a jury made up of leading scientists from academia and industry. Next to the core cash prizes, awards are also given by European science institutions, which invite the winners to spend a week at world-leading research centres such as CERN, EMBL or the European Space Agency. A number of these organisations had already been providing different forms of extra-curricular support: in the years 2000 to 2010, the "national CERN science teaching network", for example, brought together 123 groups with a total of 2,342 upper secondary school students and 360 teachers in camps on particle physics, with 276 teachers receiving up-dating instruction in the process. The local organiser of the 2011 event is TEK (Academic Engineers and Architects in Finland), and the event is held at the Academies' House of Science and Letters.

8. Germany: Union of the German Academies of Sciences and Humanities

In Germany, with its federal constitution, responsibility for education rests largely with the Ministries of Education and Science of the 16 federal states. In recent years – and to a certain extent as a reaction to the surprisingly poor performance of German schools in international benchmarking exercises – numerous initiatives aimed at rejuvenating science education have sprung up, often supported by scientific institutions and foundations. A number of initiatives also receive support from the Federal Ministry of Education and Research (BMBF).

Among the members of the Union of the German Academies of Sciences and Humanities, the umbrella organisation for the Academies in Germany, *Berlin-Brandenburg Academy of Sciences and Humanities (BBAW)* fulfils the role of lead academy with respect to science education at all levels (primary schools to university). Several activities are currently promoting awareness for the urgency to take action on education issues.

In the field of inquiry-based science education, BBAW has been cooperating since 2005 with Freie Universität (FU) Berlin and the French Académie des sciences. This cooperation was articulated through a series of distinct projects, the first being „*Sonnentaler – Naturwissenschaften in Kita und Grundschule*“ (science in pre- and primary schools), which can be described as the German version of „*La main à la pâte*“.

International contacts were intensified in parallel to the FP-6 co-funded “SciencEduc” project. BBAW was among the co-organisers of the national conference “Science is primary” in 2005, which allowed for experiences from France, Sweden, and the U.S.A. to be featured and compared, and which also involved representatives from other federal states. Teachers’ workshops soon became part of the activity, usually centring around certain conceptual themes (“Floating and sinking”; “chemical tests”; “motion and design” etc.). They discussed practices and teaching materials from the U.S. National Science Resources Center (associated with the National Academies and the Smithsonian Institution) and the ways in which they were adapted in Sweden for a different educational system. As a result, the cooperation between FU Berlin and the Swedish Academy of Sciences and their programme “Science and Technology for All” (NTA) developed swiftly, with NTA offering, for example, initial support for innovative teacher training.

A second significant Europe-wide project was „*Pollen – Seed Cities for Science*. A Community Approach for a Sustainable Growth of Science in Europe“ (2006-2009; www.pollen-europa.net). The project helped to network IBSE-related experiences in 12 „seed cities“ throughout the EU, notably among educational districts that sought support for sustainable reforms and innovative science teaching in primary schools by mobilising the commitment of the whole community. Outcomes of the pilots and recommendations for regional action plans were presented and explained to national education authorities with the intention of leveraging wider ranging change across the school systems. One focus of the Berlin-based project component was the differences in attitudes towards science that had been observed between boys and girls – a crucial concern being the decreasing number of science students, and in particular of girls who choose a career in science.

The German equivalent and partner project had been launched by FU Berlin and BBAW: *„TuWaS!” (Technik und Naturwissenschaften an Schulen*; www.tuwas-deutschland.de). The project was conceived as continuing the project in Germany beyond the funding cycle foreseen for the EU-funded pilots.

At the conceptual and pedagogically operational level, the programme relies on the four stages of the inquiry process as identified also elsewhere: (1) *Focus*: children share their knowledge about scientific concepts; (2) *Investigate*: children follow guided experiments and investigate new ideas that build on their existing knowledge; (3) *Reflect*: children analyse the collected data and their observations, trying to explain the results and comparing them to their pre-existing knowledge; (4) *Apply*: children apply their new insights to new settings.

At the institutional level, the programme rests on five main pillars: (1) continuous professional development of teachers in order to build confidence and competence in experimental and inquiry-based methods; (2) provision of tested and validated new teaching materials, including experimental kits for classes of 30 children (currently, 24 teaching units are available, mainly in chemistry and physics); (3) coordination and integration of IBS-teaching elements into the regular school curriculum to make sure that the up to 40 hours spent on teaching units do not go to the detriment of exam results; (4) involvement of regional and municipal educational administrations, business and civil society, and opening up the laboratories of research institutions for students; (5) regular evaluation.

A further expansion of these FP-6 supported IBSE-oriented projects is the FP7 co-sponsored, „*Fibonacci*“ which aims at a the wider dissemination of inquiry-based science (and also mathematics) education (IBSME) in Europe.

The Academy also offers a programme of *guest lectures* that is suitable for upper secondary schools (http://www.bbaw.de/forschung/Akademievortraege/Akademievortr_2010_2011.pdf). The offer, which involves world class experts who cover areas of science that range from history, through environmental studies to quantum mechanics, has met with an enthusiastic reception in schools, some of which have autonomously created science weeks which are now also fed by Academy lectures. The programme was started in 2001 when a specific week in the academic year was proposed for these events at schools. Since 2006, schools and lecturers are free to agree on dates that are convenient for both parties. This initiative is part of the Academy’s commitment to maintain a constructive and regular dialogue with the general public in Berlin and the wider region on issues of scientific and topical public interest such as genetic engineering, stem cells research, energy security, health and ageing, climate change etc.

In order to better understand the factors that can be influential in shaping new science education policies, BBAW has established an *interdisciplinary research group* “The future of science and technology education in Europe” („Zur Zukunft technischer und naturwissenschaftlicher Bildung in Europa“; 2008-2011). Under the direction of Ortwin Renn, the group assessed international research on science education and technology literacy and has embarked on an international comparison with the aim of elaborating a set of recommendation for the relevant political authorities in Germany [4]. The work of the research group responds to the concerns of a national economy with a labour market that is suffering, in a way not dissimilar to what can be observed elsewhere in Europe, from a serious shortage of qualified scientifically educated and technically skilled staff, with current demographic trends likely to make the problem worse in the near future. Social, historical and psychological reasons are examined for what seems to be an insufficient attractiveness of engineering and science professions. Comparisons with other European and Asian countries and with the U.S.A. have shown that a sustainable and inclusive long-term strategy is needed to nurture and support the growth of a strong cohort of aspiring engineers and scientists from an early age on. Such an inclusive approach, which should not be restricted to exceptionally talented pupils, would, it is argued, eventually create a scientifically and technologically literate society which in turn would value more strongly and more explicitly careers in fields of engineering and science and support the related necessary investments. Specific didactic approach were also investigated as part of the group’s research remit - learning through play, projects under the learner’s own responsibility, informal learning environments, strong links to every-day problems, and more generally inquiry-based science education. Finally, the issue of science communication was addressed: among the factors considered were the changing perception of technology and educational standards, as well as labour market trends and developments in higher education. Related to the first heading, a strand of investigation examined the dynamics of societal debates about the acceptance of large-scale technologies and possible undesirable side-effects of the spread of technologies used by individuals in their daily lives, thereby offering openings also towards science communication efforts taken forward by the Academy in other contexts. One of the issues discussed controversially in the group and at the workshops organised was the question of whether

[4] The report was published at the end of January 2012, see: http://www.bbaw.de/publikationen/stellungnahmen-empfehlungen/Stellungnahme_BBAW_MINT.pdf.

technology studies, both as a hands-on discipline and as a social science discipline, should be introduced into the foundational educational canon. Some argue that the necessary knowledge can also be conveyed in the context of the traditional science lessons.

Sociologists were interested in better understanding whether certain sceptical attitudes towards certain technologies could be identified as being specific to a certain stage in the life-cycle of individuals in the early 21st century, or whether they are cohort-specific. The relevance of these questions seems undeniable, for depending on the answers found envisaged changes of the current state of affairs would need to address more the culturally very diverse backgrounds of the population of children in present-day schools or the generic broad societal attitudes towards science and technology. A related topic is gender-specific attitudes, in Germany and elsewhere, towards careers in science and technology. It is predicted that by 2015 the ailing labour market can no longer satisfy demands for the highly-skilled segment of applicants from the national reservoir of young people, while restrictions appear to continue to limit immigrant labour supply as an alternative remedy. The group also explored the opportunities offered by liberalised access to European and international highly-skilled human resources. For the second phase of the project (2012 to 2014) the group intends to conduct a comparative cross-cultural study on attitudes towards natural sciences and technology in different countries such as the U.S.A., the Arab Emirates, China and Japan. The objective is to discover the factors that contribute to a high esteem towards professions in these fields in different societies.

Both Acatech, which functions as the German national academy of science and engineering, and Berlin-Brandenburg Academy of Sciences and Humanities (BBAW) are, alongside most other science organisations in Germany, members of *"Wissenschaft im Dialog"* (WiD - Science in Dialogue), Germany's centre of expertise for science communication (www.wissenschaft-im-dialog.de/). The BBAW president is a Board member, alongside the president of the Association of German Natural Scientists and Doctors (GDNÄ). WiD encourages the dialogue between the general public and scientists through exhibitions, science festivals, symposia, etc. For example, the *exhibition ship MS Wissenschaft* ("MS Science") tours 30 cities in every year as a floating science centre for primary school children that focuses thematically on the subject of the respective "Science Year". A similar WiD sponsored programme exists at railway stations in cooperation with Deutsche Bahn. The annual *Wissenschaftssommer* ("Science summer festival") is the major science fair in Germany. Every year, WiD's science year presents science for everyone across the country with the programme normally centring on a specific area of science.
WiD's European engagement is focused on participating in the science festival Euroscience Open Forum ESOF which has the ambition to grow into the European counterpart of the annual science meeting of the American Association for the Advancement of Science (AAAS). ESOF 2006 was held in Munich, and WiD combined it with the national science summer festival. WiD is also a member of EUSCEA (European Science Events Association), a platform of 70 organisations in 32 countries specialising in science events and science communication (the WiD director is current president of EUSEA). In this context WiD participates in the FP-funded *„2WAYS-project – Communicating Life Science Research*" which seeks to bring recent advances of current European life science research to a wider public. Pilot projects composed of pairs of partners develop innovative, interactive and dialogical presentations of recent peer-reviewed European life science projects. Impact studies are conducted to evaluate the reactions of visitors. Through local science parliaments of 60-100 students (16-20 years old), who meet for 3 days and debate controversial questions, delegates are dispatched to the Young Europeans Science Parliament. This gathering was convened in the European Parliament at the end of 2010 with 58 students from 29 cities in 17 countries. Supported by resident experts, four committees discussed a set of predefined questions related to topical issues in the life

sciences, such as: (1) Use of embryonic stem cells: Blessing or Curse?; (2) Using the results from genetic tests: what are the consequences for society?; (3) When genes are responsible for an aggressive behaviour? (4) Personalized Medicine: increasingly diagnoses with the help of DNA analysis? Students formulated resolutions which were afterwards discussed in a plenary meeting, and consensually modified or agreed upon.

Since the profile of *BBAW* as an active research academy includes a strong component of work in the Social Sciences and especially in the Humanities, the Academy launched an experiment in 2006 with students' labs in applying inquiry-based methods also in those fields of research. „*Schülerlabor Geisteswissenschaften*" (students' lab humanities) targets upper secondary school students majoring in Humanities studies, and has been exceedingly successful ever since its launch. In its basic pedagogical strategies, the lab follows the same principle as science-oriented students' labs. Topics addressed cover historical, literary, philosophical and other questions. The project has won a number of prizes and has found imitators elsewhere in the country. In the Berlin-Brandenburg region, the Academy now also offers a programme called „*GeistesWERKstatt*", as a sort of summer school for particularly talented high-school students of Humanities disciplines. The summer camps are typically linked to one of the Humanities research clusters of the Academy. Such is the success of the programme that the 2010 expert conference on innovative approaches in science education „Keine Angst vor Wissenschaft!" (No fear of science) also included a dedicated session on cooperation between Humanities research centres and schools. Session topics at the conference deliberately confronted also critical questions about the rationale for these extra efforts in the Humanities, given that those university courses are not suffering from the declining student population that plagues courses of study in the sciences and in technology fields. Against this background, the question was raised whether the existence of separate labs for Humanities and Social Sciences and for the Natural Sciences was not counterproductive, reinforcing in effect the perpetuation of the "two cultures" rather than moulding a new socially conscious and culturally sensitive science literacy. Also the issue of continued professional development of teachers in Humanities disciplines - which is a key element in inquiry-based *science* education - was touched upon.

Some of the other members of the Union of the German Academies of Sciences and Humanities have different levels of involvement in science education: *Nordrhein-Westfälische Akademie der Wissenschaften und der Künste and Heidelberger Akademie der Wissenschaften,* for example, reported in 2010 no such involvement, even though the governments of the respective federal states and important foundations in those regions are actively promoting innovation in science teaching. In Heidelberg, for example, it is the university for education, not the university or the Academy, that took the lead in acquiring European funds, as for example through the Comenius 2.1 project "*Teacher-Scientist – Partnerships*" (2006-2009), developed as a tool for the professional development in science education. Taking its cue from teachers' and students' needs, the Comenius project sought to integrate secondary school classrooms and research environments, notably by linking up with two large European research projects on climate change (CarboEurope and CarboOcean) and with the FP-7 sponsored project CarboSchools+, where schools develop partnerships with leading global change research institutions and scientists. The project was meant primarily to serve pre-service teacher training and assessed approaches for involving active scientists in classroom- and curriculum-related project work with (secondary) schools.

Hamburg Academy of Sciences and Humanities has been engaged in a variety of regional activities targeting pupils in two federal states in the North of the country. In 2010, the Academy established an *interdisciplinary school lab* for secondary school students by bringing together physics, political science, international law and *peace and conflict studies* around a realistic non-proliferation scenario (www.awhamburg.de/schuelerlabor-friedens-und-konfliktforschung.html). All events proposed for 2011 were also fully booked. Through role plays (*inter alia*: lab technicians, arms traffickers, law enforcers and customs officials, international observers, diplomats) and based on realistic background material, students familiarise themselves with the scientific, legal and institutional intricacies of effective arms control and the limits of international diplomacy.

This highly interdisciplinary lab is part of the nationwide network of "Schülerlabore" (students' labs) for hands-on experiments especially in the sciences and in mathematics (http://www.lernort-labor.de/en/index.php). The initiative "*Lernort Labor (LeLa)*" functions as umbrella organisation, offering a platform for networking, exchange, advice, access to experimental kits and evaluation, and providing access for research on these new forms of science education, and as a reference point for all efforts to better include such activities in mainstream teaching practices. The initiative "*Haus der kleinen Forscher*" targets with its IBSE-related approaches pre-school children (or rather their teachers). "Schülerlabore" has a scientific base at the Leibniz-Institute for the pedagogy of the sciences in Kiel (IPN), and has been funded by the federal ministry and Deutsche Telekom foundation. Kiel, capital of the Northern federal state of Schleswig Holstein, was venue of the events of the annual science festival "*Stadt der jungen Forscher*" (City of young researchers) in 2011, a competition where cities are selected for their innovative engagement for science and technology among youngsters; the winning city is home to a succession of science events throughout the year. Projects bring together schools, universities and allow children to work with leading scientists. Also the annual federal expert conference of the various science networks – some of which have been mentioned in this chapter - is held during the celebrations to exchange experiences and prepare political action.
In the Hanseatic city and federal state of Hamburg, the Academy of Sciences and Humanities is also a partner in "*MINT Forum Hamburg*", which is a new platform for all regional actors that aim at rejuvenating science education. The Forum brings together schools, universities, the municipal and federal administrations, businesses, associations and foundations and functions as knowledge broker for all interested parties, with online access available also for students and parents, but also as a platform to explore and launch new pilot projects. Twice yearly all actors meet for exchanges on best practice at all levels (discussing, for example, topics such as evaluation; linking formal and informal science education; sustainability; adaptation of IBSE approaches throughout the school career; etc). Expert conferences on methods in inquiry-based science education are also foreseen for later in 2011 and a large outreach event is planned for 2012.

Acatech, the German academy of science and engineering, had examined (ever since the mid-2000's and under the chairmanship of the Academy president Joachim Milberg) the causes of the current shortage of young scientists and engineers. It had also sought to identify measures to better promote these fields. An expert group investigated five key areas: (1) Promotion of skills in children and adolescents; (2) Vocational training and studies; (3) job market: appeal and image of technical and scientific occupations in Germany; (4) Doing Gender in science and engineering, and (5) Technology and society. The findings of the expert group were published and the Academy issued a number of recommendations in its strategy paper "for promoting interest in science and engineering: recommendations for the present / research needs for the future". They were presented and discussed at what was called the "*Nachwuchsgipfel*" (the national "summit for the next generation") on 23 March 2009. Those recommendations issued in that relate to S&T education at pre-university level can be tentatively grouped into a few clusters: (1) developing an interest and skills in science and technology is a life-long task that should not be left to schools and the period of school education alone; engagement should be continuous and main-streamed; (2) IBSE-based approaches in pre-school and classroom should be accompanied by activities in informal settings (musea, science centres etc.) and through the media (TV; online etc.) where also parents can and should be involved; (3) more attention is to be given to appropriate teacher training, including continuous professional development, especially if the presence of technical and technology studies is to be strengthened in mainstream curricula; (4) also industry will have to make some creative efforts to better present the opportunities and interesting aspects of careers in science and engineering, especially in order to attract also women and minorities into science and engineering professions.

As a result of this and related projects the "*Marilyn concept*" was formulated in an attempt to make S&T being more "sexy". The following elements were isolated: (M) - more credibility to be created through more open discussions about the risks and opportunities of S&T in contemporary societies, but also through a better monitoring of impact; (A): attractive images to be launched through a better calibrated PUSH programme, so as to improve the public perception of scientists and engineers; (R): Reduced technophobia to be achieved by more subtle communication of the benefits of S&T for society at large and also for contemporary culture; (I): Improved didactics to be introduced through inquiry-based education, also as part of teacher training; (L): Life and topical reality to be provided as orientation for programme elements by showing the impact and relevance of S&T innovations for our daily lives; (Y): Young peoples' interest to be captured by matching and adapting the science taught at schools to students' needs and experiences; (N): New culture of S&T literacy to be inaugurated as the overall aim.

