9th International Conference

on Inquiry-Based Science Education in Elementary Schools

Science Education for the 21st Century

Compendium

December 4th & 5th, 2017
The National College

INNOVEC
Innovación en la Enseñanza de la Ciencia

We appreciate the support of the following institutions for the realization of the event:

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The United States-Mexico Foundation for Science

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Compendium of Ninth International Conference on Inquiry-Based Sciencie Education in Elementary Schools. Science Education for the 21st Century. The event was held on december 4th & 5th, 2017 in The National College.

CONTENT

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PRESENTATION

Throughout its 15 years of existence, Innovation for Science Education (INNOVEC), along with Secretaría de Educación Pública (Ministry of Education), federal and state authorities, academic institutions, and private enterprise organizations, has focused its efforts towards a single objective: **to bring high quality science education to all Mexican students of basic education.**

Every year, around 10,000 teachers and 350,000 students of regular, native, multigrade, and special education have received the benefits of **Inquiry-Based Science Education Program (SEVIC, from its acronym in Spanish)**, implemented by INNOVEC. Through a series of scientific activities progressively organized and supported by a life- and inquiry-based pedagogical approach, students following the program SEVIC develop abilities and knowledge which allow them to understand phenomena of the world around them, as well as to apply what they have learned to everyday life situations which turn out to be critical for health, the environment, and a harmonic life in society.

With the aim of analyzing and discussing global tendencies in life- and inquiry-based science education, as well as studying best practices to contribute to the development and optimal operation of the program SEVIC in our country, since they year 2001 INNOVEC has organized nine biannual international conferences on inquiry-based science education.

Within the frame of INNOVEC's fifteenth anniversary, on December 2017 took place the **Ninth International Conference "Science Education For the 21st Century"**, whose main objective was to analyze the diverse contributions on science education towards the formation of a global citizenship, the development of scientific capabilities, harmonic life in society, economic development, and environmental sustainability in the 21st century. These conferences are spaces open to reflection and analysis, were trending topics in education are treated by national and international experts, who share their ideas with teachers, educational authorities, and the general public interested in science education. Best practices in the classroom, which have proven to be effective when teaching science following a life- and inquiry-based approach, are integrated into a solid curriculum proposal, as well as the professional development of teachers, pedagogical materials, assessment processes, and the support from the community. Those are the elements nurturing the discussion generated in these forums.

In particular, this ninth conference addressed the following topics and questions: In which way does a quality education improve the development of people? A science education for the development and commitment of individuals towards society. How can science education contribute to an integral education promoting innovation, respect for nature, and a harmonious life in a global society? How to assess progress in the development of scientific skills and capabilities by the students? The role of private enterprises and foundations in the enhancement and development of scientific capabilities by the students.

This report records the talks, discussions, and conclusions generated by this event. We hope that the present publication may be of interest for everyone focused in the teaching and learning of science in Mexico, and becomes an integral part of the specialized bibliography on inquiry-based methodology that our institution grants to the general public.

INAUGURAL CEREMONY

INAUGURAL CEREMONY

Pablo Rudomín Zevnovaty
Member of the Board of Innovation for Science Education (INNOVEC) and Member of The National College.

Good morning. It is an honor for El Colegio Nacional to welcome you all in what you may consider your own home, and to host in its premises this series of lectures, which are fundamental for the developing of our country.

I have always insisted in the fact that there is a fundamental difference between information and knowledge, and the underlining idea behind today's presentations is precisely how to turn information into knowledge, as well as how to use knowledge while making decisions in our everyday life, so that we may reach a more rational approach to the various situations we have to face.

I would like to welcome the people who share this presidium with me. To begin with, of course, we have Mtro. Javier Treviño Cantú, Subsecretario de Educación Básica (Vice Minister of Basic Education), who is representing Mtro. Aurelio Nuño, Secretario de Educación Pública (Minister of Education). As I told him earlier, and as he will surely explain in his presentation, education in primary school is very important because it is there where children build the world view which will remain through their development as adults. I would also like to introduce Ing. Jaime Lomelín, President of the Board of INNOVEC, an organization which, with its enthusiasm, has imprinted strength to this Conference; Dr. Mario Molina, Member of El Colegio Nacional, does not need to be introduced: you all know he is deeply involved in development and environmental questions, a fundamental aspect of our life; Dr. Nuria Sanz, Director and Representative of UNESCO; Lic. Ulrike Wahl, adviser of Siemens Stiftung in Latin America; and Ing. Guillermo Fernández de la Garza, Member of the Managing Board of INNOVEC and Executive Director of the United States-Mexico Foundation for Science (FUMEC), an institution promoting education, as well as relations between Mexico and the United States, which is this moment may play a fundamental role towards reaching more balanced relations with our northern neighbor.

