XII^{e} Rencontres du Vietnam

– Fundamental science and society –

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Report on the two-day conference that took place on 7 - 8 July 2016
at the International Centre for Interdisciplinary Science and Education (ICISE),
Quy Nhơn, Bình Định, Vietnam.

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Introduction

In July 2016, the XIIth *Rencontres du Vietnam* brought together policy-makers, diplomats, scientists, representatives of international governmental and non-governmental organisations, and representatives of civil society, for a two-day conference on the topic "Fundamental science and society". The event was organised under the high patronages of François Hollande, President of the French Republic, and Tran Dại Quang, President of the Socialist Republic of Vietnam.

The aim of this event was to stimulate an innovative exchange among the participants and to encourage, in a relaxed atmosphere, an open discussion on the challenges that the world faces today. To do so, seven round table discussions were organised, each of them highlighting a different link between basic science and today's challenges. Why should emerging countries invest more in basic science? What role can science play in sustainable development? How does the scientific method contribute to peace and development? Why is science education so inefficient? What should politicians do to integrate science into decision-making processes?

Today, science plays an increasingly influential role in global debates, but there still is a long way to go for the better integration of basic science into strategies for the resolution of global issues. The world of politics and the civil society have to realise that scientists can help design more creative approaches and partnerships for addressing the challenges of today. They should be the first readers of this report.

Celebrating the 50th anniversary of the *Rencontres de Moriond*

The XIIth *Rencontres du Vietnam*(1) were also the occasion to celebrate the 50th anniversary of the *Rencontres de Moriond*(2), the renowned series of physics conferences created in 1966. Jean Tran Thanh Van, President of the *Rencontres du Vietnam* and one of the founders of the *Rencontres de Moriond*, recalled the two principles at the basis of the creation of the *Rencontres de Moriond*: to promote exchange and collaboration between experimentalists and theorists; and to promote young scientists, offering them the opportunity to give a talk in front of renowned senior researchers.

The first *Rencontres* took place in Moriond in 1966 with only 20 physicists, theorists and experimentalists. 50 years later, 10,000 scientists from over 50 countries – some of them Nobel Prize laureates – have attended the conference, which has become one of the top high-energy physics conferences in the world. Why this success? Étienne Augé, Vice-President of Paris South University (France), explained that the members of the organising team and research committee have established, over the long term, confident relations with all the research teams and research projects around the world. Indeed, Jean-Marie Frère, Professor at the Free University of Brussels (Belgium), stressed the fact that the research committee of the *Rencontres* makes its own, independent judgement on the submitted papers and bases its decision solely on their scientific relevance, and not on their 'impact factor'.

Étienne Augé added that all the participants have to stay the entire week of the *Rencontres*, so that they have time to discuss, in a pleasant and relaxed atmosphere, recent findings and new ideas, which remains the best way of establishing strong, international relationships and collaborations.

Based on the model of the *Rencontres de Moriond*, in 1993 Jean Tran Thanh Van created the *Rencontres du Vietnam*, as well as the International Centre for Interdisciplinary Science and Education (ICISE), in the province of Bình Định (Vietnam), where the 12th edition took place. The venue provides scientists with an ideal context to exchange ideas, discuss scientific findings and collaborate in a warm atmosphere.

> **"Consider this centre as your home and come here often to help us promote science and friendship as driving forces to contribute to the development of this province and of Vietnam."**
>
> *Jean Tran Thanh Van, President of the* Rencontres du Vietnam

(1) http://rencontresduvietnam.org/
(2) http://moriond.in2p3.fr

Basic science: uncertain but essential

Basic science and technology are intimately related, but countries and corporations often neglect basic science and do not invest enough resources to develop it. Likewise, developing countries often just let the developed ones take care of basic science. But, as David Gross, Nobel laureate in Physics (2004), explained, this is a dangerous approach, as basic curiosity-driven science turns out to be the most productive way of developing new, invaluable tools for society – tools that would probably never be discovered by technological-driven research.