The *Gesellschaft deutscher Naturforscher und Ärzte (*Association of German natural scientists and medical doctors) - or more precisely: the Association's educational commission - had published as early as 2002 a "*Memorandum on General Education through Science Teaching*" (abridged English edition in 2010). The memorandum argues for a transdisciplinary and problem-oriented understanding of science teaching within the single disciplines. Skills such as inquiry and problem-solving should be equally valued learning outcomes; the overall objective of education - character-formation and the ability of students to arrive at morally sound, evidence-based decisions - should not be absent from science education either.

Contacts with science academies outside Germany are developed independently by other non academic networks. The employers' federation, for example, supports the association of excellence centres in mathematical and science education, to which schools can gain access through a tough country-wide selection process. This network deliberately focuses on supporting the most excellent students and schools and offers, as part of its portfolio of activities, exchanges of experiences, professional development for teachers and contacts to industry. The network signed in summer 2011 a cooperative and exchange agreement with the *Korea Science Academy Kaist* (KSA) in Busan. Both partners are particularly interested in exchanging the best students from each cohort.

A number of foundations are important partners in innovative initiatives for schools and students. Among those that have developed a focused portfolio, the *Wilhelm-and-Else-Heraeus-Foundation* works closely with the *German Physical Society*. Pilot projects in the classroom, in teacher training and in developing new teaching tools have been supported through some 450 projects since the year 2000, in particular in the field of physics. Such projects can be stationary (school laboratories) or mobile ("Einstein on Tour"-Bus). In a somewhat similar way, *Deutsche Telekom* Foundation sponsors many projects across the country. In particular, four universities and their innovative teacher training initiatives have recently received support: their theme-specific working groups involve, next to scientists, teachers and educational professionals, also students. One example for a topic treated at the pilot project based at Humboldt University Berlin is the question of why the interest in physics collapses at the transition from primary to secondary school. Against this background, the German Physical Society is preparing a study that aims at setting new standards for the education of physics teachers, the principle being that "teacher education" must no longer be treated as by-product of a fully-fledged scientific course of study in physics. While it is welcome that the study will include a list of recommendations for core scientific topics and concepts to be covered in a new curriculum for apprentice physics teachers, it will also be useful to compare the proposed new approach with experiences in educational systems of other countries where the necessity of maintaining science teachers in close contact with the working methods and advances of scientific research has been found to be a key element in involving teachers in the reform of science education.

9. Hungary: Hungarian Academy of Sciences (HAS)

The Hungarian Academy of Sciences is the premier research institution in the country. As a research performing academy with its many scientific research units, the Academy feels a special responsibility for attracting and retaining talented young people into scientific careers. HAS has been involved in debates about improving natural science education, though these debates were not necessarily focused to IBSE. Debates about "science literacy" became more intense as Hungary witnessed some initial disappointing PISA results. The Academy of Sciences plays an active role in the modernization of the educational system in Hungary. A presidential committee on public education has been established that supports the Academy President's work in this respect. A number of meetings and conferences have been organized on the issues of science education.
However, looking at the country as a whole, it would seem exaggerated to speak of a "national" debate, as the range of participants is limited and largely confined to science educators, educational researchers and teachers; somewhat worryingly, it spears as if scientists themselves and their research institutions are not very present in these debates.
Comparatively few EU-sponsored science education projects have seen the participation of research institutes of the Academy. The Institute of Ecology and Botany of the Hungarian Academy of Sciences (IEB-HAS) is involved, for example, in *CO2nnect* ("CO_2 on the way to school"), an international school campaign promoting education for sustainable development on the theme of climate and transport. CO_2nnect was developed as part of the project SUPPORT ("*SUPPORT: partnership and participation for a sustainable tomorrow*"), which sought to integrate the principles, values and practices of sustainable development into all aspects of education and learning. Following this principle, CO_2nnect does not offer a ready-made teaching package, but rather wishes to inspire and help teachers in building activities for and with their pupils, involving schools, researchers, local decision-makers and other actors in society in order to reduce CO_2 emissions from local transport.

At the level of its own research programmes, HAS has long supported a "*Research Group on the Development of Competencies*", based at the University of Szeged and led by the Head of the University's Graduate School of Educational Sciences, Benő Csapó. The same university is also a partner in the FP-7 sponsored *PRIMAS project* ("Promoting Inquiry in Mathematics and Science Education across Europe"; http://www.primas-project.eu/partners.do#N65550). Being an Institute of Education at a major research university with a large teacher training programme, the school has been able to make sure that several leading experts participate in the project; against the background of this collaborative work at European level, they will seek to influence national policies on teacher training. Otherwise, it seems that leading research or educational establishments have not participated in some of the key FP-6 and

FP-7 projects which other Academies found useful, such as ScienceEduc, Pollen and Fibonacci, or the „Hands-on & Brains-on" project. Those institutes and individuals who did participate, on the other hand, were, it appears, not sufficiently well associated with or interacting with the major teacher training institutions and, as a result, it cannot be overlooked that those projects had only minimal impact at the level of national policy.

Irrespective of EU-sponsored actions, some university-based research groups have dealt with science education and pointed out problems revealed by such research, such as the decreasing interest in science and motivation in learning sciences, and the poor impact of learning sciences on cognitive development. Among the causes identified were the discrepancies between children's cognitive development and the demands of learning materials, the poor quality of textbooks, and inappropriate teaching methods. Changes have been proposed by academics for example through the Round Table on Education and the resulting "*Green Book for the Renewal of public education in Hungary*" (2009). Unfortunately, these issues, which touch upon the future of the country as an equal member of a European knowledge-based society, have not been attracting the curiosity of the media so far.

Thus, if compared to the beginning of the decade 2000, there has been some change in the attitude towards the importance of early science education: however, decision makers in politics and civil servants in the ministerial bureaucracy are not yet paying enough attention to the warning signals such as the less than encouraging results of the international assessment and benchmarking programmes. Academy and research universities have long point to the evidence that indicates a direct relationship between science education, research, development, innovation, and global competitiveness of particular countries and of the EU as a whole. The government could have taken more decisive action at home and, during Hungary's EU Presidency in the first semester of 2011, also in Europe, in order to strengthen S&T education as a policy matter of first priority. Interestingly, a number of large private companies are increasingly concerned about the need to maintain and improve the quality of scientific research and have started to lend support to activities that seek to innovate the teaching of science at school. They support teachers in their research activities and offer scholarships for talented students to support their studies and extracurricular activities.

At a more specific level, but reflecting the attention the Academy and the country devote to minority issues, researchers from the HAS Institute of Sociology participated in the international FP-7 project "*EDUMIGROM*: Ethnic differences in education and diverging prospects for urban youth in an enlarged Europe". Also the nationwide talent support programme that was featured at the 2011 Talent Day conference (see below), and that is headed by Descartes-prize winner Peter Csermely and sponsored by numerous EU, government and corporate donors, have dedicated sub-programmes to nurture and mentor scientific and artistic talents among the most prominent of the country's minorities, the Roma. Peter Csermely, one of the co-authors of the Rocard report, recognized this and launched at the medical Semmelweis University, a dedicated medical foundations programme, targeting promising *Roma students*. The launch was supported by Jozsef Palinkas, president of the Hungarian Academy of Sciences. This support is mirrored with activities of the Academy president elsewhere in the country, keeping the search and support for talents alive, for example by addressing the first EU Presidential Conference on Talent Support and the First European TalentDay in April 2011 during the Hungarian EU presidency, and by being among the patrons of the Hungarian Research Students' Movement.

10. Ireland: Royal Irish Academy

The Royal Irish Academy, the academy for the sciences and humanities for the whole of Ireland, is a learned society, promoting excellence in scholarship, recognising achievements in learning, directing research programmes and undertaking its own research projects, particularly in areas relating to Ireland and its heritage. As such, the Academy sees it as its responsibility to work towards ensuring proper academic standards at all levels of education; in particular RIA has a tradition of advocating and promoting science education at second and third-level. For this purpose, the Academy was instrumental, as early as the year 2000, in establishing the Taskforce on the Physical Sciences (see: *Report and Recommendations of the Taskforce on the Physical Sciences*, Dublin: Government of Ireland). In 2008, the Academy published the report of the Irish part of the international ROSE project („Relevance of Science Education“) that demonstrated in great detail the changing attitudes of young learners at the end of secondary school (age 15) vis-à-vis science and technology. (*The Relevance of Science Education in Ireland*).

Already in 2005, RIA had published the outcome of its workshop *School Science Infrastructure: Can Ireland Delivery?*': it responded to the mismatch between a declining uptake of the physical sciences by students at 2nd and 3rd-level on the one hand, and the government's ambition of building a knowledge-based economy in Ireland, which would privilege investment in R&D in sectors such as ICT, the pharmaceutical and biotech industries. The report argued for a revised education policy as part of the wider socio-economic objective of achieving a scientifically literate society in a holistic way. It favoured a clear development of science education from primary and throughout second level, with a logical progression from the Junior Certificate curriculum to the Leaving Certificate curriculum. It further proposed a complete revision of the Leaving Certificate syllabi in Chemistry and Physics that would allow for greater use of practical examinations for assessment purposes and called for greater emphasis on science-technology-society aspects and links. Recommendations also included some that would allow the government to respond immediately to the gathering crisis, which included: emphasis on professional development of science teachers at second level in order to complement the proposed changes in the curriculum; better recognition for teachers taking part in science education initiatives such as Science Foundation Ireland's STARs Programme; positive bias towards science in the Higher Diploma in Education; increased funding for science education infrastructures.
Later RIA reports in 2008 and 2009 were concerned with the larger intake of Irish students and the consequences for physics and chemistry undergraduate degree courses. The workshop report *Making the Best of Third Level Science* highlighted the issue of educational preparation in science and maths at the 2nd-level as a key factor determining subsequent levels of 3rd-level participation and progression. Shortcomings with respect to the attainment of Leaving-Certificate students, particularly in mathematics, were pointed out. Investment into the professional development of science teachers was seen as one of the key elements to reverse this negative trend. Critically, these analyses and proposals have been concerted efforts, involving exchanges with the industrial sector and some professional institutes (e.g.: Engineers Ireland, Institute of Physics, Institute of Chemistry in Ireland).

Reviewing these earlier initiatives, a number of recurring issues and proposals are easily identifiable and include:

- the importance of appropriate support and continuous professional development of science teachers at primary and second level;
- the need for measures to increase the number of physical science graduates pursuing careers in science education at primary and second-level education;

- the declining number of students taking chemistry and physics (though not biology) all the way to the end of second-level education;
- the need to revise chemistry and physics syllabi so as to allow for more practical coursework and assessment;
- the need to review the system of assessment for entry into higher education.

In 2011, a dedicated *Science Education Committee* has been established by the Academy, which has excellent links into all the relevant HE institutions dealing with science education, hence also to the FP-funded projects. The Committee is an interlocutor for government and, internally, links to cutting-edge science are maintained, by making sure that several of RIA's Science Committees are also regularly consulted and briefed. A key objective of the new Committee would be to take the lead, on behalf of the RIA Council, in developing an Academy position on science education issues, including the promotion (and merits) of IBSE. In support of this, a dedicated meeting was convened in July 2011 where selected expert stakeholders active in IBSE had an opportunity to brief the Committee, in particular on: (i) ongoing Irish IBSE initiatives, particularly at secondary school level, (ii) published research/ 'body of evidence' that underpins IBSE approaches, and (iii) possible priority issues for investigation by the Committee. Speakers included representatives from FP7-funded science education projects, Engineers Ireland, National Council for Curriculum and Assessment, the ROSE project co-ordinator, Dublin's Centre for the Advancement of Science and Mathematics Teaching & Learning, and the National Centre for Excellence in Mathematics and Science Teaching & Learning. An involvement of the Department of Education & Skills will only be sought once the Committee's priority actions will be identified.

The activities of the Academy thus reflect some of the growing concerns about the S&T future of the country. Against this background, the appreciation of and debate on the importance of early science education and improved numeracy at primary and secondary level in Ireland has greatly intensified in the decade since the year 2000. Given the policy commitment of the Irish government to achieve a knowledge-based, smart economy, the Department of Education and Skills now has responsibility for both primary and second-level education across all subjects including science and mathematics. The categories of people engaged in the debate therefore also include civil servants from other relevant Ministries, university academics and academicians, employer representative bodies for particular sectors such as ICT - with the multi-national sector noticeably prominent - , and professional scientific and engineering institutes, as well as a variety of other bodies and individuals. The need to improve S&T education is by now seen as tackling what some describe as an actual or looming national crisis. Calls to action speak to potential skills shortages and worrying signs of a lack of interest in STEM disciplines have been identified by a variety of stakeholders in their respective domains. The Economic and Social Research Institute (ESRI) has reported a serious and disturbing level of disengagement by some students at Junior Certificate level, and the National Council for Curriculum and Assessment (NCCA) expressed the opinion that "many teachers believe reform is badly needed".

The 2010 report of the government-appointed "Innovation Taskforce" (see: http://www.taoiseach.gov.ie/eng/Innovation_Taskforce/Report_of_the_Innovation_Taskforce1.htm) identified the need to raise substantially the level of competence and attainment in science and mathematics such that they feed into STEM disciplines at third and fourth levels. Mathematics attainment was seen as being particularly crucial in this regard. The Irish Department of Education and Skills has responded to the latter issue recently by launching the National Literacy and Numeracy Strategy on 9 July 2011, whose main points can be summarised as follows:

- the number of examination subjects at Junior Certificate level will be reduced to eight commencing with 2012 first-year student intake;
- primary schools will increase time for literacy study to 90 minutes a day; maths study will increase to 50 minutes a day with effect from September 2011;
- standardised assessment will be used at 2nd, 4th and 6th class level, to provide parents with focused results on their child's performance;
- greater involvement of parents will be sought, with better information on how to help their child's literacy and numeracy development;
- for the first time the same standardised assessment will be introduced in 2nd year at post-primary level;
- the strategy aims is to increase from 40% to 60% the proportion of students taking higher maths at Junior and Leaving Certificate level;
- targets include improving the ratio of children performing at the highest level in standardised testing such as OECD assessments;
- the duration of the Bachelor of Education degree course for student teachers will increase from three years to four years;
- Higher Diploma in Education courses will increase from one to two years;
- student teachers will spend longer in schools for gaining teaching experience as part of their course of study;
- there will be a major expansion of in-service, professional development courses for teachers with increased summer literacy training courses;
- the Strategy will cost an estimated €6 million in 2012, rising to €19 million by 2017.

Irish teacher organisations have expressed concern that further cuts across the primary and secondary educational sectors consequent upon the terms of the bailout of Ireland agreed during the recent financial crisis, would militate against effective delivery of the strategy.
The curriculum for Ireland's primary and post-primary schools is determined by the Minister for Education & Skills who is advised by the National Council for Curriculum and Assessment (NCCA). The curriculum sets out not only what is to be taught, but how, and how learning in the particular subject area is to be assessed. The NCCA has a number of Committees working on the science syllabuses and these have produced drafts of revised syllabuses for Leaving Certificate Biology, Chemistry and Physics. It notes that the revised syllabi will allow *"learners ... to apply their knowledge and understanding as they engage in a wide variety of activities where they can develop key skills and use them across a range of learning areas in both familiar and unfamiliar situations. The use of skills in solving or finding answers to problems is just as important as getting the right answer. The most notable difference to assessment is the proposed inclusion of a second, practically based component of assessment. The combination of the written and the practical assessments will give learners more varied opportunities to show what they can do as well as what they know."*

The NCCA worked with a network of schools during the school year 2009/2010 to show what practical assessment might look like in real life and produced examples of types of practical assessments, including questions, tasks, marking schemes, and video footage. The NCCA planned a wider consultation on the revised science syllabuses in 2011 (see the NCCA document: 'Learning by Doing: changes in senior cycle science' at http://www.ncca.ie/en/Curriculum_and_Assessment/Post-Primary_Education/Senior_Cycle /Senior_Cycle_Developments/Science/learning_by_doing.pdf).
In relation to mathematics education in Ireland, and following prolonged discussion regarding inadequacies in the teaching of mathematics at primary and second level, the NCCA and the Department of Education & Skills are currently looking at curriculum reform and teaching strategies to try and improve mathematical competence in pre-university education. A revised Primary School curriculum in mathematics was implemented in

2001/2002 (see http://www.curriculumonline.ie/en/Primary_School_Curriculum/Mathematics/Mathematics.html).

The NCCA conducted a review of post-primary mathematics education in 2005, which led to the publication of a discussion paper, *Review of Mathematics in Post-Primary Education* (see http://www.ncca.ie/uploadedfiles/MathsReview/MathsDiscusPaperEng.pdf). The review was prompted by a marked decline in uptake of higher-level mathematics, particularly in the Leaving Certificate. There was also concern about the standards of mathematical achievement in state examinations and in the relevant OECD tests. Following a wide-ranging consultation, a report was issued (see: http://www.ncca.ie/uploadedfiles/mathsreview/Maths_Consult _Report.pdf) presenting a summary and analysis of the views submitted and proposing steps to re-shape the teaching, learning and assessment of post-primary mathematics.
Following on from the NCCA review, „*Project Maths*" initiated a phased change in the mathematics syllabus at junior cycle and senior cycle over a four-year period beginning in 2008, with a corresponding incremental change in the examinations. Current mathematics syllabuses at both junior cycle and senior cycle will be fully replaced by September 2012. An initial group of 24 schools introduced the first two revised syllabus strands in September 2008, and these have been refined in light of their experience. In September 2010, these schools introduced the fifth strand of the revised syllabuses. National roll-out of the changes began in September 2010, with the introduction of strands 1 and 2 in all schools. The changes continued in September 2011 and will continue in September 2012, until all five strands have been introduced in all schools.

The aim of "Project Maths" is to encourage a better understanding of maths and its concepts, to reinforce the practical relevance of maths to everyday life, and to ensure better continuity between primary and second level, and junior and senior cycle. In terms of content, the most significant change is an increase in the amount of statistics and probability to be studied at both levels, whereas in terms of pedagogical methods a greater use of active methodologies to promote better student engagement in mathematics classes is expected (see: http://www.ncca.ie/uploadedfiles/mathsreview/PMaths_En.pdf).