So, after having welcomed our guests, I give the floor to Ing. Jaime Lomelín, President of the Board of INNOVEC.*

** Transcription*

Jaime Lomelín Guillén
President of the Board of Innovation for Science Education, INNOVEC.

Good morning, Mtro. Javier Treviño Cantú, Subsecretario de Educación Básica del Gobierno de la República; Dr. Ruy Pérez Tamayo, President of El Colegio Nacional; Dr. Mario Molina, Nobel Prize of Chemistry, Member of El Colegio Nacional, and a faithful ally of INNOVEC; Dr. Pablo Rudomín, Príncipe de Asturias Prize, Member of El Colegio Nacional, and Member of the Board of INNOVEC, whom we owe the pleasure of being in this beautiful building today; Dr. Nuria Sanz, Director and Representative of UNESCO in México; Guillermo Fernández de la Garza, Executive Director of Fundación México-Estados Unidos para la Ciencia and Assessor of INNOVEC; Ulrike Wahl, Representative of Siemens Stiftung in Latin America. I heartly greet Dr. Eduardo Backhoff Escudero, President of Instituto Nacional para la Evaluación de la Educación (National Institute for the Evaluation of Education)[1]; educational authorities, teachers, technical pedagogical assessors, and representatives of society who are with us today.

Speaking on behalf of the Managing Board of Innovación en la Enseñanza de la Ciencia, it is a pleasure to address you in such a memorable occasion. First of all, because of the importance of the topics to be discussed during these two days, which will become of the utmost relevance for education in our country, but also because this Ninth International Conference coincides with the 15th anniversary of our institution.

Fifteen years of constant work with Sistemas de Enseñanza Vivencial e Indagatoria de la Ciencia (Systems of Experience- and Inquiry-Based Science Education; SEVIC, by its acronym in Spanish) have enabled us to walk along with the national educational system in search of innovative strategies for the teaching of natural sciences in basic education. The result of the efforts of everyone involved, has been fundamental to create an effective pedagogical proposal, which allows us to work in the development of scientific abilities and competences in children, capital features for success in what is called "the society of knowledge".

[1] When the talk was delivered, he was president of Junta de Gobierno, INEE. Currently he is president of Consejo Directivo de Métrica Educativa, A.C.

From left to right: Pablo Rudomín Zevnovaty, Jaime Lomelín and Ulrike Wahl.

This task has been very pleasant because it has allowed us to acknowledge that the curiosity of children is the main factor enabling the practice of science in the classroom. Genuine questions, doubts, and ideas about the way nature works, as well as their willingness to collaborate, allowed us to apply an inquiry-based pedagogy, which enables children to discover by themselves the answers they seek, and imprints in them the desire to keep on learning through their whole life. Their amazed and excited facial expressions when they discover and understand, is the best motivation to keep on going with this project. Of course, all this is possible due to dedicated and enthusiastic teachers, who willingly receive specific instruction and actively participate implementing the suggested strategies, as well as testing and validating the result of these processes in the actual learning process of their students. Without this important labor on the part of participating teachers, we could never have reached this far. In INNOVEC we are thoroughly thankful for the dedication and leadership of Mexican teachers.

Therefore, it is a pleasure to have this morning with us Mtro. Javier Treviño Cantú, Subsecretario de Educación Básica, who along with Mtro. Aurelio Nuño, Secretario de Educación Pública, have solidly applied an educational reform which will be of the utmost importance for our country. INNOVEC appreciates their effort towards the accomplishment of a deep educational transformation in Mexico, which must bring us together with the sole purpose of raising a generation of successful, educated, competent, and sensible Mexicans, open to the new realities of our world.

For this reason, the main topic of our Ninth Conference is "Science Education For the 21st Century". We believe that the challenge of providing a high-quality science education to our children calls for a shared leadership. No single sector of society is able to accomplish such a thing, so we need the combined willpower and efforts of academics, private enterprise, government, heads of family, and society as a whole. We live in a world where science and technology become more important everyday; communication networks have rendered available an amount of information which some years ago would have been unthinkable. Social networks have turned the planet into a single community, able to share events instantaneously and which immediately reacts to any kind of special situations.