To illustrate his remarks, David Gross quoted Abdus Salam, theoretical physicist, founder, in 1964, of the International Centre for Theoretical Physics (ICTP) in Italy, and Nobel laureate in Physics (1979). Salam believed that unless a society, country or university is very good at science, it will never be good at technology. It will be a consumer of science and technology, but it will never be the innovator or the inventor, which would have allowed it to compete in the global world.

Ton Nu Thị Ninh, former Vietnam Ambassador to Belgium and to the European Union, agreed and insisted on the crucial role of science for Vietnam and emerging countries. She invited these countries to move from just being consumers of science and technology to initiators and creators of science, to take back the ownership of their own development.

The theoretical community, creator of science *par excellence*, is the first link of the chain. Theory often connects and unifies different experimental approaches to solve problems posed by Nature. Also, as David Gross highlighted, theorists collaborate together in projects or groups, which interact continually, exchange information, and share their ideas freely. This exposes them to constructive criticism and suggestions, which is key. Many of the most exciting developments are at the boundaries of traditional fields (physics, chemistry, biology, medicine…), requiring cooperation among many different theorists.

> **"The questions posed by Nature – not by man, society, philosophy or ideology – are good, so that when you are pursuing curiosity-driven research, you are pursuing the ultimately correct research programme."**
>
> *David Gross, Nobel laureate in Physics, 2004*

Jean-Marie Solvay, President of the International Solvay Institute and Administrator of the Solvay Group (Belgium), highlighted how, at the International Solvay Institute, they support curiosity-driven research by organising conferences in physics and chemistry with the mission to bring together the most talented minds to discuss crucial questions confronting the research community, in the very spirit of the *Rencontres de Moriond*. He explained that they believe that respectful

communication, peer-review, competition and consensus based on objective evidence are at the heart of understanding and progress, and that the scientific methodology in its essence is beneficial to society. It is the only way for humanity to solve the many problems it is facing.

> **"More and more, as our planet becomes smaller and as we become more numerous, we need to build together a global community that can deal intelligently with the problems we are facing. Fundamental science is a strong driving force in this endeavour."**
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> *Jean-Marie Solvay, President of the International Solvay Institute and Administrator of the Solvay Group (Belgium)*

Frédérick Bordry, Director for Accelerators and Technology at the European Organization for Nuclear Research (CERN) (Switzerland), recalled the history of the world's leading laboratory for particle physics, a place where the quest for knowledge stimulates curiosity and creativity, and leads to the development of cutting-edge innovative technologies, which are transferred to society. Unprecedented instruments developed at CERN have found applications in a variety of fields including medical imaging, tumour treatment, solar panels, food sterilisation, big data, not to mention the World Wide Web.

Indeed, since its creation in 1954, CERN has grown into a model for global scientific and technological collaboration, demonstrating how science can unite nations by bringing scientists together for the benefit of all. With its 22 Member States and more than 3,000 staff members, scientific associates and students, as well as about 12,000 scientific users from 100 countries across all continents, CERN is one of the world's largest and most complex scientific institutions.

In that spirit of collaboration, in December 2012, CERN was granted Observer status at the United Nations (UN) General Assembly, a status that CERN is honoured to enjoy and that allows the Organization to strengthen and broaden its contribution to various on-going UN initiatives, including the 2030 Agenda for Sustainable Development (see page 10).

At the Science and Technology in Society (STS) forum (Japan), presented by Koji Omi, its founder and chairman, the aim is to provide a new mechanism for open discussions on an informal basis, and to build a human network that would, in time, resolve the new types of problems stemming from the application of science and technology.

The forum community – scholars, researchers, policy-makers, business leaders and media leaders from all over the world – explores the opportunities arising from science and technology, and addresses how to remove the barriers to using science and technology to solve the problems faced by humankind.

However, the advance of science and technology raises important ethical, safety and environmental issues: possible negative applications are threatening mankind's own future. Since progress in science and technology is expected to accelerate and will be necessary for sustainable human development in the 21st century, wisdom must be exercised to keep it under proper control.

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The importance of pursuing basic science in emerging countries

As we have seen previously, basic science is a prerequisite of progress and development. All countries in general, and emerging countries in particular, have to stop being consumers of science and technology, and have to instead become creators. As Ton Nu Thị Ninh justly put it: "By becoming good at science, emerging countries will be able to take back the ownership of their own development." But how can emerging countries catch up with developed countries on the quality of their research?