Increasingly, the participation of Irish teams in FP-funded programmes in science education is leaving its mark on the debate and on practices aimed at rejuvenating science education: the NCCA is open to directly incorporating the outputs of such projects into curriculum and classroom resources and this is expected to be officially incorporated into national policy within two years. All of the Irish project beneficiaries are involved in teacher education and the outputs of these projects are directly inputting into teacher training at both pre-service and in-service level. Of the projects mentioned below, certainly those based in Dublin have made the best use of the short communication lines: there has been ongoing communication between the science education projects referred to above, government and other stakeholders. Members of the Dublin-based *Centre for the Advancement of Science and Mathematics Teaching & Learning* (CASTeL) have met with relevant policy makers from the Department of Education & Skills – Inspectorate, Teacher Education Section, Professional Development Supporting Teachers, NCCA and the Teaching Council - to disseminate the work of projects such as ESTABLISH and FIBONACCI.
Next to FP-7 projects broadly set in the area of science education and including specific scientific fields such as astronomy, energy research, marine sciences, or stem cells research – Irish HE institutions are involved in five IBSE-related projects co-funded by FP7. In the university environment, a key actor is "CASTeL – the Centre for the Advancement of Science and Mathematics Teaching & Learning", a multidisciplinary research team involving scientists, mathematicians and educationalists from Dublin City University (DCU) and St Patrick's College, Drumcondra. For example, it coordinates "*ESTABLISH*" („European Science and Technology in Action, Building Links with Industry, Schools and Home"; 2010 –

2013), a consortium of some 60 partners from 11 European countries who promote IBSE in secondary schools (12-18 year olds) and develop IBSE units and evaluation tools that are culturally adapted for each country. Stakeholders involved include secondary school pupils, their parents and science teachers, the scientific community, from local enterprises, multinational companies and the scientific communities, science-education researchers and policy makers, including curriculum developers and assessment agencies.

DCU is also a partner in *PATHWAY* (2011 – 2013), while St. Patrick's College, is a beneficiary in "*Fibonacci*" (Jan 2010 – Feb 2013), and University College Cork (UCC) is actively involved in *PROFILES* (2010 – 2014). The Irish participation in Fibonacci is focused at primary school level, whereas the other four projects focus on secondary schools. Most of these projects have components that are involved in developing educational resources for use in teacher professional development (both pre-service and in-service), and for use in the classroom and in changing teaching practices. *ESTABLISH* evaluates the impact on teachers' attitudes, understanding and learning processes related to IBSE before and after taking part in professional development courses in IBSE. In Ireland, for example ESTABLISH has conducted teacher education workshops with over 35 in-service teachers. At least some of the FP-7 supported activities have lead to a real interest of the scientific community, in the Academy and outside, for helping the renovation of science education. The very basis of the ESTABLISH approach, for example, is to incorporate authentic scientific experiences in Academia and industry into science education curricula; the project activities therefore involve three small and medium-sized enterprises.

It is still too early to judge the substantive impact of the current FP-7 co-sponsored pilot projects; at policy level. However, thanks to the good lines of communication that have developed between key domestic actors as indicated above, these European actions have been helpful to further alert the government to the priority of this field even in times of budgetary crisis. For example, at the launch of the ESTABLISH project the (then) Minister of Education & Skills, expressed strong support for the FP7 initiatives on science education and agreed to support actions to further promote European-level funding in this area. It is to be hoped that also the new Irish government (elected in spring 2011) will be keen to promote the renovation of science education and its support as part of the EU funding portfolio through 2020.

11. Italy: Accademia Nazionale dei Lincei

The Accademia Nazionale dei Lincei (in short: "Lincei") is a learned society which functions as the national academy of sciences, even though at regional and local level Italy has many other academies which often have themselves long traditions in their respective contexts. Lincei has become actively involved in promoting the renewal of science education in elementary and secondary schools in fairly recent times. The Academy, representing a select group of leading Italian scientists, has been catalysed into these activities by the acknowledgement by its president Lamberto Maffei of the necessity to support efforts at rejuvenating science education and ensuring that it is rooted in general culture. There is now a strong desire among scientists belonging to the Accademia to spread this notion across the Italian scientific community at universities, regional academies and research centres.

While political decision-makers (politicians, civil servants in the ministry of education etc.) have taken cognizance of the issue of renewing science education, it has taken longer for scientists in the universities to speak out and act on their concerns. In fact, while there is a diffusely perceived need to rethink the way science and technology are taught and a variety of actors are engaged in pilot projects, these experiences are, to a large extent, operating in an isolated fashion, lacking coordination and appear not to have triggered a wide public debate about "scientific literacy". Many initiatives have been promoted, over the last few years, following the PISA results of Italian students. In some Italian regions where the data are particularly alarming, the Ministry of Education, supported by European funds, has launched an information and awareness campaign. Overall, Italy scored below average in 2006, with particular weaknesses in the area of inquiry-based approaches – more worrying still: it now appears that reasonably good results at elementary school level are lost as cohorts proceed through middle school. A report on the use of laboratories for scientific education in Italian schools by an Inter-ministerial Group for scientific culture in 2006/07 found that even in schools where laboratories are available only 42% of teachers used them, showing an uneasiness with the experimental and inquiry-based methods, and, ultimately, a deficiency in teacher training.

At national level, the in-service teachers training project "*Piano ISS – Insegnare Scienze Sperimentali*" (Teaching Experimental Sciences), launched by Italy's Ministry of Education, has been running over the last four years. The teaching of experimental sciences that it advocates is essentially based on inquiry approaches to the teaching and learning of science at all school levels (see: http://www.anisn.it/piano_iss.php). The project aims at erecting a robust structure that can serve as backbone for a national professional development for science teachers (primarily in-service, but, no doubt, with repercussions also on pre-service training). Given that 90% of primary school teachers who would be expected to be able to use inquiry-based methods for the teaching of science had no scientific background during their professional training, the task appears truly daunting.

A "core group", made up by six expert trainers and teachers and led by the Italian coordinator of the Fibonacci sub-project has proposed the translation of educational resources for science education into Italian. They include international reports on science education, a teachers' guide on IBSE approaches, and the Fibonacci starting package booklets. Also nine modules containing several activities for elementary and secondary schools have been translated and adapted to the Italian educational context (La main à la pâte; FP-6 project Pollen; FP-7 project Fibonacci; Italian Plan ISS – Teaching Experimental Sciences; previous experiences and activities carried out by members of the "core group "). Nine experimental kits (boxes) have been created for each module containing material for experiments. Several kits used for the different modules have been donated to the teachers in the pioneering local network.

The success of new projects will depend on a number of factors: the role of school presidents and the involvement of active and nationally well-known scientists, and international networking can be identified as crucial.

At the level of schools belonging to the pilot network, it is largely thanks to the strong commitment of the presidents, that changes in teaching practices have been introduced in line with IBSE approaches. It is certainly too early to speak of direct inspiration changes to curricula at the national level, also because the national curriculum for elementary and middle schools has already incorporated some elements that are conducive to adopting IBSE approaches, including the possibility to focus on "big ideas" in science.

Lincei has been organising for many years a series of conferences in various branches of natural sciences ("*I Lincei per la scuola*") specifically targeting teachers and students of secondary schools. Related activities in mathematics education have been promoted by „Unione Matematica Italiana" (UMI; Italian Mathematical Union), an association gathering most Italian mathematics professors and researchers, which enriched debates about mathematics education through conferences, seminars, publications and relations with other organizations and public bodies. The „*Commissione Italiana per l'Insegnamento della Matematica*" (Italian committee for the teaching of mathematics) is a permanent UMI committee that studies issues in relation to the teaching of mathematics with the aim of proposing new solutions to public schools (see: http://www.umi-ciim.it/).

In other contexts, other academies also support science education: the Regional Mathematics Olympiads promoted, for example, by *Associazione Subalpina Mathesis* with support from the Accademia delle Scienze di Torino, is an activity Lincei is not institutionally and directly involved in which was presented at the ALLEA General Assembly 2010.

In project supported by the European Commission, *ANISN*, the Italian National Association of Natural Science Teachers, and Lincei's partner organisation for the national IBSE project, is a major Italian participant in FP7-funded IBSE projects (Fibonacci). Fibonacci has been an important foundation stone also for the national project. In the framework of Fibonacci, the first Italian pilot centre on IBSE has been created at the Stazione Zoologica Anton Dohrn in Naples, a prestigious research centre in Italy, in 2010/2011. 38 teachers from elementary, middle and high schools from a local network of 10 schools have received training by a "core group" of experts according a structured and multilevel plan (including classroom courses, on-line fora, peer to peer community, observations at schools, etc.). Feedback indicated that teachers recognized that IBSE approaches profoundly acted on the perception of what science is and how it works.

ANISN seems to be the right partner for Lincei for implementing the new project awarded by the Ministry, which focuses on in-service upskilling, because the association had been cultivating over the years of good experience in teacher training and events in collaboration with schools, universities, science centres, scientific institutions, museums and local authorities. At the national level, the association has been participating in teacher training policy initiatives and in implementing programmes with the Ministry of Education, but also in hands-on with the Natural Sciences Olympiads for middle and high schools students. In Europe, ANISN joined as partner a number of EU-funded projects (Edu-Geo, Volvox, Evolution MegaLab, Science on Stage, Fibonacci), but has also been active in the preparation for the International Biology Olympiads and the International Earth Science Olympiads, as well through a permanent collaboration with the European Learning Laboratory for the Life Sciences (ELLS), the education activity of the European Molecular Biology Laboratory (EMBL).

In the context of European cooperation, the agreement signed by Accademia dei Lincei with the French Académie des sciences in 2010 meant a new beginning. In collaboration with ANISN, Lincei intends to work on introducing and spreading the IBSE method in elementary and middle schools across Italy, building on the experiences and adapting the methods of the French "La main à la pâte" programme. The Italian Ministry of Education and Research has shown great interest in the project and granted funding to Lincei for the launch of an experiment in Italian schools ("*Scientiam inquirendo discere*" – Learning science through inquiry). The objective is to implement, with the aid of new methodologies, a renewal of science and mathematics education in the Italian school system. ANISN seems to be the right partner for Lincei for implementing the new project awarded by the Ministry, which focuses on in-service upskilling. ANISN will take part in this project (and their project office will be housed at the seat of Lincei), which, starting from a number of pilot projects, will revolve around transfer of knowledge and expertise, the establishment of centres of competence and clusters of experiences in several cities across the country. The project revolves around and rests on those activities of the pilot centres, and is articulated in three phases: Phase I involves the establishment of the executive and advisory national structures and groups (incl. a website with Italian versions of resources largely adopted from the French programme *"La main à la pâte"*), Phase II will see the organization of and the build-up of activities in pilot centers, the launch of training modules, and thematic peer-to-peer working groups, starting from year 2, and in Phase III the implementation at schools and the diffusion of the programme results through additional pilot centers will be pursued. This initiative has been described as a direct outcome of contacts established at European level, through FP-funded projects and via the ALLEA-based European Academy network on science education.

Lincei, in cooperation with ANISN, has promoted the establishment of three pilot centres (Pisa, Venice and Naples) where the IBSE based science education programme will be implemented in a selected number of 45 schools. A small network of Roman schools will also be integrated into the project. For the launching phase (academic year 2011/12), 35 trainers, 150 experimenting teachers' trainers and 4.500 students are expected to be involved in the project. Lincei and ANISN have established contacts with the three institutions of higher learning where the work of the pilot centres will be carried out (Scuola Normale Superiore in Pisa, Istituto Veneto - a very prestigious regional Academy - in Venice and Stazione Zoologica (which is already an active participant in the Fibonacci project) in Naples. The coordination centre for the envisaged activities has been established at Lincei headquarters in Rome. Operationally, the total number of schools involved is 45, distributed in the three pilot centres and in the school network in Rome.

Following the agreement with the Italian Ministry of Education, Lincei has given an impulse towards renewing school-based education also more in general. Next to the SID programme, two further programmes have been launched, one on Italian as a scientific language and the other one on the teaching of mathematics. A website has been created where the main activities pursued under the three programmes are outlined (www.linceiistruzione.it).

12. Kosovo: Kosova Academy of Sciences and Arts

In the view of education and science experts at the Academy, early science education has not yet been recognised as a priority for education policy makers, academia and the general public in Kosovo. Recent changes in the Kosovo Curriculum Framework have introduced "science" as one of six learning areas (besides Language and Communication, Mathematics, Society and Environment, Health and Welfare, Life and Work), thus placing more importance on this field, but there is still a long way to go until this change is reflected in the classroom. The Curriculum Framework is competence-based, and so far, only general competences for specific education levels have been identified. The next step is to define competences for the six learning areas (thus: including "science"), to be followed by the definition of learning outcomes and highlights of the new content.

Kosovo has not been participating yet in FP-funded programmes in science education.
Regardless of the fact that Kosovo has not been exposed to FP-funded science education actions, there is a positive attitude among decision makers towards changes in teaching and learning. There are also a number of donor-funded projects focusing on curriculum development and teacher training that inevitably create expectations among teachers and general public.

The Academy is in continuous communication with the Ministry of Education and the National Curriculum Development Team and can function as a conduit for the communication of expectations and experiences from and to the European level and as partner for European initiatives.

13. Latvia: Latvian Academy of Sciences

The Latvian Academy of Sciences, as the assembly of the leading scientists in the country, is formally involved in policy matters primarily where higher education and research are concerned. It did not, on the other hand, play a leading role in the reform of science and maths education in Latvia in the years 2005 – 2011.

The reform sought to address the lack of S&T professionals by adapting the conclusions of the Rocard report (and similar documents, as the one issued by the Nuffield Foundation) in order to introduce changes in the curriculum and to promote closer cooperation and interaction between various stakeholders. MST teaching and learning were to contribute to the acquisition of problem solving, communication, digital, social and entrepreneurship skills, to be acquired through IBSE approaches, but also a variety of other more classical as well as newer methods (games, simulations, workshops, fieldwork and project work). Students should learn to think creatively and critically, and the classroom content for maths and sciences should be more closely reflecting real life and professional needs. The reform acknowledged the need for further and continuous teacher training (methods; technologies; peer-to-peer learning and cooperation etc.), and the important cultural challenge to overcome a teacher-centred educational practice and replace it with a student-centred approach.

Funding was received from a European Social Fund Life-Long Learning programme, and the first phase of the reform focused on curriculum development (biology, chemistry, mathematics, physics and science) and in-service training (2005-2008) for upper secondary schools (grades10–12). 50 pilot schools became regional centres of competence for methodological advances and 2.950 teachers received further qualifications through teacher training. In the second phase the reform was rolled out to include science and maths in grades 7 to 9.

A key challenge will be the sustainability of the innovative changes implemented. Links with the universities and especially with the teacher training institutions in the field of MST will be crucial. Two pilot projects already involve university professors – here, one can also detect a future arena for involvement of the Academy in public debates about the future of maths, science and technology education in the country.

14. Lithuania: The Lithuanian Academy of Sciences (LAS)

The Ministry of Education and Science, which is responsible for all levels of education (http://www.smm.lt/en/index.htm), has been monitoring the relative decline of the position of science in school curricula over the last two decades and there are also indications that science is perceived as being harder to learn. Against these tendencies, the Academy has been reiterating in public debates the necessity to stimulate scientific research, but is not, as an institution, actively involved in promoting IBSE approaches. The Academy is also somewhat reluctant to blurring the insistence on promoting "science literacy" with debates on societal issues such as inclusivity, upholding instead the value of the advancement of knowledge as a societal good in itself.

On the other hand, individual members of the Lithuanian Academy of Sciences have been and still are engaged in introducing their domains of science to schoolchildren, and more generally in creating interest in and raising awareness for the advances in science and mathematics outside the Academy. Exchanges between academia and classroom take different forms, for example lectures at secondary schools and for groups of gifted schoolchildren, popularizing science for schoolchildren and the general public – whether

through articles in the press or by taking part in science festivals. Members are also known to have authored original books targeting this readership (e.g. "A hundred puzzles of physics") and there are initiatives for translating other quality popular science books. It should be stressed that activities aimed at supporting the production and dissemination of science books are not limited to the natural sciences; also LAS researchers in the life sciences (e.g. "Following the plants in Varėna region") and in the humanities (e.g. "We are Balts") have authored such volumes.
The elected expert-member of the Lithuanian Academy of Sciences for educational sciences, Palmira Jucevičiené, is Director of the Institute of Educational Studies and Head of the Department of Educational Systems at Kaunas University of Technology (KTU), and has been publishing with colleagues, inter alia, on reforms in physics education. The Institute of Educational Studies at KTU has been a key actor in the EU-supported long-term transformational project "*Kaunas Learning City*", involving local administrations, businesses, schools, teacher associations, and parents, but the project has comparatively few clearly articulated trajectories for the development of science and technology education.
In terms of participation in international actions in the field of reforming science education, also Siauliai University (the former Šiauliai Pedagogical Institute and Šiauliai Polytechnical Faculty of Kaunas University of Technology) has been prominent, for example by hosting the *International Organization for Science and Technology Education*'s 7th regional symposium for Central and Eastern Europe on "Development of science and technology education". At the level of higher education, the Institute for Gender Studies of Šiauliai University is coordinator for the FP-7 supported project on gender-mainstreaming measures in engineering and technology curricula in higher education (*HELENA*). The degree to which these initiatives will have an impact on national level curricula can only be measured at a later stage.

It has to be noted, furthermore, that in a variety of settings the Lithuanian scientific societies (including the *Lithuanian Mathematical Society*) also debated with teachers in their respective disciplinary domains about the reform of the science and maths education both at primary and at secondary level. Whether the Lithuanian Physical Society, Mathematical Society, or Chemical Society – they are well represented among the members of in the Lithuanian Academy of Sciences (e.g.: the current presidents of the former two are members), which, at the individual level, may constitute a link to these efforts. However, those societies function as independent associations, and if they interact with science teachers or their disciplinary associations who, in turn, also act autonomously, this could not be accurately described as a direct institutional involvement of the Academy.

Thus, while LAS as an institution is not involved in pilot projects on inquiry-based science education, the Academy has made other attempts to create new arenas for exchanges between leading scientists and school children. Such activities tend to target, for the time being, mainly gifted and talented children: for example, the Academy held, in autumn 2009, a joint General Assembly with the Lithuanian National Academy of Schoolchildren, which is a public institution (see: http://www.nmakademija.lt/) that brings together high-achieving students. It is in its 6th year of existence, with more than 150 school children having participated in eight distant learning sections by now. The best among them are invited every year to three learning sessions. It should be noted that about half of the pupils at NAS are winners of international and national school Olympiads and competitions. In the past, NAS students were taught primarily by outstanding individuals from the business, science and cultural sectors in Lithuania and abroad, as well as by NAS alumni, whereas at the joint General Assembly senior academicians introduced them to their areas of scientific inquiry, in the exact or experimental sciences, as well as the life, social and humanities.