Therefore, our main task is, as has been mentioned by Dr. Pablo Rudomín, Member of the Managing Board of INNOVEC, to turn such information into knowledge, to use it as the building blocks of a foundation which allows us to understand properly the way natural and social systems work. This requires a deep transformation in our educational system, since we were formed according to different axioms. New social, economic, and environmental realities; globalization versus isolationism; opening or closing our commercial borders; equitable distribution of wealth; and challenges such as sustainable development and global climate change, are factors demanding a society able to deeply understand its own problems, to analyze them cooperatively, and to be open to several ways of reasoning and perceiving, to different approaches. In this important task, science education plays a major role, it is an education to question and picture the future we want to live in, as well as the way to build it.

At this moment I would like to recognize the indefatigable effort of the distinguished members of El Colegio Nacional, to whom we owe the opportunity of hosting our conference in this building. To begin with, I will mention Dr. Ruy Pérez Tamayo, whose life-long task has been to understand the functioning of science and the reasons why it is relevant to our society; his research and texts fill us with pride, and they constitute an important contribution to our formative processes. I would also like to highlight the work of Dr. Mario Molina, also a member of El Colegio Nacional and a close friend of our Managing Board, whose social leadership and commitment have allowed us to consolidate several of our institutional goals; we are thoroughly grateful to him. In a similar way, we thank Dr. Pablo Rudomín and Dr. José Sarukhán, who have always supported our proposals, and whose mere presence enriches our event.

It is a pleasure for us to greet educational state authorities and our friends from the international community who are with us today, and who have traveled from distant places with the sole purpose of sharing, building, cooperating, and communicating in this global network of science educators of which INNOVEC is proud to belong.

Ladies and gentlemen, we recognize your presence here this morning. I wish you a happy and productive day in the sake of science education for children and young people in our countries. Thank you very much.*

** Transcription*

Mario Molina
President of Mario Molina Center for Strategic Studies on Energy and the Environment

Good morning everyone. Distinguished presidium participants, ladies and gentlemen, welcome to El Colegio Nacional. It is a pleasure to me, as a Member of El Colegio Nacional, the fact that this Ninth International Conference on Science Education For the 21st Century is taking place in our premises.

I would like to briefly mention, even though it is evident, the incredible importance of science as a transforming device in the progress of civilization, and in the way it has improved our life standards, since the 19th century but especially from the 20th century onward. An example I find very relevant is that, thanks to science, human life expectancy has practically duplicated during the last 50 years, which after all allows many of us to be present here today.

The changes in society have been huge, and through them we have been able to sustain such an enormous population, exceeding currently 7,000,000,000 inhabitants. On the other hand, this fact itself generates serious problems in our environment and in sustainable development, and that is exactly why we need even more science, we require innovation to accomplish discoveries which allow us to maintain this incredible progress of civilization.

Science education is of the utmost importance, and it is the main objective of INNOVEC. This revolution in education has had an enormous impact in the whole world, but fortunately in Mexico as well. As you well know, in traditional education since primary school and all the way up to, and including, university studies, pupils passively listen to what the teacher tells, and then proceed to memorize it. This has required a fundamental change, originated in science academies, beginning with the Academy of Sciences of the United States of America, to understand the way in which children learn better, and what is the science behind education. As a result of this effort it has become evident that it is more efficient for students to actually engage in scientific practices, to execute experiments and participate actively, instead of just listening and memorizing. This represents a truly deep change in education, but the culture and philosophy of educational procedures is not easy to modify, so only now we are starting to apply this method at a general scale. Currently, half a million primary school students in Mexico are using these educational methods, but we expect in the near future, and thanks to the educational reform among other aspects, to firmly establish these educational methods and to spread them to middle, middle-high, and superior education. At universities, students may attend lectures by famous professors, but participate actively by asking questions and cooperating among each other during their everyday lessons.

From left to right: Guillermo Fernández de la Garza, Nuria Sanz, Mario Molina, Javier Treviño Cantú, Pablo Rudomín Zevnovaty, Jaime Lomelín and Ulrike Wahl.