Establishing standards for good research

In emerging countries, there is an urgent need to establish standards for good research, independently of it being basic or applied. Kurt Wüthrich, Nobel laureate in Chemistry (2002), explained that the quality of the work being done has to be internationally evaluated, which is probably the most difficult part in establishing a science community of a reasonably high level in emerging countries.

Indeed, Kurt Wüthrich lamented the fact that, in emerging countries, there is usually no established body able to evaluate research proposals at an international scale. This is partly due to a language barrier. In China, for example, most of the research proposals are written in Chinese, which makes it impossible to send them abroad for evaluation. And yet, Wüthrich insisted on the fact that there is no point in establishing rankings of the scientific achievements within a country, it has to be on a worldwide level.

Kurt Wüthrich presented the solution adopted by China to establish a high-level science community. He explained that, at some point in the 90s, the Chinese government decided that only a limited number of universities could provide PhD degrees, and only certain professors within those universities could lead research groups that could include PhD students. Wüthrich admitted that this solution might

seem harsh, but he also stressed the fact that allocating the resources available to only a few groups would help the emerging countries, as those groups would have a chance to attain an acceptable level of performance. Ton Nu Thị Ninh added that, indeed, in Vietnam, policy-makers have a bad habit she called 'sugar sprinkling': they invest a little bit everywhere. She declared that this strategy does not work and that governments should really focus on a few areas only.

Moreover, in order for the emerging countries to reach a reasonably high level in science, Wüthrich invited them to get involved in international collaborations, like CERN, for example. Such collaborations are a perfect school for learning basic science. That being said, emerging countries must be able to bring something to the collaboration, which means that there must be some centres of excellence in the country.

Studying abroad and coming back

Nowadays, there are more and more students from emerging countries going to Europe or the United States to study and, as Pierre Darriulat, Director of the VALTY Institute (Vietnam) emphasised, this has both a good and a bad side. Indeed, while it is beneficial that the young generation goes abroad (although, Darriulat conceded, some students have to stay in the country, or the research dies), it is important for countries to get them back. Thus governments have to establish ways to offer these students a future back in their home country. Darriulat gave the example of Vietnam, where the government and student families spend fortunes to send students abroad, the problem being that the government does not follow up when they come back; all the investment is lost.

One possible solution could be to establish PhDs under joint supervisions: one mentor from the emerging country of origin and one from a developed country. This approach has many advantages: for example, when the student comes back, he/she can share what he/she learnt abroad with the local team. However, Darriulat recalled that the two-mentor PhD does not help if, as mentioned previously, the country of origin does not build up a structure making it possible for the student to come back and continue their research on a reasonable level. He added that governments really have to create possibilities for the bright people who are gone abroad to come back; countries have to give them good opportunities and salaries.

> **"We need to give the young generation the opportunities to change things to the better, to take initiatives that will contribute to the progress and development of the nation. The true wealth of a nation is in the brains and hearts of its people much more than in the safes of its banks."**
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> *Pierre Darriulat, Director of the VALTY Institute (Vietnam)*

Supporting researchers

Ngo Bao Chau, winner of the Fields Medal in 2010, concurred with Darriulat on the fact that governments have to support researchers by creating infrastructure and

facilities, by providing funding for graduate students, by opening job positions in science, and by providing better salaries to scientists. Indeed, science has to guarantee a comfortable living so that more young people embrace a scientific career. Ngo Bao Chau explained that, in Vietnam, the general thinking is that studying science is hard and not financially rewarding, as opposed to studying economics or finance, and this has to change. In that respect, governments have to understand that scientists are the future of their country.

Yu Lu, winner of the Tate Medal in 2007 and member of the Chinese Academy of Science, explained that China can now attract professors from the United States. In China, where the economy is growing, scientists actually get better funding. Likewise, the Chinese PhD students who went abroad to study are now attracted back home. Nevertheless, China still has work to do. Its university administrative system remains very rigid, and some scientists prefer to go to Singapore or Hong Kong, where the system is more flexible.