15. Montenegro: Montenegrin Academy of Sciences and Arts

Recent developments in pre-university science education in Montenegro must be seen against the backdrop of the country's overall societal, economic and political transition after independence. Reforms of pre-university education rest on the 2001 *Book of Changes* as the key strategic document and seek to make the country's educational system comparable to those elsewhere in Europe. The legal framework, new curricula and a wide-ranging training system being in place for both school directors and teachers, the implementation of reforms has been on its way since September 2004.

In 2009/10, the Montenegrin Academy of Sciences and Arts (MASA) led the compilation of a very substantial advisory expert report "*Montenegro in the 21st Century – in the Era of Competitiveness*" (for a summary in English, see: http://www.canu.org.me/cms/images/stories/Montenegro%20in%20the%2021st%20Century%20-%20In%20the%20Era%20of%20Competitiveness-cover.pdf). The project was divided in ten subsections, one of them "Education", subdivided, as all other sections, into several sub-items, each of which in turn describing the status quo, identifying problems, and proposing possible actions in the short, medium, and long term. MASA had anticipated some of the major challenges the country is likely to face over the next decades in terms of new technologies and lifestyle trends which, combined, will require that the level of national education in the STEM areas be raised. The Academy recognises that scientific-technological progress risks being slowed down by the current decline in interest of students in STEM areas: for currently, the number of graduates employed in science and research, and the total number of young researchers in Montenegro, are far below the EU average and, indeed, also below that of Eastern Europe. Measures need to be taken at government level, and the Academy can also play a role in popularizing those areas and in improving the quality and integrity of teaching.

The MASA report included, scattered over diverse sections, references to the relevance of science education and speaks of the need to create conditions that would replace the threat of brain drain with a circulation of brains. Studies and international benchmarking exercises such as PISA have shown that the average level of scientific literacy among Montenegrin students is significantly below the OECD average. The phenomenon of a decline of student interest in natural and technical fields is a side effect on Montenegro's transitional economy: students prefer courses in management, commerce and services also at university. In addition, the educational reform reduced the number of compulsory lectures in natural sciences, while as electives they are not popular, because of the weaknesses in their curricular organisation, old-fashioned teaching, and poor equipment of science classrooms.

The report recommends elaborating, adopting and gradually implementing a *Strategy for the natural sciences subjects in pre-university education* in Montenegro. Given the challenges ahead, creating a work-force and citizenry with a solid knowledge in STEM fields, and a larger number of experts trained to the level of Masters and PhD, is an essential and prime responsibility of the government. There is an urgent need to improve the quality and efficiency of education also in the research system.

All across the educational systems, the need for reform is palpable: children should be taught to think freely, in an unconventional, creative and critical way; in order to deal with ever more complex problems of everyday life wider visions and multidisciplinary knowledge need to replace separated disciplinary curricular items so that students learn about multifaceted and holistic approaches and can gain and process integrated knowledge. For this, the weight of memorised facts need to be reduced across all science curricula and more time needs to be dedicated to acquire skills in adapting functional knowledge. A diversification of the sources of learning is needed, as is the introduction of a type of teaching that encourages and builds on curiosity, develops the ability of observation and introduces students to an experimental and inquiry-based approach to learning. Evidently, for teachers to be brought fully on board, working conditions at schools need to be improved, generally speaking by reducing the number of students per class, but more specifically also by ensuring that schools are equipped with the necessary teaching aids, especially for experiment-based teaching.

While it is necessary to remove weaknesses in the organisation of elective science courses in primary and secondary schools and to improve the quality of education offered, one might also consider introducing special courses in grammar schools for high-achievers, in order to enable the better students to gain a deeper and more profound knowledge. Even the foundation of elite schools for gifted children could be considered which would employ experts for regular "master classes".

At a more general level, the public debate on the need to invest in science (hence also in science education) can be helped by campaigns of science popularization, and by supporting the work of the media, institutions and events that promote science and technology. The participation of the young in excellence centres, as well as support for the erection of a Museum of Science and its functioning as a science communication cluster should also be part of this strategy.

As yet there is no sustainable strategy for detecting and nurturing talent from the earliest stages on. Some efforts have been made, however, to stimulate the interest of secondary school students in science (summer schools in physics, biology and chemistry; knowledge competitions at the municipal and national level; group visits to the Large Hadron Collider at CERN etc.).

Part of such a strategy then, stakeholders seem to agree, is to enhance exposure to real science and to the institutions, individuals and practices of scientific research. During several years, the Montenegrin Science Promotion Foundation PRONA organized the week-long Summer Physics School for Young Talents, bringing together the best high-school students in the country-level tests in physics. In August 2009, for example, distinguished scientists from the USA, Japan, Russia, France, the UK, Germany, Slovenia, Serbia, and Montenegro gave lectures and demonstrated various phenomena; some students were also trained to perform experiments at the Science Festival "Researchers' Night" held in the country for the first time in September 2009. With support from research, academic, business, public and other sectors, student demonstrators ran numerous hands-on experiments. The „Examination Center of Montenegro" organized group visits to the Large Hadron Collider at CERN in 2008 (for the best secondary school students in the country's physics competition) and 2009 (for the physics teachers in elementary and secondary schools whose students showed the best results at those competitions).

It is expected that also the establishment by MASA of the Young Researchers' Centre will eventually have a positive effect on the image of science and scientific careers in society. The report also suggests that programmes for the promotion and popularization of science need to be expanded, since the annual Science Festival in Montenegro each September is one of the exceptions.

The MASA report and the spurt of new initiatives coincided with the release of current figures from the latest Eurobarometer's survey "Young people and science" (2009). They indicate that young Montenegrins are more interested in science and technology than their peers from EU27 countries; the same goes, by and large, for their interest in new S&T inventions, ICT, medicine, earth and environment, and the universe. While Montenegrins agree that young people can contribute overall, when developing an interest in science, to the country's prosperity, respondents also show a sobering sense of agreement that much remains to be done to improve the attractiveness of natural science teaching and its relevance for success on the labour market.

Following the report, and translating the commitment to further modernise the country, a „*Strategy for early and preschool development and education* (2010-2015)“ was recently adopted by the government, which includes, among others, the following tasks: (1) develop a curriculum of pre-service teacher education that would focus on early and pre-school education; (2) develop and implement a teaching programme for educational work with pre-school children under the age of three; (3) establish specialist and Master courses for early and pre-school education.

The study programmes for these courses at the University of Montenegro (Faculty of Philosophy, Department for Pedagogical Studies) has been prepared, including a new course „Science in Early Childhood Development and Education“ and awaits accreditation; it is envisaged that programmes can start in the academic year 2012/13.

It is important to acknowledge that these developments are still to be considered the outcome of the national strategy document of 2001, for Montenegro has not participated in FP-funded projects in science education, even though contacts have been established with the FP6-co-sponsored project Pollen and with the FP7-co-sponsored project Fibonacci.
The relevant Ministry would certainly wish to see such projects to be continued also in the next Framework Programme and hopes that Montenegrin institutions will be able to participate; it seems that of relevant institutions that would qualify as partners - Bureau for Education Services and Faculty for Natural Sciences and Mathematics, Univ. of Montenegro - at least the second is now willing to take part in such activities.
The Montenegrin Academy of Sciences and Arts has expressed a real interest and desire for involvement in helping the renew science education in the country. Formally, the introduction of inquiry-based science education would benefit from an engagement of the key national institutions. Next to the Academy of Sciences and Arts, the Faculty of Natural Sciences and Mathematics of the University of Montenegro and the Bureau for Education Services, which is the leading institution for monitoring, evaluation and improvement of education processes at the level of pre-school, elementary school and secondary schools. There is also room for stronger public-private partnerships (especially with relevant NGOs) in support of the renewal of science education, which could give a new energy to some initiatives from inside the country and from outside. Ultimately, however, the final decision to launch an IBSE-inspired program in science education in Montenegro will depend on the Ministry of Education and Science.

16. Netherlands: Royal Netherlands Academy of Arts and Sciences (KNAW)

KNAW has been active in arguing for an increase in the quality of primary and secondary education for many years. In 2010, the Committee on primary and secondary school education was set up, which advises the Academy’s Executive Board on relevant issues. The Committee convenes whenever the Academy is asked to respond to or express its views on an educational matter. It has defined two priorities for the 2010-2015 funding period: getting children interested in science and improving the disciplinary knowledge of teachers.

In line with the government policy, the Academy is seeking to generate support for the network of science education hubs (wetenschapsknooppunte). In a first phase, such hubs were located at all universities, with at least five of them directly experimenting in IBSE methods. Universities, primary school teachers and educational institutions work together

– a tested collaboration that had received support during three years under the Delta-Plan on science and technology education (see below). This approach, if somewhat threatened in the current climate of budgetary cuts, rests on the analysis and activities conducted under the multiannual programme “Delta Plan for Science and Technology” (*Delta Plan Bèta Techniek)*, a nation-wide initiative promoting science and technology education launched by the Ministry of Education and Science in 2004. Its long-term objective was to generate a more attractive and more differentiated education in S&T fields, leading to a lower dropout rate and to more graduations from both the vocational sector and S&T university degree courses (target for 2010: 15% more S&T graduates from the HE programmes in the sciences and technology fields compared to 2003). Improved career prospects for scientists and engineers, a better gender balance, and a student population comprising more students from ethnic minorities and from abroad were also listed among the goals. Commissioned by government, as well as the education and business sectors the Delta-Plan was to ensure the labour market was prepared for the knowledge-based society the country was aspiring to become in line with the Lisbon goals (see: http://www.deltapunt.nl/).
The Science and Technology Platform, initiated in 2004, did produce some remarkable results: one third of all primary schools have introduced S&T teaching, with 2500 primary school teachers undergoing dedicated S&T training (through VTB-pro). In secondary school, by 2010 almost half the pupils choose an S&T track, which pushed enrolment in S&T fields in tertiary education to close to a 1/3 of each annual cohort. The Delta-Plan experience also indicated that quality vocational training must not be underestimated as one of the stepping stones towards a knowledge-based economy. Cooperation between industry and education appears to have been central to the success of the programme, just as the sustained link between education and research needs to ensure that the rapid changes in science are reflected in education, despite the slower pace of innovation in the curricula. Recommendations presented to decision-makers at the end of the programme during a global conference in autumn 2010 included the insistence on starting a large-scale research program *Curious Minds* about talents of very young children, with special reference to the field of science & technology, and to develop further the science “hubs” as a vehicle and arena for cooperation between universities and primary schools. The Academy was actively involved in the programme, and notably in the final conference.

To some extent, the establishment of the dedicated new Committee on education reflects this commitment. Previously, the production of the relevant reports in relation to questions of education in STEM fields was in the hands of the relevant scientific divisions or of ad hoc commissions of the Academy.

For example, 2009 saw the publication of “*Rekenonderwijs op de basisschool: analyse en sleutels tot verbetering*” (Maths education at school. Analysis and keys for improvements). The report reacted to a growing concern about the mathematical proficiency of Dutch children and contributed to the public debate about the way mathematics is taught at school. Two schools of thought had been opposing each other: those who advocate teaching mathematics in the “traditional” manner, and those who support “realistic” mathematics education. The debate had a polarizing effect and seemed to be carried on without a proper evidence base in scholarly research. Together with the Ministry for Education, Culture and Science, KNAW launched a study on mathematics education to “survey what is known about the relationship between mathematics education and mathematical proficiency based on existing insights and empirical facts; [and to] indicate how to give teachers and parents leeway to make informed choices, based on our knowledge of the relationship between approaches to mathematics teaching and mathematical achievement.” The Committee’s conclusions gave a new quality to the debate: (1) it confirmed that overall the mathematical proficiency of Dutch primary school pupils was declining and justifies urgent intervention; (2) it observed that no compelling evidence can be produced indicating a fundamental difference in results between the two opposed instructional approaches ("traditional" and "realistic"); (3) it pointed to the fact that the key to improving mathematical proficiency could be found in the teacher's competences; the Ministry was urged to strengthen teacher training and post-graduate courses in mathematics and mathematics teaching.

In 2010, a year or so after issuing the report, KNAW could demonstrate that the emphasis on improving teacher training had caught on in political circles. There was, as yet, no evidence on the effects in-service up-skilling of currently employed teachers – considered the fastest method to remedy the systemic shortcomings that had been identified. The recommendation to make available additional resources for research into mathematics education had been satisfied by the national research council NWO. At the same time, the conclusion that results do not allow to prefer any of the two approaches, led to the issuing of new textbooks that allow for better quality alternatives to the "realistic" approach which had dominated the market for years.

In 2003, the Academy's *Biology Council* – together with the Netherlands Institute of Biology and the association of science teachers - had issued a report on the relevance of top-class biology school education that would reflect the role of life sciences as a lead science of the 21st century. The report emphasised the need to ensure that aspects of biology are taught throughout the school career "from four to eighteen years" and stressed the crucial role of teachers at all levels. Teachers, the report argued, face the difficult task of linking processes analysed by the life sciences and products derived from those discoveries to those domains of social and economic life on which results of such research will have impacts. This calls for new teaching tools and innovative teaching methods; it demands offers of continuous professional development. These, the report concluded, were sufficient challenges for a ten year plan to reform biology education.

Next to issuing such reports, the Academy – convinced that science and scholarship depend on inspired teaching - also awards *Education Prizes* to reward and encourage improvements in the quality in Dutch education. The prize is presented annually to the twelve best subject cluster projects by Dutch secondary school pupils (subject clusters including "Nature and Technology"; "Nature and Health"; "Economy and Society" and "Culture and Society"). The winning pupils receive a year's worth of tuition fees and an Academy certificate; the supervising teachers receive a work of art and are invited on a group cultural trip (the Dutch travel industry being one of the sponsors); their schools are given a plaque by the Academy and receive Academy members as their guests. The competition has been regularly highly oversubscribed ever since its inauguration in 2008, with 441 submissions from 168 schools received in 2011.

KNAW had argued for a specific responsibility of Academies for education – and science education in particular – already when it was co-organiser of the "*European Conference on Primary Science and Technology Education: Science is Primary*" in 2004 in the framework of the Dutch EU Presidency. Among the issues discussed at a workshop under the heading „The role of academics / the scientific community" were the request for the scientific community to play a more active role in stimulating science education at primary school, whether by simply highlighting the importance of science education at an early state of the school career, by assisting teachers or school-teams, by ensuring the scientific quality of curricular materials, or through other innovative initiatives such as 'Children Universities' which promote the exchange of pupils with "real" scientists. Due to their access to political power and to the media, the conference concluded, National Academies have a role to play in influencing educational policy and in joining or launching relevant public debates about the need to improve science and technology education.

Based on the workshops and the plenary sessions, conclusions were presented and adopted by the Dutch EU Presidency and presented to the European Commission and Parliament. These so-called Dutch Presidency Conclusions stated that "science and technology education is the best context to develop higher order cognitive skills needed [scil.: in a knowledge–based society], and primary school age is the age to start". The value of a leading role of the scientific community is emphasized as is the merit of using the experiences of pilot projects in Europe and the USA for developing didactic materials and conceptual introductions adapted for use in other countries.

In subsequent years, efforts were made to translate scientific discoveries into inquiry-based learning programs at primary schools, notably through as cooperation between the Netherlands consortium of – largely university based – science hubs and KNAW (2009-2011). These efforts included programmes for primary schools and some focused on teacher training, including offers of courses for continuous professional development for in-service teachers, having developed relevant teaching materials in the process.
Radboud University Nijmegen for example awards an annual prize for scientists who have succeeded in making a scientific breakthrough. In collaboration with teachers of science they are invited to develop a learning activity according to inquiry-based principles around their discovery. Project teams consist of active scientists, teachers and in-service teachers. During the activities children develop experiments based on their own questions.
The project cycle covers one year, from the award (September), through the preparation of a winter school workshop to be held in February, implementation in schools (spring/summer) and evaluation in July/August. It is to be emphasized that the project is accompanied by a research project that looks into its impact on student's and teacher's scientific process skills and attitude regarding science and science education and link those insights to reflections on student learning outcomes.

Another ALLEA report has provided an overview over the many forms in which Academies support early career researchers. Among the more innovative approaches are the so-called Young Academies, pioneered in Germany, soon adopted in the Netherlands, and now spreading across Europe and worldwide. The Dutch Young Academy (DJA), which is a group of competitively selected top-performing early career researchers, affiliated to KNAW, has made science education one of their high-profile interventions in science-society relations. DJA believes it is important for primary and secondary school pupils to find out for themselves what science is and what scientists actually do. One of their major projects is therefore *The Young Academy on Wheels*, in which – following a competition in which school classes respond to prize questions posted on the DJA website - a busload of DJA members and their PhD student-assistants spend a day running research workshops with secondary school pupils. After an evaluation in 2008, the programme was scheduled to expand to eight schools to be visited per year, the guiding principle for these visits being: science is fun and part of daily life! At a more operational level, themes are selected in such a way that they can be embedded into the regular curriculum – even if sometimes titles are deliberately chosen to suggest a departure from classroom routine, as in, for example the theme description "messing about with food".

A day programme with the *Young Academy on Wheels* begins in the morning with a TV personality escorting the participating classes to the school yard, where they welcome the bus with 25 scientists, including eight PhD students who will function during the day as facilitators for the eight groups of ca. 1-12 students each. Throughout the day, plenary sessions and workshops alternate; this, depending on the topic, can include experiments, games or films. The plenary sessions – moderated by the TV personality - also serve to exchange experiences between the eight groups. Logistics of the day are in the hand of a sub-contractor. The day is prepared with teachers and school administrators; pre-event visits ensure that certain basic conditions are available so that the programme can be carried out successfully.

DJA has also launched innovative science education activities for younger school children. The "Youngest Academy" (*De Jongste Akademie*) has as its core component a website and research game in which groups of pupils aged 10 to 14 can compete against each other (www.dejongsteakademie.nl). There are a number of other offers – games, quizzes - all skilfully seeking to include inquiry approaches and encouraging scientific explorations among the students.

17. Poland: Polish Academy of Sciences (Warsaw) / Polish Academy of Arts and Sciences (Cracow)

The two main Polish Member Academies reported comparatively little involvement in science education activities in their country. The Polish Academy of Sciences (PAN) with headquarters in Warsaw is primarily a research performing academy and as such the largest research institution in the country, while the Polish Academy of Arts and Sciences (PAU) with its offices in Cracow is a learned society with a long tradition.