I would like to mention a very important aspect: As you well know, in recent years we have been having serious problems in the way society functions, related with demagogy and false information. Therefore, it is even more necessary today than ever before to prepare citizens in such a way that democracy may work properly. Of course, in Mexico we must also communicate this culture to the children, so that they may develop well as citizens. This is not science as such, but values and culture, questions related with economy, sociology, politics, etc.; but it is very interesting and very important that these new methods for teaching science are remarkably more efficient to transmit such values than traditional educational systems; for example, introducing a subject with a focus in ethics and then asking students to memorize such information... is something that will never work well. On the other hand, if children learn to work in a group, to discuss their ideas, to cooperate with each other and with the teacher while designing experiments, or picking up garbage, or observing nature directly, understanding the way it functions, how plants and animals grow, then they naturally develop these values, which are essential for our society to work properly. We know that some of the main characteristics of the international scientific community, which are not intrinsically scientific but social, are honesty and the aim for a world that works better as a whole, the idea that all innovation, discoveries and inventions, can eventually be used to improve the life standard of all inhabitants of the planet. For such reason, I consider extremely important to have this kind of meetings, like "Science Education For the 21st Century", since their transcendence is fundamental for the development of society. I wish this conference turns out to be very productive for all of you. Thank you very much.*

** Transcription*

Javier Treviño Cantú
Undersecretary of Elementary Education.

Good morning. To begin with, in representation of Mtro. Aurelio Nuño Mayer, Secretario de Educación Pública, I heartily greet and thank in the name of Secretaría de Educación Pública, Dr. Mario Molina and Dr. Pablo Rudomín, both of them Members of El Colegio Nacional and the Managing Board of INNOVEC. I would also like to thank Ing. Jaime Lomelín and Ing. Guillermo Fernández de la Garza for this invitation, as well as greet Dr. Nuria Sanz and Lic. Ulrike Wahl.

We have been working these last months and these last years with INNOVEC (Innovación en la Enseñanza de la Ciencia) in a highly efficient way. When Secretario de Educación Pública, Mtro. Aurelio Nuño Mayer, presented the new educational model, he mentioned one of the new axes ruling such system: The collaboration between federal government, state governments, and social organizations, as well as teachers, which allows us to strengthen the other axes of the model, that is, to strengthen the school, to strengthen continuous formation, including the original preparation of teachers, to strengthen the curriculum (in a little while I will speak more extensively regarding curriculum), and to strengthen all aspects of equity and inclusion in the new educational model.

Given its remarkable relevance, I would like to acknowledge the effort of INNOVEC in organizing this Ninth International Conference On Experience- and Inquiry-Based Science Education For Basic School. This is fundamental for those of us working on basic education. In the whole country, science education for the 21st century is a very important topic, and I am certain that this series of conferences will be very profitable for all participating teachers, as well as for school principals, supervisors, and technical pedagogical assessors; I am happy that you all are with us today, because we will make progress towards the strengthening of the new curriculum in science education for the 21st century. I would like to thank once again Dr. Mario Molina and Dr. Pablo Rudomín, the kind hospitality of El Colegio Nacional as the host of this Ninth International Conference, and so, in representation of Secretario de Educación Pública, Mtro. Aurelio Nuño Mayer, I declare open the Ninth International Conference. Congratulations, and may it help improve education and welfare of children in Mexico.*

** Transcription*

KEYNOTE SPEECH

The New Educational Model and the Challenges of the 21st Century for Mexico

Keynote Speaker. Javier Treviño Cantú
Moderator. Guillermo Fernández de la Garza

Javier Treviño Cantú

Undersecretary of Elemental Education
Ministry of Education

Today I would like to talk about five fundamental topics:

1) the scope of the Educational Reform;
2) the three stages of the Educational Reform;
3) the five axes of the Educational Model;
4) the Key Learnings for integral education; and
5) a little bit about the program La Escuela al Centro (A Central Role For the School) and the way it has been implemented.

Those are the five topics I would like to briefly mention in this presentation.

When we talk about the scope of the Educational Reform, we must picture a transformation in school organization, in school infrastructure, in the National Assessment System, in the new operational model for schools, in the characteristics of teachers and administrative personnel, in the new educational materials, plans, and programs. This breadth regarding the scope of the Educational Reform is extremely important.

Now, when we talk about the stages of the Reform, we must focus in three fundamental aspects:

1) to begin with, the design stage, the judiciary structure of the Educational Reform, its institutional frame;
2) the great national referendum accomplished in several different ways; and
3) the purpose and basis of the new Educational Model.