Phua Kok Khoo, Director of the Institute of Advances Studies and President of World Scientific Publishing (Singapore), confirmed this tendency. In Singapore, 40% of the professors of the two main universities of the country come from overseas. Several reasons explain this: Singapore has a strong economy and, more importantly, the universities enjoy sustainable support from the government, which seems to really understand the importance of fundamental research and education.

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Basic science and sustainable development

Many of the challenges that society faces today – understanding climate change, dealing with shrinking biodiversity, and ensuring access to safe water, health, Internet and education for all the inhabitants of the planet – involve several stakeholders and must be addressed, in a coordinated way, by experts coming from a number of different disciplines, including science.

Indeed, in the 2030 Agenda for Sustainable Development, approved on 25 September 2015 by the United Nations, UN's Member States recognise the crucial role played by scientific research for the implementation of new tools and the development of innovative approaches.

The 2030 Agenda for Sustainable Development

The 2030 Agenda is a plan of action for people, planet and prosperity. It seeks to strengthen universal peace in larger freedom. It includes a set of 17 Sustainable Development Goals (SDGs) and 169 related targets to end poverty, fight inequality and injustice, and tackle climate change by 2030.

- The fundamental objectives of the Agenda are the eradication of extreme poverty and the protection of our planet. These objectives are the epitome of the role of the UN for the well being of humanity;
- The UN has a unique role to play in advancing sustainable developments of economic, social and environmental dimensions. Indeed, the new Agenda is based on the determination to act simultaneously on various fronts, putting an end on poverty and hunger, protecting the environment, combating inequalities, promoting human rights and gender equality, and building more peaceful societies;
- The UN act for the promotion and sharing of scientific knowledge as a tool for achieving sustainable development.

Conducting purpose-driven research

But how, in concrete terms, can basic research contribute to the realisation of the Sustainable Development Goals? Nikhil Seth, Executive Director of the United Nations Institute for Training and Research (UNITAR), addressed the audience with this crucial question. He explained that a lot of work needs to be done on the interface between science, economy, society and the environment, and that the research has to be oriented towards solutions. What is needed for the realisation of the SDGs is solution-based science, for example: to increase the nutritious value of food, to develop precision farming, to improve water management, but also to establish sustainable consumption and production patterns. Nikhil Seth added that an attitude shift in the science community itself has to occur: scientists have to break themselves away from the silos in which they locked themselves. Maurizio Bona, Head of Relations with International Organisations at CERN, added that there also has to be more trust between scientific and political communities.

"Environmentalism does not work anymore.
We have to look at interdisciplinary approaches."
Nikhil Seth, Executive Director of the United Nations Institute for Training and Research (UNITAR) (Switzerland)

Grammenos Mastrojeni, Coordinator for eco-sustainability and science policy within the Italian development cooperation, highlighted another obstacle encountered at the interface between the scientific and political spheres. In the political sphere, the development of sustainable solutions needs to go faster in comparison with scientific and technological progress, so there is a problem of time-scale. To solve this mismatch, the Italian development cooperation called the Italian scientific

community to work on innovative knowledge for development, to pursue, instead of curiosity-driven science, purpose-driven science, to what the Italian researchers responded enthusiastically.

Stick to the plan

Of course, economic policy is decisive. Finn Kydland, Nobel laureate in Economics (2004), observed that science is *a priori* available to everyone; there is certain knowledge in science known to the whole world, even if some adaptation to local environments is always needed. So, Kydland asked the audience why some countries are struggling so much on the road of development.

Kydland explained that the decisions about capital creation and innovative activity, which result in the development of new products and processes, are very forward looking. They cost a lot as they take place: new factories are built, they cost millions of dollars and the returns come over many years. The value of these returns is compared to the costs, but future is uncertain, and what especially is uncertain is future government policy. That, Kydland said, is where the problem usually comes from: we could have a government deciding on a plan for many years into the future, with the objective to maximize the welfare of its citizens, but there will always be the temptation to deviate from that plan, and that deviation can be very bad for society. So, there is a need for a commitment mechanism that would keep the government in line.