Their engagement is mainly at the level of informal science education and science communication. Thus, the Polish Academy of Sciences is involved is events such as the Lower Silesian *Science Festival*, initiated in 1998 and organized every year for several days at the end of September in Wroclaw and in further 2-day sessions in the following month of October in eight provincial towns in the region (Jelenia Gora, Legnica, Walbrzych, Zabkowice Slaskie, Zgorzelec, Glogów, Dzierzoniów and Bystrzyca Klodzka). The festival primarily targets young people and seeks to show the attractiveness of scientific work. Over the last ten years, some 500.000 visitors attended the lectures and laboratories during the festival; interest is growing and in 2010 alone, the number of visitors reached 100 000.

The Polish Academy of Arts and Sciences in Cracow has a special outreach programme that combines the philosophy of the scientific cafés with the tradition of Open Lectures. In co-operation with the daily newspaper 'Dziennik Polski', the *Kawiarnia Naukowa* (Scientific Café) is open for the general public and has become a regular feature in the cultural and scientific calendar of the city of Cracow.

Jointly, the two Academies have a dedicated commission on the peer-review evaluation of textbooks for education.

18. Serbia: Serbian Academy of Sciences and Arts (SASA)

The Academy plays a key role in national debates about science literacy and about the reform of science education. The dedicated SASA Committee for Education, chaired by academician Milosav Marjanović, is recognized and respected in Serbia as the place where questions of education are discussed. (http://www.sanu.ac.rs/Odbor-obrazovanje/Index.aspx). It convenes regular open meetings with the participation of representatives from the Ministry of Education, from the National Educational Council, Belgrade University, etc., where problems of education are debated. The Committee also organizes a number of symposia each year, which deal with some current issues in education policy and practice.

Several factors have contributed to a growing interest in the need to reform science education, especially among political decision-makers and scientists, less so among the general public and in the media. There is an alarming decrease of interest for taking science degrees at university level; also the implementation of the Bologna process brought new challenges; finally, and perhaps most threateningly for the country's S&T sector, career prospects (positions; salaries; recognition; etc) for science graduates are uncertain.

The support of the Academy for IBSE approaches takes different forms: SASA is developing a closer working relationship with the newly merged Ministry of Education and Science striving to generate sustained political support for such approaches. The merger may bode well for the appreciation of the concerns of the scientific community to be heard on matters of education. The country can claim to have by now a tradition to building on in terms of involving scientists in helping to renew science education.

The best example is the *Science Center Petnica* which is the biggest and probably the oldest independent not-for-profit organization for extracurricular, informal science education in South Eastern Europe. Since 1982, Petnica has organized more than 2,500 programmes (seminars, workshops, research camps etc.) for nearly 50,000 students and science teachers in 15 disciplines of the sciences, technology and the humanities. While most programmes are designed for secondary-school students, many offers also target primary-school pupils, university students and science teachers. Participants come from all countries of the former Yugoslav federation. All courses are taught in Serbian, but there is also an annual English-language, international course for international participants (Petnica International). During a fortnight in July/August students from the age group 17 to 21 can conduct a scientific project in one of 15 disciplines (Astronomy, Physics, Electronics, Computing, Mathematics, Biology, Molecular Biomedicine, Chemistry, Geology, Geography, Archaeology, History, Linguistics, and Psychology).

Petnica Centre is located in Western Serbia and has fully equipped boarding facilities, classrooms, laboratories, library (40,000 books and journals, and computer database with thousands of electronic journals and books) and a carefully designed Teaching Resource Centre. Students and teachers have access to 35 computers 24-hours a day, since the centre is a member of the National Academic Internet Network (AMRES) - overall, the centre is probably significantly better equipped than most Serbian schools.

Serbia was the first country in South-Eastern Europe to apply IBSE methods, which today extend to about 10% of primary schools in the country, reaching some 300 classes and teachers and 6,000-8,000 pupils. The Serbian Academy of Sciences and Arts supported pilot projects in IBSE methods initially in lower secondary schools, but the optional course "Discover the World" was put forward in the elementary school as early as 2003.

The Academy also supported the project "*Ruka u testu*" for primary schools, which was developed in collaboration with the French Academy of Sciences and "La main à la pâte" following an agreement between the two Academies and the University of Belgrade in 2008. The website http://www.rukautestu.rs is a partial translation and adaptation of the French website of La main à la pâte. For lower secondary schools, an agreement signed between the Academies in 2010 has allowed the involvement of the VINČA Institute of Nuclear Sciences of the University of Belgrade.
Over the years, SASA has supported the publication of different resources for teachers (twelve books, four international thematic projects, etc.). SASA also sought to stimulate a broader public debate about "science literacy": in the framework of "Ruka u testu" the educational journal "*Prosvetni pregled*" published more than ten appendices about science literacy and the IBSE method. All these short texts have been collected for easy reference on the "Ruka u testu" website (http://rukautestu.vin.bg.ac.rs/?Page_Id=1193).

The programme offers free pedagogical kits for primary schools and has launched or participated in a number of collaborative and interdisciplinary projects: about 1,000 pupils and 150 teachers were scheduled to take part in "first signs of spring" (Greenwave Spring in Serbia) and there was also a good participation in the Serbian section of the global collaborative project "In the footsteps of Eratosthenes".
Next to these various hands-on engagements in reforming science education, SASA has also launched several discussions – internally first, but then also outside the Academy – in relation to the problems of mathematics education, with particular contributions on the part of academician Milosav Marjanović, author of numerous studies on the teaching of mathematics. Curricula at the university institutions, which prepare primary and secondary school teachers, have been inspected and courses of mathematics have been found to be seriously lacking didactical analysis of the school subject matter.

Targeting an audience beyond Serbia, SASA also helped with the organization of, by now, five regional conferences with support from the French Academy of Sciences which were all very well attended (*South-East European Summer School for Hands on Primary Science Education*, pt.1-4, ed. S. Jokić / M. Marjanović, Vinča Institute 2006-2009; http://rukautestu.vinca.rs/handson4). In the European and global context, Serbia takes part in the FP-7 funded project Fibonacci, the local project leader being Stevan Jokić from Vinča Institute. As part of this project, the Serbian team sought to transfer IBSE principles and practices to a broader community of educators, both through hands-on teacher training and through the translation into Serbian of textbooks, manuals and conceptual introductions developed in the European and French programmes. In recognition of his efforts, Jokić was awarded, together with Jorge Allende (Chilean Academy of Sciences), the coordinator of the IAP Science Education Programme, the *„puRkwa prize*" in 2007. The prize is presented every year jointly by the Ecole Nationale Supérieure des Mines of St Etienne and the French Academy of Sciences to pioneers in the innovation of general science education in school curricula for children below the age of sixteen.

The Academy bases its engagement in the field of science education on its conviction that without investment in science (and that includes: into the creation of a substantial body of scientists and experts) modern society cannot develop. This is why the efforts in science education are closely related to efforts in science communication: taxpayers deserve to be adequately informed about results, prospects and choices, especially since science is mostly financed from public funds. Helping to develop a scientifically literate public is therefore in the best interest of science itself, it is argued. This includes a substantial engagement in public debates about genetically modified organisms, energy choices, advances in biomedical technologies, ecology and biodiversity and global warming.
This is also why the Academy takes an active part in the annual "*Festival of Science*", organized under the patronage of the Ministry of Education. The festival aims to introduce the youngest into the world of science with presentations and experiments that follow, by and large, the inquiry method. The Serbian experience confirms the positive reports from other countries where the public enjoys the opportunity to be an experimental scientist themselves for a day, and, through exchanges with top scientists, comes to appreciate both the beauty and urgency to widen his knowledge. Lately, the science festival has teamed up with the "*Night of Museums*", thereby further advancing the synergies between formal and informal learning environments.

19. Slovakia: Slovak Academy of Sciences

The Slovak Academy of Sciences, as the premier research institution in the country, engages in various ways in discussions with the Ministry of Education, Science, Research

and Sport about the improvement of science education. The Academy has not, however, first-hand experiences with introducing inquiry-based science education into the curricula. Rather, its exchanges with the Ministry include general debates about “science literacy” and provision of advice and expertise with respect to new textbooks for primary and secondary schools (for example by scientists from the Institute of Mathematics). Recently also the Academy’s researchers in pedagogy have been involved in efforts to promote the renewal of science education.
The Academy has signed an agreement with the community association "*Young Scientists of Slovakia*" which focuses on stimulating an interest in science and scientific research among secondary schools students. In June 2011, for example, the Academy supported the 3rd International Youth Science Conference of Young Astronomers at the Slovak Centre of Astronomical research in the High Tatra (Conference Centre of the Slovak Academy of Sciences at Stará Lesná). Gifted young scientists from upper secondary schools (less than 20 years old) could present their scientific work, but also share plans for science careers with other young people interested in Astronomy and Space Physics and professional scientists from the Academy and from Slovak universities. Proposed fields for projects include: atmospheric studies and space geophysics; solar physics and heliosphere; solar system & extrasolar planets; stellar astrophysics; interstellar and intergalactic medium; extragalactic astrophysics and cosmology; high-energy astrophysics and particle physics; positional astronomy and astronomical equipment and computers and informatics in astronomy. Each of the selected delegations was composed of one to four upper secondary school students with outstanding scientific talent in the fields of natural sciences, physics and astronomy and one teacher as mentor. The total number of participants had been limited by organisers to 60.

20. Slovenia: Slovenian Academy of Sciences and Arts

In Slovenia, the Education Development Bureau at the Ministry of Education and Sport, is the key actor for any reform of science education and receptive to discussions on school curriculum reforms which have sprung up in universities and in the media. IBSE has found its way into the latest curricular reforms also thanks to the exchanges at European level provided by the FP-co-sponsored projects such as Pollen and Fibonacci. The implementation on the ground, it is reported, is still deficient, though, and requires in particular a boost to continuous professional development of teachers, equipping them with the necessary knowledge about IBSE methodologies.

In recent years, the Academy – nowadays a learned society - launched a series of workshops to explore the need and opportunities for expanding the understanding for the importance of science. Under the title "Knowledge as a value: education for the 21st century” workshops investigated the fields of biology (on occasion of the Darwin year when public interest was guaranteed due to discussions about evolution), mathematics, physics and chemistry. If the scientific community is gradually developing an interest in contributing to the reform of science education reform, as yet the Academy as an institution is not involved in pilot projects on inquiry-based science education. Individual members, on the other hand, contribute actively to public debates about “science literacy”, for example in the science section of the national daily "Delo".

Next to the University of Ljubljana, a number of schools and institutes take part in FP-funded projects in the broad area of science education, including *Institut Jozef Stefan* (formerly the Academy’s Institute of Physics), who are a partner in the FP7-project “KidsINNscience - Innovation in Science Education – Turning Kids on to Science” which involves ten partners in Europe and Latin America and aims to identify innovative approaches for teaching and learning science and adapt them for use in mainstream schools.

21. Spain: Instituto de España

The Instituto de España functions as umbrella organisation to seven national academies (which are, broadly speaking, divided up by disciplines) and also has a large number of associated members among the regional and local academies spread all across the country. All the Spanish Academies are learned societies, but several also carry out long-term research and documentation projects.
There is no programme in inquiry-based science education that any of the Spanish Royal Academies are directly involved in. Together with various sponsors the Royal Academy of Exact, Physical and Natural Sciences has been running a science outreach and education programme ever since 1998, which, on demand, also touches down at secondary schools, museums, military academies etc., across all provinces. So far, more than 600 courses were given, on 200 different topics. Many of the introductory lectures of academicians are collected each year in printed volumes and made available to the general public. Special attention is given to structure these presentations in such a way that they can serve also as a pathway for secondary school teachers to become acquainted with the latest developments in their respective sciences – also the value of direct exchanges with leading researchers is not to be underestimated. In Madrid, the Instituto de España also offered a programme about "Qualitative vs. Quantitative methods in Science".

22. Sweden: Royal Swedish Academy of Sciences

The Academy's activities aimed at supporting and improving science education dates back to the 1980's and have more recently been coordinated by the *Science and School committee* at RSAS (KVS). Ever since 1991, RSAS has been awarding annual prizes to up to four teachers in maths, biology, chemistry and physics who through their enthusiasm, their new ideas and their inspiring work have awakened their pupils' interest in these fields. The Ingvar Lindqvist-Prize, also called the *Teachers' Prize*, is named after the Academy's president in the period 1988-1991.
RSAS has been organizing for many years one or more annual teachers' days in different locations across the country. During these days, Academy members give inspirational lectures on topical issues in fields of scientific discovery that are developing rapidly, or that stand out in public debates. Recent examples of such themes are "From Big Bang to Uncertain Future, "Material in Many Dimensions" and "Thought and the Brain". These teacher days primarily target high school and upper secondary school teachers.

Despite its efforts and achievements over two decades, the Academy is still sceptical whether the concern that drives their engagement is properly grasped and reflected in political and societal debates about science literacy. Together with the Royal Academy of Engineering Sciences (IVA), RSAS seeks to inject the topic into political debates. In 2009, a government-commissioned „*technology delegation*" was working on a report which was delivered in time for the on-going elections; one of its assignments was to raise the awareness of how future needs for young people are linked to science and mathematics education. Among other things, a campaign was launched under the title "The Broad Way", aimed directly at middle school students, which argued that by choosing the science track in high school students would have the widest choice of options for their subsequent university studies.

The Academy also uses conferences and workshops to create awareness, introduce new vantage points and stimulate exchanges with professionals, bureaucrats and political decision-makers. In 2006, the two Academies held the 2nd European Conference on Primary Science and Technology Education ("*Science is Primary II: Engaging the new generation*") which focused on inquiry-based primary science education, robust methods for evaluation and research, and sought to provide an overview over European perspectives. The conference gathered teachers, principals, policy makers, program coordinators, researchers, scientists, teacher trainers, representatives from school administration and mass media.

The Science and School Committee have organized three symposia on current school-issues, recently in May 2010 under the title "*Learning, assessment of knowledge and grading*" with invited speakers from the UK and the USA.

The most important, largest and most visible effort, however, is the NTA-programme (*Naturvetenskap och Teknik för Alla*; Science and Technology for all), started in 1997 as a project by RSAS and IVA. The programme supports teachers in their efforts to stimulate pupils´ curiosity, knowledge and possible interest in a career in science and technology. It currently targets primarily classes from kindergarten through to 7th grade (students of 13 years of age). It is owned, run and funded through the municipalities, often with funds from the Ministry of Education and Science or from private sponsors, and offers methods, tools and services for improving learning and teaching in science and technology. Within the first 14 years, endorsement and participation had been received from more than one third (104 out of 287) of the ca. 300 municipalities in Sweden and from 18 independent schools (totalling some 120,000 students and 8,000 teachers each semester).

The programme was launched when it could no longer be overlooked that municipalities, which run most schools, were poorly prepared for the new national syllabus introduced in 1994 which for the first time set objectives for elementary school students for the subjects biology, physics, chemistry and technology. In many cases, it was found that teachers had no formal education in science and technology, and that schools were lacking equipment and laboratory spaces etc. As if to illustrate the concerns born out of the observations on the ground, a nationwide study revealed that students in the final year of compulsory school found it difficult to accurately answer questions on "ecology", "the human body", and "matter". The most worrying results were met in physics. In addition, the study revealed that almost without exception boys were more successful than girls, a fact that did not pass unnoticed in a country dedicated to gender-conscious policies. Soon, other reports pointed to another set of shortcomings arising from the observation that there was little contact between the educational practice in schools and current S&T research and between school education and curriculum research. Contacts between research and practice were also rare in teacher training curricula.

A RSAS delegation had paid a visit to the National Academy of Sciences in Washington in 1996/97 and learnt about NAS's efforts in and studies of science education issues, notably the initiatives of the National Science Resource Centre (NSRC) and of "Science and Technology for Children (STC). In 1997, STC was presented during a RSAS teacher seminar in Linköping to the municipality officer in charge of school development. Progressively, the idea matured to adapt STC material to serve Swedish curricular needs. Thanks among others to the personal engagement of the then NAS President, Sweden was granted free access to the STC material for a period of 10 years. STC units were translated and adapted and tested by engaged teachers in their own classrooms. The IBSE approach thus developed and implanted poses at its centre the necessity for children to learn at an early age about the "nature of science", ", i.e. to practice and maintain the natural inquiry skills humans are born with.

In the participating municipalities, the NTA programme helps create long-term plans for school development that involve also local industry and institutions for higher education and research. In each participating municipality a local coordinator for the programme is appointed.

The programme is committed to inquiry-based science education. Inquiry in the NTA approach comprises (1) asking questions, (2) collecting data, and (3) discussing how the data can be used to answer the question. Such inquiry may also include socio-scientific issues whether as a trigger for the question or as a reflection on consequences of the observations made.

The regular NTA programme is owned, run and financed by the municipalities or their equivalent while the development of new or revised materials and services is organized and financed by the academies through fund-raising. The programme is organized around "units" that all have some relation to the curriculum and its further development. The units target children from kindergarten age all the way to 9th grade. The thematic experimental units – e.g. "floating or sinking" and "plant growth and development" – allow for a structured teaching sequence, involving brainstorming, making predictions, observing or making experiments, and applying knowledge to contexts outside school. The programme provides teachers with all the materials needed for integrating the unit into the classroom activities: kits comprise experimental material and written instructions for the teacher and the students, as well as suggestions that facilitate monitoring of the progress made. All materials are designed to emphasise observational, experimental and reflective skills among pupils. Any given unit takes some 10 to 12 weeks to complete. Once a unit is completed, the teacher returns the material to one of the local centres, where the kit is replenished and made ready to be used by another class. All units are initially tested in several versions in multiple classrooms, and there is a constant drive to revise and improve units, based on an expanding infrastructure for didactic research in science and technology. Prior to the first borrowing of a specific unit, teachers are required to attend a day of training for the thematic area as part of their continuous professional development. Advancing teachers' competences is at the core of the programme. Typically, it is in teams of colleagues that teachers are invited to seek to review their attitudes towards, and approaches to, science and technology. In the process, they are given opportunities to expand their knowledge of current developments and debates and by acquiring new methods and tools. Training is initially offered at an introductory level (1/2 day). At a more advanced level, investigations in thematic areas make use of the 20 or so NTA units in biology, physics, chemistry, technology and mathematics. Evaluations have shown that the NTA programme is appreciated also by teachers already trained in science education, because it gives suggestions about varying and extending courses taught of the themes set by the curriculum. The adaptability and flexibility of the units allow teachers to change the sequence or modify them according to their preferences, previous knowledge or classroom needs and typical opportunities. The programme aim is to improve the performance of elementary school students and teachers under the Swedish national curriculum; as part of a long-term plan for sustaining this reform dynamics, recurring unit meetings are organised that also involve stakeholders from other sectors of society (industry; academics; etc.). This reflects the overarching NTA objective to seek the engagement of local industry, institutions and people outside the school.