The first stage takes place when it is established, both in the constitutional reform of December 2012 and in the reform to the judiciary frame of 2013, the constitutional right of children and teenagers to have access to quality education. The creation of the National System For Educational Assessment, managed by the National Institute of Educational Assessment; the Professional Teaching Service based on merit, in the case of basic education and middle-superior education; a System of Educational Information and Management which allows to take more knowledgeable decisions; the reorganization of resource management; the strengthening of school councils for social participation, as well as a better coordination between federal and state educational authorities, both sharing this responsibility. It is important to remark that during this first stage, with the constitutional reform, the creation of a law regarding Professional Teaching Service, the reforms to the general law of education and to the law pertaining the National Institute For Educational Assessment, is when we see the creation of institutions which allowed us to be ready for the second stage, which was the national referendum, as well as for the building of the new Educational Model.

In the year 2014, as many as 21 regional and national forums took place, allowing us to build a proposal for the new Educational Model along with academicians, specialists, teachers of superior education, and social organizations. In this way, we managed to systematize all information, so that by 2016 we had already organized the results of a very broad referendum. More than 200 forums in the whole country managed to capture the views of everyone involved in the National Educational System.

After this second stage we were able to focus in the third one, namely, the presentation of the Educational Model and the way to implement it. Such presentation of the Educational Model took place following five fundamental axes: 1) the curriculum approach, of which I will talk a little bit later on; 2) the strategy involving the program *A Central Role For the School*, which has been implemented for more than one year at the National Educational System; 3) professional formation and development for teachers, paying attention both to initial and continuous formation; 4) an important strategy regarding interventions on inclusion and equity; 5) the axis of management of the Educational System.

As can be noticed, it is an integral Educational Reform which coherently organizes the expected learnings for children and teenagers at each educational level, with a proper long-term vision. In a very basic way, we can state that between 2012 and 2016 we accomplished the judiciary frame, the great national referendum, and the proposal for the new Educational Model. However, this does not encompass the spirit of what we are looking for with this institutional

and judiciary process, which is to have better contents, better schools, better teachers, so that our children may learn to learn, and learn to live harmoniously in society. With this in mind, now I would like to talk about the first axis, the curriculum approach, which relates closely to the main topic of the present conference: Key learnings for an integral education.

Of course, we absolutely follow the principles and statements of the Third Article of our Constitution, regarding high-quality basic education which is secular, public, mandatory, national, democratic, based on scientific advancements, and following the generally accepted lines on the aims for education in the 21st century.

When the Minister of Education Aurelio Nuño presented the new Educational Model, it was accompanied by two additional documents. The title of one of them was *Fines de la educación en el siglo XXI* (Aims For Education In the 21st Century) in which, after a thorough collaborative work with teachers, academicians, experts in pedagogy, and other people involved in educational topics, it is stated the kind of Mexican citizen we want to form through mandatory education, and the expected learnings to be attained at each level. I make an open invitation to all of you to read this document, which can be found in the website of the Ministry of Education, since it is exactly there where we can find, as Dr. Mario Molina mentioned, the importance of forming Mexican citizens with values, with a great tradition regarding freedom and creativity, so that we can slowly transform pedagogy and go forward regarding basic education. The document defines the expected profile of a person graduating from basic education, as a result of a new curriculum for children and teenagers.

Here I would like to briefly mention this expected profile of people graduating from basic education according to the new Educational Model. Our aim is that, at the end of the basic education cycle, children and teenagers: are able to communicate with confidence and efficiency, have initiative and favor collaboration, and what was mentioned by Dr. Mario Molina, that they acquire self-knowledge and are able to regulate their own emotions; also, that they appreciate beauty, art, and culture, that they assume their own identity and accept cultural diversity, that they have critical thinking and are able to solve problems through creativity. Then we are being able to make the transition from a pedagogy of memorization to a pedagogy which truly enhances creativity and problem solving through reasoning. We also want people who graduate from basic education to show respect for their body and for the environment, to be aware of the phenomena of both the natural and social worlds, and here science education is fundamental; they must also cultivate their ethical formation and respect the law. The formation of solid values is essential, the value of respecting the law, the respect for the rule of law, for democracy. It is also important that they can use digital abilities pertinently and permanently.

Those are the main characteristics of the expected profile for people graduating from basic education. I make an open invitation to read and analyze the proposal we made regarding *Key Learnings*, since it is not only a detailed presentation but also a very ambitious one, about the new curriculum for this first axis of the Educational Model. Now we will analyze the main parts of this new curriculum, built with the aim of forming citizens who are free, responsible, and informed, able to have a proper life in the 21st century.

The curriculum proposal for basic education has three main components. To begin with, the *Fields of Academic Formation*; in the second place, *Personal and Social Development for children and teenagers*; at the end, *Curriculum Autonomy*, which is a novelty I would like to comment here.