Unity is strength

Dominique Guellec, Director of Science and Technology at the Organisation for Economic Co-operation and Development (OECD), explained that its institution's mission is to promote policies that will improve the economic and social well-being of people around the world. OECD provides a forum in which governments can work together to share experiences and seek solutions to common problems. OECD works with governments to understand what drives economic, social and environmental change. It measures productivity and global flows of trade and investment, and analyses and compares data to predict future trends. OECD also sets international standards on a wide range of things, from agriculture and tax to the safety of chemicals.

Guellec looked into research budgets over the past six years. He showed that they have been, at best, stagnating, but in the majority of the countries declining, most notably in large countries (Germany might be the only exception). It turns out that when these countries entered into a budgetary crisis, after 2008, they had to cut budgets, and research was one of the firsts to be hit.

Guellec emphasised that increasing research budgets, if existing, are oriented towards specifics goals: creating jobs and increasing growth have become the top priority of governments in most countries. This is definitely not good news when it comes to curiosity-driven research or even research for sustainable development.

So what can be done in a context of reducing resources? Guellec's answer was straightforward: international cooperation. A good solution is to pool or coordinate resources across countries to increase efficiency. At a global level, it is possible to get as much output with less spending, by reducing duplications and aligning research programmes. In this spirit, at OECD, people are exploring the possibility to develop data-repositories, where research groups from different countries can freely exchange information, so that everybody can have a global view on the research.

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Basic science and peace

If science is an invaluable tool for providing solutions to global issues, the *way* science is done is also a solution in itself. Indeed, various models of scientific international collaboration led to many successes over the last decades (CERN and JINR (Joint Institute for Nuclear Research - Russia) are great examples of such successes) and proved how much science is a driving element for achieving peace.

David Gross presented four elements of the scientific method which, he believes, are the reason why science has so much to offer to the pursuit of peace. First, the best way to understand Nature is to observe and experiment, and develop ideas based on those observations and experiments. Second, the sole truth comes from agreement with Nature, not from conformity with pre-conceived ideas, religion or philosophy, or with a political or ideological power. Third, scientific theories and models are provisional. And finally, scientific findings must be available to all.

Gross applauded the fact that basic science is a truly international endeavour; there are no national borders in science. He made a call for extending basic science's model of collaboration and competition, as well as the scientific method, to other spheres of the society, in particular the political one.

Indeed, Herwig Schopper, former CERN Director-General, explained how CERN and SESAME (the Synchrotron-light for Experimental Science and Applications in the Middle East) promote a better understanding between the two worlds – scientific and political. In both CERN and SESAME's Councils, there are, for each Member State, one delegate representing the government and one representing the scientific community; this provides a unique basis for dialogue between politicians and scientists and creates confidence.

SESAME, science *for* peace

Built in a region where peaceful interactions between neighbouring countries remain a challenging goal, the Synchrotron-light for Experimental Science and Applications in the Middle East (SESAME) facility is strong evidence of a willingness to overcome the current difficulties in the name of, and for the sake of, science. The project, set up according to the CERN model and developed under the auspices of UNESCO, brings together partners from across the Middle East, namely Bahrain, Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, the Palestinian Authority and Turkey.

“What are the ingredients needed for such a project to see the light of day?” asked Eliezer Rabinovici, Vice-President of SESAME. First of all, he said, an infinite amount of optimism! Also, the project has to be of high-quality science and every country must be able to contribute and must benefit from it.

“SESAME is a project where scientists took the governments to a place they never thought they would be.”

Eliezer Rabinovici, Vice-President of SESAME

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Basic science and climate change

Today, climate change is the biggest threat to our planet, and science and research provide the key to understanding the speed and effects of these changes. To assess the science related to climate change and monitor its effects, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) set up, in 1988, the Intergovernmental Panel on Climate Change (IPCC). IPCC provides policymakers with regular assessments of the scientific basis of climate change, its impacts and future risks, and options for adaptation and mitigation.