It has been argued that an inquiry-based pedagogy fits well the Swedish National Curriculum which seeks to inject democratic principles into education, enabling students to critically observe and examine facts, communicate and discuss, notice and evaluate consequences and work independently and with others to solve problems. The national science and technology curriculum for primary schools has syllabi for biology, chemistry, physics and technology, which mention most of the IBSE concepts. The syllabus for science covers three main areas: “Nature and Man” (*sic*), “Scientific activity” (which essentially includes the techniques of inquiry), and a third area, “The use of knowledge”, which goes beyond the regular scope of the NTA programme.

A number of not insignificant obstacles still need to be overcome: evaluations have revealed different outcomes for boys (who benefit more from NTA-based teaching notably in the first area, “Nature and Man”) and girls.

Another critical issue is the lack of science and technology training that the majority of primary teachers have received prior to entering their service at schools. This is probably a problem that the programme alone cannot make up for. The IBSE methodology is based on the principle that learners are guided through well structured observations and experiments and their description from their prior experiences and gradually infer new meaning and understanding from the prepared experiments; only once these new explanations are understood and absorbed can they be applied to new situation. When next to the student also the teachers lack scientific training, methodology and the language to describe them, progress is easily stalled, as spontaneous problem-solving and progress rarely if ever occur. The programme design for the preparatory training sessions takes into account the necessity of proceeding through the acquisition of “pedagogical content knowledge” (Shulman). Instructors are of course aware of the delicate nature of this knowledge, when it is not solidly grounded in a full science degree course, which is why there is concern about the efforts needed for more substantial in-service professional development. Feedback and evaluations from the NTA programme suggest that more emphasis must be placed on teachers’ knowledge of scientific methods and content, so that they can more competently reflect on and adapt the content of the units to their students’ needs. It is expected that such a deeper understanding would allow teachers also to better address the needs of girls in S&T education.

Another field for further development – both, of the units and in terms of teacher training - is what is covered largely by area 3 of the S&T syllabi, i.e. inquiry and critical reflections on science, technology and societal issues. Here, a more extended sense of the notion of inquiry needs to be established, by which the student “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” (Wickmann).

Over the 14 years of the existence of the programme, the Academy Committee has promoted NTA by writing articles both in scientific journals and in media with a wide circulation, with variable levels of feedback, and through conferences and training sessions also abroad. The Academy - and through it the NTA Programme – has participated in a number of FP-co-sponsored projects, such as *ScienceEduc, Pollen, Helena* and *Fibonacci*, where the Swedish expertise and experiences are often taken as models for the development of adapted national programmes.

Gradually, debates not dissimilar from those that propelled to the fore IBSE approaches have also come to touch *mathematics* education. There has been a state delegation on mathematics education in school and the Department of Education is presently paying attention to maths development, and has created a number of new programmes. A few years ago the Academy Committee established an active cooperation with the National Resource Center for Maths; the first NTA-unit on maths has by now been has by now been developed, tested and put in 'regular production' in schools. It is likely that more units will be developed, as there is a great interest and strong demand from schools.

While the NTA programme and many of the other efforts of the Academy to improve science, technology and maths education predate the public debates triggered by the OECD benchmarking exercises, the sensitivity for the importance of early science education among decision makers and in the media has increased due to the relative decline in performance of Swedish schools in the more recent PISA and TIMSS. But it is probably also accurate to say that the growing interest (and understanding) among non-specialists is also a consequence of published international and Swedish research into the matter. Also analyses of conditions for European and global competitiveness have contributed to strengthening the position of those who argue for a more systematic reform of science education across the country, and not only in selected municipalities.

Systemic change is beginning to be visible, though: a new curriculum is expected to be explicit as to what content in science and other subjects teachers are supposed to cover in the early school years. Also a form of habilitation will be introduced that will certify that teachers teaching science in elementary school are qualified to do so; hitherto this has not been the case. Alongside these measures the government has made available substantial resources for in-service teacher training and for the further development of MST teaching. New assessment methods will need to be introduced, which presents a considerable concern for all schools. A first set of support material in this area for teachers was developed for and by NTA in 2010 and disseminated in early 2011 with financial support from the State School Agency (*Skolverket*).

All four Swedish ALLEA Member Academies - Royal Swedish Academy of Sciences, of Engineering Sciences, of Agriculture and Forestry, and of Letters, History and Antiquities are members of the non-governmental organisation *Vetenskap & Allmänhet* (VA, or Public & Science) which works to advance and encourage the dialogue between researchers and the general public. Its offices are located at the Royal Swedish Academy of Engineering Sciences. Many of VA's activities – whether projects, studies, surveys or events – focus on stimulating a constructive dialogue between researchers and the general public. Events supported by VA include researcher nights, science cafes, or the FP-funded 2WAYS project. Among the many study projects, the long-standing strand of work on young people and their relationship with science and technology is of direct relevance here.

A session on young people's attitides towards science and technology at the 10th conference on the public communication of science and technology held in Malmö in June 2008 discussed the phenomenon observed in many countries, namely the concern about a declining interest among young people in science in general and more particularly in studying science.

In 2007, a drawing contest among children who were asked to depict themselves as researchers attracted submissions from 3,000 children aged 6-12 years; given that the competition was connected to the events of the annual science night it is perhaps not surprising that their view of science and scientists was overall positive.

Young people's attitudes towards science, technology and researchers were presented in a series of studies conducted in 2007 and summarised in English in the 2008 report ”Knowledge Rocks! -Summary of a youth study by VA”. The studies found that Sweden is battling with some of the same problems known also from other countries: while young people are generally interested in new knowledge, in their eyes “Science” may often have a negative connotation; “usefulness,” context and relevance are important, and these categories are defined in the context of their own experiences. All initiatives to stimulate interest in science have to reckon with the researcher stereotypes that are rife notably in the popular media; one way of dismantling the stereotypes is, of course, to create arenas for researchers to meet children and young people.

23. Switzerland: Swiss Academies of Arts and Sciences

Swiss Academies is composed of four independent academies, the Swiss Academy of Humanities and Social Science (SAGW), the Swiss Academy of Medical Sciences (SAMS), the Swiss Academy of Sciences (SCNAT) and the Swiss Academy of Engineering Sciences (SATW). The academies themselves are mostly networks of national scientific societies and organisations.
Any intervention in educational matters by organisations – like the Academies - that operate across Switzerland is complicated by the fact that there is no single federal ministry responsible for science education. Primary and secondary schools are under the competence of the 26 cantons. The confederation plays a role of coordination and/or moderation, chiefly through two agencies, the Federal Office for Professional Education and Technology OPET and the State Secretariat for Education and Research. Otherwise, each canton has a different educational system and decides on its own school curricula. Nonetheless, the Academies and others have been successful in promoting innovative interactions between science and society that also reach the classroom. In recent years, the country has come to witness a public debate about science literacy; the Swiss Academies play an active role in these debates. Another round of debates has been triggered by the observation of a critical lack of specialised staff.

At a more general level, the promotion of science literacy as part of the mission of the Swiss Academies has lead to a number of new projects in collaboration with the Swiss National Science Foundation and with the foundation "*Science et Cité*". Also museums, together with the universities, play a role in promoting and reinforcing science literacy, as do, evidently, science centres, such as Technorama – to whom a link is provided through the Academy supported project "Science et Cité".

For 2012, Swiss Academies are planning to set up a new web-platform ("educamint") offering school teachers assistance and guidance with the vast number of materials and events on that are available for children of any age in the STEM fields (in German: MINT - mathematics, informatics, natural sciences, technology and engineering). While the Academies are active in such activities in informal environments, they are not directly involved in improving formal natural science education through inquiry-based methods in primary and secondary school classrooms. However, the 2009 White Book *„Zukunft Bildung Schweiz"* (Future – Education – Switzerland) about the future of the education system in Switzerland (with a target horizon 2030) did identify a number of major challenges and proposed some necessary adjustments of the educational system, which have a bearing on science education. The report also triggered an unusually harsh public controversy resulting in strong media coverage, even though the focus of the debate soon shifted to other societally relevant issues in education which were not dealt with in the report itself. In fact, the polemic reached such a level of disconnect from the report, that the Academies were forced to issue clarificatory statements and hold meetings to refocus the debate.

A key concern of the report was the soon-to-be-felt shortfall of highly qualified staff in engineering and health professions. Some of the arguments, which were given little attention in the public debate, were precisely those that are of relevance for the reform of S&T education. They include the request to better network S&T domains in higher education and the relevant corporate sectors, but also the suggestion to create stronger linkages between science education at school and the real life experiences and requirements. The report also emphasised the need of the school system to improve in terms of promoting inclusiveness and equal opportunities, and demanded better support for the professional development and recognition of teachers. The clarificatory statement by the Academies included an appeal to the public to engage with the recommendations contained in the report, notably in seeking to make sure that some of the most problematic shortcomings of the report itself – such as: lack of specificity when it comes to implementation – could be rectified. As a consequence a number of meetings with experts, politicians, representatives of business and trade unions and the general public were held. Among the elements of consensus that emerged from these meetings were an agreement about the desirability of a higher degree of national coordination, and a set of implementation measures and research needs. A second statement based on these and other results was planned to be issued later in the year.

A number of Swiss institutions is taking part in European or national pilot projects on "inquiry-based science education" (IBSE), but the Academies as institutions are not directly involved. The *Swiss Mathematical Society*, a member organisation of the Swiss Academy of Sciences (SCNAT) offers activities specifically dedicated to the teaching of mathematics such as in-house training for teachers, summer school for the pupils (http://www.math.ch/mathematics-at-school/).
Otherwise, there is a multitude of often entirely independent initiatives that operate frequently with the help of sponsorship from the corporate sector, or are altogether of the scientific outreach function of large knowledge intensive industries.
The IBSE approach is (partly) taken by many student labs, for example the iLab at Paul Scherrer Institute in Villingen, the largest Swiss research centre for natural and engineering sciences (research in "Matter and Material"; "Energy and the Environment"; "Human Health"). ILab targets students of different ages, who, under the supervision of active scientists, are given a glimpse of the principles of scientific research and discovery (http://ilab.web.psi.ch/). Arranging these interactive experiences is part of the institute's efforts to provide pre-university professional orientation. Through a series of purpose-built experiments students can learn whether they might be interested in further scientific studies. They also have an opportunity to interact with some of the country's leading scientists.
Novartis in Basel offers thematic student labs on topics such as food, water, soil, clothing (http://www.novartis.ch/careers/schullabor/naturwissenschaftliche-phaenomene.shtml), but also has hands-on activities related to specific scientific fields (biotechnologies; gene-sequencing). The life science learning centre (http://www.lifescience-learningcenter.ch) is an initiative of the Swiss Federal Institute of Technology Zurich (ETH), and is taken forward jointly with the University of Zurich. At the time of its foundation, a reform of the curriculum for high school teacher education was under way and it seemed a good opportunity to develop such a project jointly with life scientists and experts and practitioners from the educational sciences. Thus, if the LSLC seeks to engage the general public, it is in particular with middle schools that it wishes to interact, stimulating critical and knowledgeable exchanges about the opportunities and risks of advances in the life sciences. There is a dedicated cluster of scientists, specialist teachers and educationalists who have to watch over the content dimensions of the didactic material and the experiments on offer (to some extent also: relevance for and linkages with the school curriculum) and to provide quality assurance. In 2008, the Life Science Learning Center was named by the EU-funded Action Support Programme "form-it: Take part in Research" as one out of three Swiss examples of good practice for successful cooperation between research institutions and the educational sector (see: http://www.form-it.eu/examples.htm).
In the field of technology (and with a certain emphasis on energy and transport issues) the project "explore-it"(http://www.explore-it.org/en.html) provides materials and task kits that would enable young people to be technically innovative at school. This project is an initiative of the Schools for Teacher Education of the Swiss canton of Valais and of the University of Applied Sciences North-western Switzerland. The educational kits are

assembled at a sheltered workshop for persons with disabilities. The project also offers in-service training for teachers.

The “do-it-werkstatt” (do-it-lab; http://shop.do-it-werkstatt.ch/index.php) has its focus on technologies and textile design; the project targets teachers and students, offering advice and tools for S&T literacy, and support for classroom activities. There is also an online treasure trove of 420 resources for teaching, inquiry and discovery, all arranged thematically and, wherever possible, in line with curricular needs. The project is steered by educationalists and curricular experts, jointly with other professionals.
Real-tec (http://www.real-tec.ch/) is a project that aims to bring children, through hands-on experiments and tasks, to a more genuine appreciation of S&T and related professions. The project is cognizant of the different degrees of exposure of children to the realities (opportunities and risks) of research and development in the modern world – and of the fact that prevalent teaching methods at school do little to make up for these differences - and has deliberately sought to design its activities in a way that promotes inclusion and integration. The lab targets teenagers of 12 to 16 years of age. The project offers mobile units, designed to fit into school project weeks, and training sessions for teachers and instructors. Tasks are structured in such a way that team building and meaningful division of labour – following the acknowledgment of talents – are elements of success. Also active use of the Internet – as in real life – is part of the tasks. Kits are designed so that a variety of tasks can be fulfilled – it is for the school and the students to choose.

A common characteristic of all these efforts is that they offer experiments related to the requirements of the official school curricula. There are also elements of experiment-related in-service teacher training. In some cases, kits are also made available for use in the classroom. Whether or not these external initiatives are sustainable and can really contribute to changes in the classroom is as yet to be examined.

“*Science et Cité*” (Science and society) is a network of the Swiss Academies which functions as an independent foundation in the three largest linguistic communities of the country (German-speaking, Suisse Romande, Svizzera Italiana). The foundation aims to encourage exchanges between scientists and citizens and create a climate of better understanding and, ultimately, mutual trust. To this effect it proposes, next to science communication efforts of all sorts, a series of activities that should stimulate children and youths to take an interest in science. Unlike traditional classroom teaching, such „Science et Cité” projects require active participation (experiments; computer work; involvement in decision-making processes of scientific projects). Efforts are also made to get children interested in science through other means: cinema, development of innovative pedagogic materials for school…

“Science et Cité” functions as the Swiss node for the *GLOBE programme* (Global Learning and Observation to Benefit the Environment). GLOBE, created in 1994 by former US vice president Al Gore, seeks to encourage pupils to develop deeper insights into the complexity of system earth, allowing them in the process to better appreciate that local phenomena can have global causes and that local actions can trigger outcomes far away in space in time.

24. Turkey: Turkish Academy of Sciences

While the Ministry of Education is responsible in Turkey for both science and maths education in primary and secondary schools, the Academy – a learned society founded in 1993 – has a long-standing Science Education Project that was started with the goal of enhancing inquiry-based science education at pre-school, primary and secondary school levels. The TÜBA Science Education Committee, set up in 2002, has organized summer schools for selected primary and secondary school level science teachers and lectures by academy members to science teachers. Science education activities are planned and organized by TÜBA in Ankara and carried out through cooperation with public and private schools of the Turkish Ministry of Education. For cities outside Ankara, the planning and implementation of all activities rely on close cooperation with related institutions.

In 2007, the Academy's science education project received funding from the State Planning Organization for activities such as meetings in four pilot schools with the participation of school teachers and Academy members. Twelve such meetings were organised since 2007. The Academy also organised symposia to familiarise Turkey with the French „La Main à la Pâte" programme and international conferences such as the 2nd Asia-Pacific Science Education Conference organised by the Association of Academies of Sciences in Asia (AASA) in 2008. Six local science education workshops were held in the years 2008-2010 in different locations across the provinces in order to introduce the project to teachers, academicians and other interested parties. The TÜBA science education portal (www.bilimegitimi.tv.tr) is a tool to share the activities related to an IBSE approach with all educators and the general public. Free of charge, it gives access to science experiments, project activities, biographies of scientists, interviews and lectures.

Except for the Academy's science education programme, TÜBA's report indicates that there is no national programme that would seek to spread IBSE approaches as part of teacher training. Meanwhile, a team of teachers is meeting regularly to prepare inquiry–based classroom activities in mathematics under the guidance of an academician from the Faculty of Education. Despite the activities of the Academy, it was reported that no major changes could be observed among the political decision-makers or even among the majority of academics at the universities with regard to the need to reform science education.

25. United Kingdom: Royal Society of London

Responding to the ALLEA survey of Member Academies about possible changes in the ways in which the importance of early science education is seen by political decision makers, academics and the media, the Royal Society of London suggested that it could be observed over the last 10 years that more attention was being given to these issues both from a policy and research perspective.

While the Royal Society itself is not engaged in pilot projects on "inquiry-based science education", it had been associated with the creative science centre of University of Sussex that started out from the science education efforts of Nobel-prize winner Harry Kroto, and also has been supporting the activities of the National Science Learning Centre. The Academy's focus on policy efforts has restricted the Royal Society's work so far on studying in their work chiefly secondary schools and the factors that impact on participation in STEM education and transition to tertiary education.

These '*State of the Nation*' reports result from a four year study of science and mathematics education in the UK, based on official national statistics and other research evidence. The reports seek to identify, assess and understand patterns and trends in participation and attainment in mainstream examinations, and probe the strength of the evidence base available upon which future educational policy is expected to be based. In doing so, they also identify research needs and policy actions.

The series of four reports was launched with an investigation into "*The UK's science and mathematics teaching workforce*" (Dec. 2007). The report drew attention to the direct link between the number, quality and deployment of teachers in these domains, the quality of the education imparted, and young people's intellectual development and ability to find their way in a knowledge-based economy and society. The report examined the size of the UK's science and mathematics teaching workforce, and the extent to which this workforce is populated by specialists – and found that the statistical data on which current statements rest is deficient. For example, there is no agreement on the notion of a specialist teacher. Also the sources and numbers of new recruits to the profession, and the ability of the system to retain them in teaching professions, are not currently captured with the degree of accuracy that would allow for reliable measures to be put in place for a UK-wide advance planning of human resource needs in the sector. Access to pre-service and in-service training needs to be improved and a system of monitoring of the careers of science and mathematics teachers should be introduced.

The second report under the title "*Science and mathematics education for 14–19 year olds*" (October 2008) assessed national trends in the participation and attainment of 14 to 19 year olds in science and mathematics education for the period 1997 to 2007. The substantial policy and institutional changes in the field during those ten years appear to have done little to increase participation rates. The findings point, however, to significant differentiations between the UK's educational authorities. It seems that a better flow of information and the use of platforms for exchanges should allow for a deeper understanding of comparative data. The report highlights some of the additional challenges that a diversified education system in the Home Nations will pose in policy terms and in view of the future comparability of standards.
The report comprises a number of recommendations that reflect the need to make up for the advanced diversification among the UK nations and for the effects of outsourcing a range of quality assurance services in the educational sector: there should be greater collaboration between the education authorities in order to ensure that comparative data are collected and presented more consistently and coherently; such data should also include greater detail about patterns of socioeconomic and ethnic participation and attainment. All commercial agencies that administer examinations should be obliged to make available specific subject-based data on examination participation and performance. Policy initiatives in the field of education should draw on the existing and evolving evidence base and involve consultations with STEM education stakeholders to reduce the risk of reform being implemented that risk entailing too many unintended consequences on science and mathematics uptake.

"*Science and mathematics education for 5–14 year olds*" (July 2010) is the third report. It focuses on the early phase of formal education. It summarises the quantitative information available on attainment and the workforce in respect of 5–14 science and mathematics education and seeks to explain the factors that contribute to the trends observed. Recommendations are submitted on specific actions aimed at creating conditions that would be apt to improve science and mathematics education for the age group examined.
The report highlights a number of critical structural issues that need addressing: they include an underqualified teaching workforce, at least when it comes to the preparedness to dispense contemporary science and maths education in primary schools; the practice of "teaching to the test" can be described as one of the consequences of this lack of confidence in scientific domains. The key element to resolve this particular problem would be, evidently, to increase the number of specialist teachers. But also funding for in-service, continuous professional development for science and maths teachers must be secured, including cross-disciplinary science for non-specialists units who themselves frequently lack basic understandings of how science works. An argument is also made that the "high-stakes" tests that characterise the UK educational system may contribute to the reluctance of school children to take up science and maths. Many would argue that the current testing methodologies are not particularly well suited for assessing the success of inquiry-based

approaches in science; as the report puts it: “science is a practical subject and it needs to be taught and assessed as such”. One major concern of the report is the continued inadequate statistical basis available for policy initiatives and decision-making.

The fourth report is entitled “*Preparing for the transfer from school and college science and mathematics education to higher education first degree courses in science, technology, engineering and mathematics in the UK*” (February 2011). It looks at the pool of the country’s 16 to 19 year olds who take mainstream science and mathematics combinations suitable for entry to higher education. The report finds that participation of that cohort in STEM education is too low and that England, Wales and Northern Ireland should strive to match the higher levels evident in Scotland. Also the unsatisfactorily low number of students aspiring to become specialist STEM teachers in schools and colleges needs to be raised. Such teachers as there are need to benefit more comprehensively from dedicated subject-specific continuing professional development. Evidently, it will help their job satisfaction also if the curriculum they are expected to teach is rigorous and engaging, and that the educational facilities they are operating in are conducive to the needs of inspiring and innovative teaching of science and mathematics.

At least two important networks in the field of maths and science education are based at and/or supported by the Royal Society of London.
ACME, the independent *Advisory Committee on Mathematics Education*, was established in 2002 by the Royal Society and the UK Joint Mathematical Council with backing of all major mathematics organisations, and continues to operate under the auspices of the Royal Society. ACME informs and advises government with a view to raising standards and promoting mathematics at all levels of teaching and learning in England. ACME seeks to act as a single voice for the mathematics education community to government, providing an authoritative, credible, balanced and coherent position. The Committee receives support from the Department for Education, the Royal Society, the Wellcome Trust, the Gatsby Foundation and a range of other organisations. Current areas of focus for ACME include work on the review of the national curriculum and on the issue of attracting, training and retaining the best teachers.

The Royal Society is a member of SCORE, the “*Science Community Representing Education*” (SCORE) partnership, which supports the government’s STEM programme. Partners include the Association for Science Education, the Institute of Physics, as well as the Royal Society of Chemistry and the Society of Biology. SCORE is a response to a wide-spread concern about the long-term decline in the numbers of young people taking A-level physics and chemistry and the unacceptable shortages of specialist teachers in these subjects. Its objective is to improve science education in UK schools and colleges by supporting the development and implementation of effective education policy. SCORE's priority areas over the next four years are the curriculum, qualifications and assessment, the school and college workforce and the wider learning experience. Partner organisations undertake collaborative projects to inform the policy advice given to government and promote the sharing of best practice; engaging the wider science community through conferences, calls for evidence, task and finish groups, workshops and regular news bulletins.

Recent policy work includes “*Training our next generation of outstanding teachers. An improvement strategy for discussion*“ (August 2011). The report argues that raising the status of the teaching profession involves more than simply raising the bar for entry: a rethink of the entire multi-year process of transforming university graduates into teaching professionals is required. Given the well-known shortage of STEM graduates entering initial teacher training, they must be confident at least to receive the same level of support as they would in secondary ITT courses. Simplifying the initial teaching training infrastructure also seems a necessity in view of the declining number of applicants.

A briefing paper "*Subject specialist teaching in the sciences: definitions, targets and data*" (July 2011) addresses the confusion reigning about the notion of specialist teachers. Agreed and meaningful definitions of what is meant by 'subject specialism within the sciences' need to be formulated. Definitions should be such that they can be employed to determine targets in the supply of science teachers (i.e.: content, admissions to individual training courses and balance of subject specialists). Such clearer language should also help improve official records about subject specialist teachers, ultimately to provide evidence on the relationship between teachers' qualifications/academic background and students' attitude, attainment and progression in the sciences.

Some of the sponsors of these Royal Society-related initiatives also fund, together with the Economic and Social Research Council (ESRC), the related *Targeted Initiative on Science and Mathematics Education* (TISME; http://tisme-scienceandmaths.org/), coordinated by the Department of Education and Professional Studies at King's College London. Through a portfolio of five major research studies and dissemination activities, TISME aims to find new ways to encourage children and young people to greater participation, engagement, achievement and understanding of Science and Mathematics.

Based at King's College London, ASPIRES (*Science Aspirations and Career Choice: Age 10-14*) is a five year longitudinal study about the factors that affect aspirations in and engagement with science during the critical period between the ages of 10 and 14. Research involves an online survey of over 9,000 pupils and in depth qualitative work with over 180 parents and children. The interplay of gender, social class and ethnicity as well as the influence of peers, parents and schools, will be examined. Critically, the project will also develop, in collaboration with teachers and other experts, strategies for teaching about science-based careers in Key Stage 3.

The Leeds-based project EISER (*Enactment and Impact of Science Education Reform*) examines the responses of English schools to major changes in the science curriculum for 14-16 year olds: new science courses show more awareness of applied science and offer teaching about socio-scientific issues. Based on nationally representative data, created by the National Pupil Database and in-depth case studies of schools, the three year longitudinal analysis focuses on teachers' classroom experiences with the new curriculum. The study also assesses the impact of these reforms on student achievement, student attitudes towards science education and progression in post-compulsory science courses

EpiSTEMe (*Effecting Principled Improvement in STEM Education: Student Engagement and Learning in Early Secondary-School Physical Science and Mathematics*), is a Cambridge based project that aims to redesign key aspects of the teaching and learning of physics and maths at the formative early-secondary stage. Reflecting insights on conceptual growth, identity formation, classroom dialogue, collaborative learning, and relations between everyday and formal understanding, design, implementation and evaluation of the pilots are conducted in close collaboration with teachers from several schools. The project seeks to generate tried-and-tested resources for training teachers and teaching students,

A project aimed at "*Increasing Competence and Confidence in Algebra and Multiplicative Structures*" (ICCAMS), based at King's College London, is built around a representative survey that had produced data on the understandings and attitudes of c. 7000 students – using a methodology that allowed for comparisons with data from the 1970s. Design and implementation of the assessment tools are arrived at through cooperation with a group of teachers.

"*Understanding Participation rates in post-16 Mathematics and Physics*" (UPMAP) is the objective of a project based at London's Institute of Education. Using a mixture of qualitative and quantitative methods, it examines the relative importance of individual, in-school and out-of-school factor, with their interactions, in influencing post-16 participation in mathematics and physics in the UK among different student populations. The study hopes to provide evidence for better targeted interventions that aim to boost post-16 participation rates.

Currently, the Royal Society itself is carrying out a study that examines the ways in which the subjects '*Information and Communications Technology*' (ICT) and 'Computing' are taught in schools and colleges across the UK. With expert input from teachers, academics and other members of the computing community and through a wide-ranging consultation of stakeholders, which also sought to develop an international component by involving WG members from across Europe, the study addresses a growing concern that the current design and delivery of ICT and computing curricula in schools are putting young people off studying the subjects in tertiary education. Through a series of stakeholder events and a call for evidence, which generated over 120 responses, the project has been building an evidence base in the course of 2011 that will help guide further deliberations and will inform the recommendations to be made later in 2011/12. The international survey among Academies aimed to find out how concepts relating to the subject areas of ICT and Computing are included in different curricular contexts abroad.

As part of its study of the way advances in neurosciences affect society, a Royal Society study group examined the implications for education and lifelong learning. Among the recommendations of the study (*Brain Waves* Module 2), four recommendations were made that are of relevance for future directions of research and policy interventions with regard to S&T education: evidence from neuroscience research should (1) inform the assessment of policy options in education; (2) be part of training and continuous professional development for teachers, especially, but not exclusively in the sector of special needs education; (3) help to make progress with the design of adaptive learning technologies for use also outside the classroom and in life-long learning; (4) be the focus of better structured knowledge exchange between the neuroscience research community and actors in the educational system.

Next to these nationally funded projects, there has also been a good participation of UK parties in relevant FP6- and FP7-projects which often take practical approaches where they involve practitioners in different fields – though they also provide clarifications and critical reviews of conceptual issues - but these projects are largely uncoordinated activities of individual university departments or actors from the NGO sector, and it is still difficult to assess the impact of these actions in the UK educational system as a whole. The Academies have not, so far, participated in such projects. Anecdotal evidence suggests that specific projects, such as Pollen or Fibonacci, have helped advance skills where there has been UK involvement. Feedback on these projects indicates that they helped teachers to better deliver investigative science and mathematics in the classroom. The impact of the new methods on students is less clear; even more difficult is it to say what actions have arisen within UK national policies as a result of the FP-funded programmes.

Overall, the report shows that there is no dearth of pilot studies and projects in the UK. It seems as if the UK's Department for Business, Innovation and Skills would look to these locally funded projects for evidence rather than seeking inspiration for policy initiatives from comparative or collaborative work involving continental European parties. The national coordinator for the FP Science in Society programmes is based at the Economic and Social Research Council ESRC which also funds a good deal of the advanced national research projects into science education. A degree of synergy and exchange between the different teams can therefore be assumed; by the same token, any assessment of the possible significance of the FP-supported projects in the UK context would need to take into account these complex patterns of cross-fertilization as well.

26. Ukraine: The National Academy of Sciences of Ukraine (NASU)

The National Academy of Sciences of Ukraine is involved in national debates about improving natural science education, though the focus is not necessarily about inquiry-based science education as such, but rather more broadly on fostering inductive approaches, covering also mathematics. Together with the *Institute of the Gifted Child* (http://iod.gov.ua) founded in 2007 through an initiative of the Academy and working on innovative approaches to education, the Academy formulates recommendations for the national education curriculum that are based on the research findings.

The involvement of the Academy in the ALLEA Working Group and participation in the joint conference on introducing IBSE approaches into secondary schools have paved the way for closer cooperation with the French project „La main à la pâte", including participation in the seminar of Académie des sciences in May 2011. A detailed report submitted to the National Academy about the European and global IBSE efforts resulted in a formal decision by the Academy to support actions aimed at implementing best practices in Ukraine with the help of cooperation with WG members.

The National Academy also supervises the *Minor Academy of Sciences of Ukraine*, an extracurricular educational unit (http://www.man.gov.ua/) launched in 2000 with support from the Ministry of Education and Science. While the research institute for the gifted child views science as a tool for the identification and development of talented students, the Minor Academy of Sciences seeks to stimulate students through extracurricular science education activities and competitions. The Minor Academy gained national status in 2010 and now involves 250,000 pupils based at schools all across the country, compared to 10,000 at the time of launching.

The Minor Academy has been described as an integrated, multilevel system for the identification and selection of gifted children, improving conditions for their spiritual, intellectual, creative, social and professional development. The Academy offers opportunities for children and young people to engage in scientific-research, experiments, design, inquiry and discovery.

The Minor Academy is organised in 27 regional sections, which coordinate the work of district and municipal territorial departments and students' scientific societies. Some 200,000 secondary school students are involved in the scientific activities every year, about one third of whom is based in the rural areas of the country. Pupils are guided in their research by 6,500 educators, of whom 1,500 hold Candidate-of-Sciences degree and 300 Doctor-of-Sciences degrees.

The annual All-Ukraine research paper competition draws a massive participation of Minor Academy members through three levels (sub-regional, regional and nation-wide). In 2011 the competition was held in 10 scientific sections, divided into 56 sub-sections, and out of a total of 83,561 research papers examined by the jury, 1,142 reached the finals.

The winners of the extramural research paper competition "Young Scientist" are recommended to participate in the International School-Seminar "Spectroscopy of Molecules and Crystals".The festival "Gifted Children of Ukraine" is annually organized by Institute of the Gifted Child of the National Academy of Pedagogical Sciences of

Ukraine jointly with the Ministry of Education and Science, the National Academy of Sciences of Ukraine, and the „Minor Academy“ with the aim of supporting giftedness and developing talent. In 2011, more than 800 children from across the country displayed their abilities and achievements in the spheres of science and technology, research and experiment, art and aesthetics, ecology and nature, and physical education.

A number of other competitions also seek to identify and support young talent, such as the national science and technology exhibition of youth innovations and creativity project, or the All-Ukraine Children Creativity Exhibition in February 2011 where the country's president awarded the most remarkable creative works, engineering projects and inventions presented by talented youngsters. In 2010 the educational project "The Summer of the Intellect 2010" proposed nation-wide summer schools for senior pupils in the field of: physics and mathematics, science and technology, chemistry and biology, astronomy and computer sciences, but also in history, geography, folklore, journalism, and arts. The scope of the schools was further expanded to cover 19 fields in 2011.
Opportunities for networking exist between these summer schools and the winners of national research paper competition, which produced among other results the „Minor Academy Open Natural Demonstration" on-line, but also the "Social Network of the Minor Academy of Sciences".

In 2010, the centre initiated the "Ukrainian-German Children's University" with the purpose of developing international collaboration in the field of research activities for gifted children. Leading scientists from both countries participated in the event.

In May-June 2011, the All-Ukraine science festival took its cue from the International Year of Chemistry for a series of lectures, seminars, and exhibitions organised by the "Minor Academy" and other Franco-Ukrainian partners in six cities (Rivne, L'viv, Odessa, Dnepropetrovsk, Donetsk, and Sumy). At a scientific picnic in May 2011 in Kyiv, the young researchers showed their achievements and inventions to the general public and an audience of prominent chemists from Ukraine and France.

An important element of the Minor Academy's educational activities is their focus on experimental research. In 2010, 102 papers originating from 21 regions were presented at the national competition in physics, mathematics and technical education. It is interesting to observe, that efforts are under way to expand this approach also to domains outside the natural sciences: in late 2011, a similar competition was held for the best methodology in inquiry-based experimental projects in the Humanities and Social Sciences (philosophy and sociology, philology and study of art).

The Minor Academy regularly organizes all across the country teacher-training conferences, seminars, workshops and consultancies for their regional directors as well as for the teachers involved in the activities. The meetings focus on strategies to identify and support gifted children, on the relationship of these extracurricular efforts and the national schools systems, on new pedagogical methodologies and on disciplinary issues and they often include invited speakers from abroad. By now, the Minor Academy has become a key actor in the country, uniting efforts and resources of state and public institutes in pursuit of an effective system to select and support gifted children and youth across the country.

Sustained bilateral exchanges with the French *"La main à la Pâte"* programme are under way, and collaborations arising from the exchanges in the ALLEA Working Group will further help the Ukrainian institutions to get more involved in Europe-wide multilateral research and in applied ventures and projects, in order to share experiences through peer learning.

SYNTHESIS:

COMMON FEATURES AND SPECIFICITIES

Common features

If the survey demonstrated that Academies engage with the process of reform of science education at pre-school, primary and secondary school level in many different ways, it also is proof for the far-reaching convergence of intentions and reflections in national academies with respect to science education.

Rarely are interventions *ad hoc*; more typically actions by academies are based on in-depth reports intended for their respective governments and other stakeholders. The reasons that push an academy to engage in this field are similar everywhere, and are recognised also by many other stakeholders: the pervasive lack of interest, among pupils, in S&T, followed by a serious decrease of the number of students in sciences, mathematics and engineering, and consequently a risk of society's declining scientific literacy. There is a wide-spread concern that the national educational systems may not be capable of producing sufficient numbers of S&T graduates, and that industry will soon find a lack of the necessary skills among the available workforce. Many academies have decided to deal with the roots of this problem and to begin with their interventions at the earliest stages of formal education, in primary school and even in kindergarten, and with informal environments suitable for first encounters of children with science education.

There is no immediate correlation between the performance of a given national educational system in the relevant international benchmarking exercises such as PISA or TIMMS, and the intensity of intervention or the method chosen by a national academy to engage with the process of reforming science and technology education in its country.

Reflecting the recommendations of the Rocard report and much of the European Commission's Framework Programme support for science education, there is a broad agreement among academies that participate in the ALLEA WG on science education in the context of the global IAP science education programme, that inquiry-based approaches hold the key to renovating science education. Even if assessment practices are as yet showing little sensitivity towards the long-term ambitions of IBSE approaches, there is sufficient anecdotal evidence that young children, once equipped with the tools to understand the nature of science develop a real interest and, perhaps, even a desire to translate that taste into a career.