A few degrees, many consequences

During his keynote speech, Jean Jouzel, Vice-President of IPCC, recalled some crucial facts about climate change: what is known for sure is that, by their activity, humans are modifying the composition of the atmosphere with greenhouse gases, carbon dioxide, methane, nitrous oxide, which corresponds to an accumulation of heat in the climate system. If we keep emitting copious greenhouse gases, Jouzel warned, we will go towards a global warming of 4°C to 5°C by the end of the century, which is huge.

At +5°C, all the risks are at a very high level: ocean acidification and rising sea level, coral destruction, climate extremes, loss of biodiversity, pollution and, from a human perspective, climate refugees, health and food security issues... Consequently, it is also clear that one of the major effects of climate change will be to make peace even more difficult.

Jouzel concluded his talk with a call to limit global warming to below 2°C. If humanity succeeds to stick to such limitation, there will still be a different climate, of course, but we should be able to adapt to most of the problems. But for the moment, we are not on the 2°C track. To reach this objective, we have to clearly abandon fossil fuel in the second part of the century and focus on renewable energy.

John Church, expert in sea rise at the Commonwealth Scientific and Industrial Research Organisation (CSIRO) (Australia), focused on the problem of sea level. A few years ago, up to 50 million people were living in the first metre above sea level, and a GDP (Gross Domestic Product) of about a trillion dollars was generated in that first metre. So, clearly, the coastal zone is important and it is also continuing to develop rapidly. Church warned that, over the coming decades, many of the major cities around the world will be on the coast. Yet, with no control, we can expect a sea level rise of 0.5 to 1 meter by 2100, which means many climate refugees.

But for now, Church wanted to draw attention to one urgent need, which is to reduce uncertainties about climate change, which calls for a global climate observing system through international cooperation.

A global response to a global problem

Fredolin Tangang, Professor at the Malay Academy of Science, National University of Malaysia, concurred with Church on this point. He highlighted that the South Asia region, where half a billion people live, is highly exposed to climate change. Yet, scientists in the region did not have sufficient information, at a regional and local scale, to develop climate models. A solution came from international cooperation: the South Asia region joined the CORDEX-East Asia initiative (established by the World Climate Research Programme (WCRP)), which produces ensemble climate simulations based on multiple dynamical and statistical downscaling models forced by multiple global climate models.

Tran Thuc, from the Vietnamese Institute of Meteorology, Hydrology and Climate Change, explained that, in Vietnam, the government has taken under very serious

consideration the impact of climate change. In 2008, the government issued the National Target Program to Respond to Climate Change and, since then, a lot of progress has already been done, especially in the coastal area, through reforestation and protection of the mangrove.

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Basic science and health

In the last century, experimental sciences and cooperation between different disciplines, such as medicine, mathematics, informatics, biology and physics, have led to huge advances in medical diagnostics and therapeutics. Indeed, as Jean-François Bach, Perpetual Secretary of the French Academy of Science, recalled, "basic science has contributed a lot to improving health and longevity."

Better communication for better health

Bach added that, today, we are at the stage where new prevention methods need to be developed. Thanks to vaccination, there has been a dramatic fall in the frequency of dreaded diseases, but medicine still misses a large number of them. Thus researchers need basic science to build up new vaccines and improve existing ones.

Unfortunately, as Bach showed, we are now witnessing, in some countries, reluctance toward science, particularly in health. More people are hesitant to be vaccinated, which is worrying. This reluctance is not based on scientific facts, but on rumours and unconfirmed data. The scientific community in general has a lot to do to teach the population about scientific applications. There is a need to improve the dialogue between scientists and the general population, including politicians. Administration and politics are indeed very important for convincing people.

Health for all

There is no doubt that science has saved and substantially contributed to the improvement of health outcomes. However, achieving health for all remains very challenging. Socorro Escalante, Advisor at the World Health Organization (WHO) in Vietnam, indicated that 30% of the world's population has no access to modern medicine and that, clearly, health depends on where people grow and live. Jean-François Bach agreed on that point and raised the issue of price. When a molecule is important for the whole population, its price must be affordable. It is not acceptable

to pay a fortune to treat a patient, when companies have already gotten a return from their investment.

Health and other factors in our society – the economy, poverty, social stratification, environment – are inextricable and need to be taken together. Socorro Escalante underlined that much of this depends on the political, economic and social policies of the country. How could science influence these policies? Escalante suggested, as did David Gross, to apply the scientific method to politics, economy and social policy.

Basic science *for* health – two examples

X-ray, MRI, PET scan, CT scan… There are more and more accelerators in hospitals as a result of technology transfer from the physics field. Indeed, the three technology pillars of particle physics – accelerators, detectors and computing tools – have all found their way into the medical field.

Frédérick Bordry explained that, at CERN, in the 90s, scientists conducted a proton-ion medical machine study. From this study followed two medical facilities: CNAO (National Centre of Oncological Hadrontherapy), in Italy, in operation since 2012; and MedAustron, in Austria, which will start treating patients in 2017.

In the field of neuroscience, Sean Hill, Director of Neuroinformatics for the Human Brain Project (EU-funded project), explained that there is a tremendous amount of data being produced around the world, at the sub-cellular, cellular, tissue, brain levels, using many different experimental techniques. Yet, as he deplored, there is no framework for putting all these pieces of data together and understand the relationships between them. To address this issue, the Human Brain Project, a global collaborative project based in Europe, has the objective to put in place a cutting-edge research infrastructure that will allow scientific and industrial researchers to collaborate and develop new tools to advance our knowledge in the fields of neuroscience, computing and brain-related medicine.

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Basic science and the global facilitation of education, knowledge and technology mechanism

Science in the classroom

Science at school is too often irrelevant, boring, and learned by rote without understanding, which produces scientifically illiterate societies. But this is not a fatality. With his introduction, Pierre Léna, Professor and member of the French Academy of Science, wanted to emphasise that science in the classroom should and can be a moment of curiosity and joy.

But which part of education should be the focus of the investments in basic science? Léna showed that in the last 15 years, the total of international aid to education has significantly increased, mostly for basic and high education. The problem is that investing money on high education without having the grassroots tissue of learning people does probably not produce the best results. Léna explained that investments should focus first on basic education, then on secondary education. After this, the natural product of that investment will be better recruitment for higher education.

> **"Science education includes values such as discovering and serving the truth, developing a sense of harmony and beauty, collaborating, and serving the needs of the society thanks to knowledge."**
>
> *Pierre Léna, Professor and member of the French Academy of Science*

The teacher is key

Children are extremely curious, but, as highlighted by Jérôme Friedman, Nobel laureate in Physics (1990), "we need teachers who can nurture this curiosity and find ways to express it further." To motivate the young generation, we have to tell kids about the wonders of science, the great discoveries, etc., but also about the great things that we don't understand. Indeed, Pierre Léna agreed on the fact that the key to the success of science education is the teacher, but teachers cannot succeed if scientists don't help them by developing high quality resources and by helping them understand the process of science. Female teachers, in particular, should be more encouraged and invited to learn more about science.

Yves Demay, Director of the *École polytechnique* (France), confirmed the importance of the role played by scientists. At the *École polytechnique*, as he explained, they have two missions: research and education. These two missions are mutually beneficial: it is good for researchers to teach, to be stimulated by students, to have to produce clear explanations; and it is good for students to have researchers as teachers, to benefit from up-to-date knowledge and appreciate the exciting promises of science. And of course, as Friedman mentioned, unknown answers are also good for open-minded and innovative students.

So it is important for universities, scientific organisations, etc., to take the initiative and interact with the teaching system as much as they can. Frédérick Bordry showed how CERN, through different programmes, in particular its Teachers and Students Programmes, promotes and supports education, in particular in particle physics. CERN's programmes facilitate the exchange of knowledge and experience among teachers, students and scientists of different nationalities.

Students, in particular the youngest, also have a role to play. Children are critical agents of change, in their infinite capacity for activism for the creation of a better world. Pierre Léna stressed the fact that not only should one transfer to children the capability of understanding science and technology, but also the desire to act on the basis of this knowledge.