Depending on the degree of exposure to pilot projects and participation in collaborative and peer-learning programmes in Europe, academies have come to recognize that these experiments have sown the seeds and are models for the reform of science teaching in primary schools. They recognize that any reform of a national or regional educational system implies going beyond event-specific measures and pilot experiences, and engaging in a sustained fashion with a systemic approach. Considering the enormous number of primary school teachers already in service who have not received a sufficient basis in science during their initial training and who are not familiar with inquiry approaches, their training will be a difficult issue, will require large funds, and likely necessitate supports from private as well as public funds. All in all, the way to this educational change will thus require another effort; also sustained support on the part of the European Union remains highly desirable.

Specificities

The impact that the academies' activities have at national or local level on the educational system and practices in the classroom, and also the degree to which academies have been active and able in injecting results from FP-co-sponsored projects into these realities on the ground, vary considerably. The case studies and examples presented in the report provide ample evidence for these differences. At present, countries show widely diverging ratios in the reach of projects aimed at reforming science education in primary schools along the principles of IBSE (e.g.: Serbia 10%, Sweden 25%, France 40%), and no country has achieved a complete sustainable reform. Often the absence of frameworks for professional development for teachers is mentioned as an important obstacle.

Also there is a wide scattering of interventions and actions, ranging from direct participation in classroom and teacher-training activities (e.g.: France, Sweden), to dedicated specialised or general activities for talented and gifted pupils (e.g.: Slovakia, Hungary), to extracurricular science events (e.g.: Czech Republic, Germany).

Only to some extent degree can the different approaches chosen be described as a function of the type of academy (i.e.: whether it is a learned society or a research performing academy with their own research institutes): in those countries in which academies are themselves research performing organisations with a large number of S&T staff their concern is more directly linked to worries about the future workforce at their specialised research institutes (e.g.: Czech Republic, Hungary), but they also follow a host of other strategies to improve and widen science education.

In certain countries, Academies operate through seminars, workshops and pilot school projects, with members being exposed to new methodologies, involving also teachers, their associations, and possibly other stakeholders. Such exchanges are useful for exploring and publicizing the merits of IBSE approaches (e.g.: Turkey, Italy). Elsewhere, academies provide a platform for other expert associations that take on such a task, or limit themselves to advisory work (e.g.: UK, Estonia).

Sometimes academies are engaged also in other domains than science education for young children: secondary schools, public events, science musea, exhibitions etc. Often in these contexts the engagement takes the traditional form of lectures by academy members.

Only in exceptional cases academies initiate proposals or discussions aimed at overhauling the entire educational system. In Switzerland such a wide-ranging discussion while triggering a controversial nation-wide debate, did not allow to focus on STEM education.

In a few countries, academies put particular emphasis on identifying and nurturing talented students, either as part of a specific academy policy, or out of the specific constellation of the national education system (see, for example, Ukraine, Finland, Hungary, and plans in Montenegro). Elsewhere (for example: France; Sweden) the academy's actions are rather concerned with inclusiveness (minorities, girls etc.).

It is important to notice also that, in their efforts to bring a passion for research into the classroom, a number of Academies went beyond the reform of natural and life sciences to encompass social sciences and humanities. The examples quoted from Germany appear particularly innovative, and make full use of the problem-centred approach to introduce interdisciplinary methods of reflection and work. Other examples include the more discipline specific summer schools in Serbia and Spain and events in Estonia, which points out that an inquiry-based approach can be taken beyond the "hard" sciences.

D. RECOMMENDATIONS

RECOMMENDATIONS FROM THE G8 ACADEMIES

Following the establishment of the global and European inter-academy networks in support of a renovation of science education, a number of reports and recommendations were issued. Of particular importance is the statement “*Education for a Science-Based Global Development*” issued in May 2011 by science academies of the G8 countries and submitted to the Heads of State gathered in France (Deauville) for the G8 summit. The G8 academies had invited five other academies from emerging and developing countries to prepare the statement, with the purpose of having it becoming more pertinent worldwide. This is why the statement is sometimes called the ‘G8+5’ statement, also, a reminder that academies collocate their engagement in science education in the context of their wider support for building knowledge-based and science-literate societies the world over.

“*Education for a Science-Based Global Development*”

G8+5 science academies joint statement, 26-27 May 2011

“The Academies of the G8+5 countries strongly recommend the following action plan to their Governments:

(1) Establish the conditions for a true globalization of knowledge in science and technology. Encourage and help governments of developing countries, to give high priority to acquiring and maintaining the necessary infrastructure and human resources for science education, and to facilitate the return of those trained abroad.

(2) Support international collaboration to set up quality e-learning facilities, accessible to all, including students worldwide, and promote open access to scientific literature and databases.

(3) Share the growing knowledge derived from brain research, cognitive sciences and human behavioural research to improve learning programs for children, students and the general public.

(4) Create a network of virtual collaborative research centres at the front line of innovations in education, such as e-learning, inquiry-based and evidence-based education.

(5) Support and expand existing successful programs which facilitate the two-way interactions between scientists, on the one hand and the general public, media, and decision makers, on the other.”

The recommendations contained in the present report should be seen in this worldwide framework. They develop recommendations (4) and (5) of the G8+5 statement in a more specific way adapted to the specific European situation.

DETAILED RECOMMENDATIONS

Though academies operate in very diverse educational and institutional environments, recommendations can be made for further improving their interventions and actions in favour of science education.

Acting transversally. In academies, a scientific committee in charge of science education and its reform is an important body to mobilise the scientific community. In its work, it would have to transcend disciplinary and specialist approaches and look at the nature of science and its phenomena through the lens of non-specialists and in an interdisciplinary way. Academies - as typically multidisciplinary institutions - are well placed to privilege such an approach. Needless to say that academies should not act in an isolated fashion, but strengthen their degree of interaction and common sense of purpose with the other pioneering forces in the communities of science teachers and teacher trainers, but also parents associations, local and international businesses and policy makers, who may have an interest to reform science education.

In the societal domain. Since much of science is mostly financed from public funds, taxpayers deserve to be adequately informed about prospects of reform. Through studies, reports, colloquia, media appearances, academies, as leading representatives of the national science systems, can stimulate and enrich national debates about the need to rejuvenate science education, about the opportunities offered by IBSE and about the related measures to be taken for the training of teachers of science. Choices in science education are closely related to efforts in science communication. Because their voice is listened to, academies have to make efforts to expand the reach of their communication, conveying the urgency of renovating science education to fellow scientists, teachers, parents associations, local and international businesses and policy makers. They can help enhance awareness for the need of reforming science education by establishing national, regional or local platforms where the merits of IBSE approaches and successes of pilot projects can be exhibited. Opportunities for pointing to the need of science literacy abound, e.g. whenever public debates touch upon controversial science-induced societal choices, whether genetically modified organisms or energy choices, biomedical technologies or biodiversity, global warming etc.

Academies should also build alliances with industries and corporates: their support is of prime importance since the reform of science education would also provide them with easier access to a wider and better-qualified workforce. Such exchanges count among the important socio-economic drivers of the reform efforts.

In the political domain. Academies, representing the best of science in a given country, have the rare ability to access political decision-makers. Making full use of this opportunity to inform and influence political environments with regard to science education questions and IBSE is an evident strategic choice for academies. At the national/regional level, the academy is recognised as natural partner by funding agencies and foundations, and also by actors that have to reflect and decide about curricula in sciences. They can build arguments to institutionally anchor IBSE approaches in school curricula, or, where the curricula are already updated, they would help that realistic conditions are created to make teaching under such innovative methodologies possible.

Establishing programmes for continuous professional development (CPD) for the training of science teachers is recognised as one key area of intervention for academies. On this matter, they can contribute from several angles: they can help create high-quality didactic resources; ensure that the latter strike a balance between “real life” science topics and up-to-date scientific knowledge; provide access to equipment for hands-on related experiences, where appropriate; influence decision makers to grant funds to good training programmes and to introduce career-relevant incentive.

A key point for sustainability: Sustainability of all efforts in renewing science education will, in the coming years, include as a main task in-service training of primary school teachers: it has been observed that a large section of teachers currently employed at primary schools have never been taught science as part of their initial pre-service training: they must improve their disciplinary knowledge, which, at the same time, will make to possible for them to switch to new, inquiry-based pedagogical approaches. This requires addressing the double challenge of (i) accepting and being introduced to IBSE approaches and (ii) seeing in-serving training and continuous professional development as a necessity. Far from being another imposed professional constraint, CPD should be viewed by teachers as enjoyable and beneficial for their personal development. Academies can be important and high-level multipliers of this message, due to their access to political power and to the media. Through their European Working Group ALLEA member academies can play their part in these efforts, making sure also that lessons learnt elsewhere about teaching procedures and practices will not go unnoticed.

THE EUROPEAN DIMENSION

The European level networking: EU policies and funding of IBSE pilot projects, such as Pollen and Fibonacci, have helped and structured European exchanges. Impressive project-based achievements have been reached. A number of academies have been partaking in or benefitting from these activities. With the financial support of Europe, networking has thus proven an important force in the exchange of ideas, and, hence, in the ability to imagine and implement changes. Evidently, such external support, aimed at maintaining a cross-border exchange of knowledge, becomes all the more crucial, the more national educational systems are diversifying, either socially, or regionally, or in terms of political responsibilities of different educational authorities. By the same token, the intervention of foundations is often useful for the launch of pilot projects (see the examples provided in this report for Germany, UK, Italy).

A systemic renovation of science education is still a long way off: This report shows that it is not easy to describe in a few lines the present systemic impact of the many past IBSE-related pilot projects on the rejuvenation of STEM education in Europe , Yet programmes for the renovation of science teaching that are launched at national level (often with opportunities under more open environments) are likely to see their results accepted as basis for some restructuration in a strategic process of change. Clearly, high-level and politically respected intervention is the key and necessary complement to other interventions that would involve communities, employers and employees, teachers and parents.

Under the principle of subsidiarity European initiatives can trigger reflections and debates notably as result of a subtle peer learning process. This continent-wide networking can lead to gradual mental changes under the respect of public acceptance, which in turn prepare acceptance of the necessary administrative or legislative measures. In this domain of assisting a gradual shift of political and social discourse, the academies have an important role to play, allowing political decision-makers to propose legislative initiatives with strong social backing. Hence future actions at the European level should keep in mind the necessary linkage between Europe-wide exchange and structural impact at local/regional/national level.

Needless to say that for a good social acceptance and satisfactory implementation of a systemic reform in science education an excessive focus on the short-term aspects of employability of science educated students should be avoided: this could block long-term efforts towards real change.

The training and continuous professional development of science teachers. On this side the comments and recommendations contained in this report also apply: an overarching European framework for CPD would be welcome. Considering the approximate number of one million primary teachers already in-service in Europe and the slow-moving labour market in the sector, a significant improvement in science education largely depends on the development of an efficient and advanced methodology for sustainable CPD, so as to create the conditions of further sustainable changes in science education. Indeed, the very notion of CPD for teachers of science may need to be strengthened in some countries. Acting as catalysts, EU-funded initiatives can stimulate the national political decision-makers to create the conditions for further changes in science education and the related educational establishments so as to implement inquiry-based CPD in a sustainable (not project-based) way.

More hard evidence on the long-term beneficial effects of IBSE approaches may be required. As was shown by this report, small scale and qualitative insights point to improvements in the preparedness for change of some actors of national education systems, but the information collected so far on pilot projects does not provide enough quantitative and general evidence about the direct positive impact of IBSE. To prepare the change of mind among national policy-makers, it is desirable to get more evidence of the positive effects of such new science teaching approaches on national education systems. Hence further comparative and longitudinal projects of a European scale should help complete the current set of data (and methods) for meaningful comparisons between achievements under different teaching approaches. In particular it is necessary to design assessment methodologies that would allow to measure and compare the relative success, or otherwise, of ambitious IBSE approaches. It would be equally important to also better understand the impact of IBSE methods on teachers' attitudes towards learning/teaching methods before and after taking part in professional development courses focused on IBSE.

An expansion beyond Europe of the community efforts to renew science education. The last but not least recommendation has to do with a worldwide and global aspect: science is universal and all scientists are connected in worldwide networks. The EU could use these existing networks for a broadening of its action and, at a very low additional cost, make its past investment on science education bear fruit also beyond the Members States. The numerous and excellent training resources that were created in the past thanks to the European co-sponsored IBSE projects could easily be translated and shared with the countries of the European neighbourhood areas and including the neighbouring Muslim countries, for which the 'Arab spring' heralds new challenges and opportunities, while there are also openings in the emerging economies of Central Asia that are keen to develop their educational system. As for Africa, there could be an opportunity for EU foreign and development policy to establish science education as a long-term and centre-stage topic in dialogue and strategy meetings between the European Union and African Union, starting for example during the next 2012 summit. Academies, through their European ALLEA and global IAP networks, are fully ready to support this potentially important aspect of Europe's global engagement for peace, sustainable prosperity, human security and human rights.

Annex: ALLEA Working Group Science Education in 2011

(IAP Science Education Program regional European council)

Chair
Odile Macchi (Chair IAP/SEP European Regional Council) - Académie des Sciences (CG)
Pierre Léna (founding chair) - Académie des Sciences (CG)

Members
Maija Katariina Aksela - Delegation of the Finnish Academies of Science and Letters (CG)
Benő Csapó (Hungarian Academy of Sciences) (launch meeting: József Pálinkás)
Stanislav Dovgiy - National Academy of Sciences of Ukraine
Maria Duca - Academy of Sciences of Moldova
Carl Figdor - Royal Netherlands Academy of Arts and Sciences (KNAW)
Florin G. Filip - Romanian Academy (launch meeting)
Athanasis Fokas - Academy of Athens (launch meeting)
John Grue - Norwegian Academy of Science and Letters
Sven-Olof Holmgren - The Royal Swedish Academy of Sciences (CG)
Léo Houziaux - Académie Royale de Belgique
Stanko Popović - Croatian Academy of Sciences and Arts
Yücel Kanpolat - The Turkish Academy of Sciences
Andrej Kranjc - Slovenian Academy of Sciences and Arts (CG)
Ingolf Hertel / Randolf Menzel - Union of German Academies of Sciences and Humanities (alternates)
Peter Mitchell - The Royal Irish Academy (CG)
Miljenko Peric - Serbian Academy of Sciences and Arts (repl. Milosav Marjanovic)
Søeren Peter Olesen - Royal Danish Academy of Sciences and Letters (launch meeting)
Dukagjin Pupovci - Kosova Academy of Sciences and Arts
Gerhard Schaefer - Gesellschaft Deutscher Naturforscher und Ärzte/German Academy of Sciences Leopoldina (launch meeting)
Libby Steele / Nick von Behr - Royal Society of London (delegate York) (alternates)
Giancarlo Vecchio - The National Academy of the Lincei (CG)
Perko Vukotic - Montenegrin Academy of Sciences and Arts
Jan Zima / Jaroslav Pánek - Academy of Sciences of the Czech Republic (alternates)
Rüdiger Klein – (ex officio, ALLEA)

(CG indicates "Core Group")

ALLEA Member Academies in 2011

Albania: Akademia E Shkencave E Shqipërisë; **Austria**: Österreichische Akademie der Wissenschaften; **Belarus**: Нацыянальная акадэмія навук Беларусі; **Belgium**: Académie Royale des Sciences des Lettres et des Beaux-Arts de Belgique; Koninklijke Vlaamse Academie van België voor Wetenschappen en Kunsten; **Bosnia and Herzegovina**: Akademija nauka i umjetnosti Bosne i Hercegovine; **Bulgaria**: Българска академия на науките; **Croatia**: Hrvatska Akademija Znanosti i Umjetnosti; **Czech Republic**: Akademie věd České republiky; **Denmark**: Kongelige Danske Videnskabernes Selskab; **Estonia**: Eesti Teaduste Akadeemia; **Finland**: Suomen Tiedeakatemiain Valtuuskuntal; **France**: Académie des Sciences - Institut de France; Académie des Inscriptions et Belles-Lettres; Académie des Sciences Morales et Politiques; European Academy of Arts, Sciences and Humanities (Associated Academy); **Georgia**: საქართველოს მეცნიერებათა ეროვნული აკადემია; **Germany**: Deutsche Akademie der Naturforscher Leopoldina; Union der deutschen Akademien der Wissenschaften (Akademie der Wissenschaften in Göttingen, Akademie der Wissenschaften und der Literatur Mainz, Bayerische Akademie der Wissenschaften, Berlin-Brandenburgische Akademie der Wissenschaften, Akademie der Wissenschaften zu Hamburg, Heidelberger Akademie der Wissenschaften, Nordrhein-Westfälische Akademie der Wissenschaften und der Künste, Sächsische Akademie der Wissenschaften zu Leipzig; Associated Academies); **Greece**: Ακαδημία Αθηνών; **Hungary**: Magyar Tudományos Akadémia; **Iceland**: Vísindafélag Islendinga; **Ireland**: The Royal Irish Academy - Acadamh Ríoga na hÉireann; **Israel**: האקדמ יה למדע ים ה ישראל ית הלא ומ ית; **Italy**: Accademia Nazionale dei Lincei; **Kosovo**: Akademia e Shkencave dhe e Arteve e Kosovës; **Latvia**: Latvijas Zinātņu akadēmija; **Lithuania**: Lietuvos mokslų akademijos; **Macedonia**: Македонска Академија на Науките и Уметностите; **Moldova**: Academia de Ştiinţe a Moldovei; **Montenegro**: Crnogorska akademija nauka i umjetnosti; **Netherlands**: Koninklijke Nederlandse Akademie van Wetenschappen; **Norway**: Det Norske Videnskaps-Akademi; **Poland**: Polska Akademia Umiejętności; Polska Akademia Nauk; **Portugal**: Academia das Ciências de Lisboa; **Romania**: Academia Română; **Russia**: Российская академия наук; **Serbia**: Srpska Akademija Nauka i Umetnosti; **Slovakia**: Slovenská Akadémia Vied; **Slovenia**: Slovenske akademije znanosti in umetnosti; **Spain**: Instituto de España; Real Academia de Ciencias Morales y Políticas; **Sweden**: Kungl. Skogs- och Lantbruksakademien, Kungl. Vetenskapsakademien; Kungl. Vitterhets Historie och Antikvitets Akademien; **Switzerland**: Akademien der Wissenschaften Schweiz; **Turkey**: Türkiye Bilimler Akademisi; **Ukraine**: Національна академія наук України; **United Kingdom**: The British Academy; The Royal Society of Edinburgh; The Royal Society of London;**Vatican**: Pontificia Academia Scientiarum

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