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Basic science, open innovation and collaboration economy

Diplomacy and science, two distinct worlds

What can diplomats learn from scientists and *vice versa*? Jovan Kurbalija, Founding Director of DiploFoundation (Switzerland), highlighted that, in Geneva, he tries to explain to diplomats that a line between two dots could be straight, and to technologists and scientists, that the line is quite complex when it comes to diplomacy. Maurizio Bona observed that if science wants to count more in global diplomacy, the trust between the worlds of diplomacy and science must be enhanced. To do so, it is important to involve diplomats more in the world of science.

> **"We are obsessed by here and now. Everything has to happen here and now, this is a trait of our time and civilisation. Scientists, with their zoom out view, can remind us that there is a history and some future."**
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> *Jovan Kurbalija, Founding Director of DiploFoundation (Switzerland)*

From science to politics – an example

Dominique Guellec chose the example of digitalisation to bring to light the responsibility of policy-makers in the use – good or bad – of new technologies.

Digitalisation encouraged the democratisation of the economy, but Guellec noted that markets still are extremely centralised, with only a few big groups (Amazon, Google, Facebook…) controlling the largest part. This is not exactly what is called a 'democratic economy'.

Furthermore, the democratisation of robotics, even if it led to a huge increase in productivity, had a major impact on the workers, as it led to reduced demand for middle and low-level skills. Besides, if the Internet allows the circulation of ideas and promotes freedom, it is also a powerful tool for authoritarian governments to monitor very closely their citizens.

Thus solutions must come from the policy-makers: we need policies to make the Internet more inclusive across the world population; we need policies on innovation and competition; and we need education policies to reduce the imbalance between skilled and unskilled people.

> **"In the world of politics, the emphasis is on getting things done, as opposed to in science, getting things right. These two worlds have to connect."**
>
> *Ramesh Thakur, Director of the Centre for Nuclear Non-Proliferation and Disarmament (Australia)*

Basic science *versus* applied science

In applied science, as soon as scientists have a solution, they tend to move on to the next problem. But people with a background in basic research, who are used to working on the fundamentals, invest an additional amount of time to understand why the solution is working, which Nicolas Cudre-Mauroux, Director of Research and Innovation for the Solvay Group, welcomed. Indeed, Cudre-Mauroux showed that 90% of the time, scientists can then further improve the solution. That is why we need to move beyond the opposition between basic and applied research, and instead think in terms of collaborations. Sébastien Remy, Senior Vice-President of Airbus and Airbus Director of innovation (France), concurred with Cudre-Mauroux on this point, saying, "research teams should involve basic scientists, applied scientists and, at the end of the chain, industrial people."

Nevertheless, one important distinction gets in the way of funding basic research, as highlighted by Kurt Wüthrich. It is the question: 'What is your research good for?' Very often, in basic research, there is no answer to that question, because basic research is exploratory. Indeed, Bruce McKellar, President of the International Union of Pure and Applied Physics (IUPAP) (Switzerland), reminded that science is not a straightforward step. It takes lots of byways and requires many mistakes, and young researchers have to understand to learn from their mistakes. Cudre-Mauroux added that 'learning from failure' is kind of a cultural element that basic research brings to the rest of the innovation community. Basic research *is* about failing: learning from failure is a way to success.

Conclusion: basic science is not optional

Basic science, because of its unpredictability, does not go without saying. Today more than ever, countless efforts are needed to convince of its legitimacy, despite the abundant examples of its fertility, in particular for the benefit of health. But it is the responsibility of governments to ensure that basic science gets the funding it needs.

Governments, in particular in emerging countries, have to be aware of the importance of basic science for the development of their country; they have to understand that on science will depend their capacity to come up with innovative tools, and with new and diverse approaches for a sustainable future.

The model of scientific collaboration, with its openness and diversity, is a wonderful promoter of peace. Because of science, incredible collaborations have seen the light of day, showing to the world that people from different nationalities, cultures and ideologies can work together peacefully towards a common goal.

Basic science should be promoted as a driving element for society. Science education, in particular, must be at the centre of our preoccupations. The women and men of tomorrow should study science at school today, so that they will have tools for providing solutions to global issues.

Basic science, applied science, technology and education can together be very powerful, but we still have to work on the interfaces between these different parts of the same entity.