Let us focus now in the first component, *Key Learnings for the Fields of Academic Formation*. It is extremely important for this component, which must be observed in the whole country, to include the fundamental contents needed to develop the expected profile for people graduating from basic education. Here we are talking about *Language and Communication*, related with native languages, Spanish, and English, as well as with the way children and teenagers can use language to improve communication. We also have *Mathematical Thinking* and how to make it accessible for children and teenagers, so that they are able to solve problems according to the new pedagogy. A third field is *Exploration and Comprehension of the Natural and Social Worlds*, which includes civic and ethical formation. These are the *Fields of Academic Formation* acting as guidelines for the assessment of the various subjects. They are available in our presentation of the curriculum, where each one is detailed and organized according to educational level.

This first component of the curriculum is important, but it is not enough. Therefore, it was necessary to add a second component while integrating the new curriculum: *Personal and Social Development* for children and teenagers.

Key Learnings are complemented by the development of other capabilities. The school must grant opportunities to develop creativity, artistic appreciation and expression, body health and training, control of emotions, and values for a harmonious social life. This is an integral part of the curriculum, social and emotional education. The Ministry of Health is applying some programs, like *Salud en Tu Escuela* (Health At Your School), where professionals related with health work at the school. We also have some pilot programs which will be made permanent in the whole country by 2018, like *Arte y Cultura en la Escuela* (Art and Culture At the School).

Many of you may remember that some weeks ago there was a concert given by a new orchestra and chorus of traditional Mexican music at Palacio de Bellas Artes, which was conformed by children of 11 states around the country. This is part of the program *Art and Culture At the School*, result of a collaborative effort by the Ministry of Education and the Ministry of Culture, where we organize new activities so that children and teenagers may develop an artistic formation, including both visual and performing arts, as well as music. Another important program is *Exploradores de las Artes* (Art Explorers) with the aim of taking children and teenagers to museums and archaeological sites, and of bringing the practice of performing arts to the school, which is fundamental. There is also the effort of approaching children and teenagers to the habit of reading, and for this we have a program called *El Fondo Visita Tu Escuela* (The Fondo Visits Your School), in collaboration with Fondo de Cultura Económica, the main government editor house; in this program, book authors, tale-tellers, and book illustrators visit schools and help students to develop their interest for reading. In a similar way, we are encouraging the continuous preparation of teachers regarding art and culture, as well as the formation of orchestras and chorus of traditional Mexican music throughout the country. The first orchestra was integrated by members of 11 states, but we are already working in the whole country.

Therefore, *Health At Your School*, *Art and Culture At Your School*, and *Social and Emotional Education* are an integral part of the curriculum. The second component, *Personal and Social Development*, is fundamental, and science education plays an important role here as well.

There is a novelty in the curriculum because from the national referendum we knew that it was not enough to work on the fields of academic development, like *Language and Communication*, *Mathematical Thinking*, and *Exploration of the Natural and Social Worlds*, including civic and ethical formation. It was not enough to integrate the students to social and emotional education, to health, to culture and art at school. We needed an additional element, something new, and that is now a part of the curriculum.

We are now at Phase 0 regarding the implementation of a pilot program, which is the curriculum component of autonomy. *Curriculum Autonomy* follows the principles of inclusive education, and at the moment we are in the process of developing detailed guidelines for *Curriculum Autonomy*. Which is the true meaning of *Curriculum Autonomy*? That each school in the country is able to decide part of its curriculum, a given percentage. This is extremely important because we are not only encouraging schools to develop an autonomous management upon a principle of confidence, but we are also strengthening decision-making regarding Curriculum Autonomy.

There are at least five different aspects regarding *Curriculum Autonomy* which schools tend to focus in, and that is why in the first three months of next year we will present its detailed guidelines. A given school may choose to give more depth to *Key Learnings*, *Language and Communication*, *Mathematical Thinking*, or *Exploration of Natural Sciences*, and that is very important.

Curriculum Autonomy is capital in full-time schools, where students attend for eight hours every day, as compared to regular schools where they spend only four-and-a-half hours daily. At the start of the office of President Enrique Peña Nieto there were only 6000 full-time schools, while near its end there are more than 25,000 in the whole country. These schools will be able to decide upon 20% of their curriculum time every week. It will be their decision if they focus in *Key Learnings*, or broaden the opportunities for *Personal and Social Development*, or go deeper regarding *Social and Emotional Education*, or *Art and Culture at School*. However, they will be able to choose, and several schools are doing so already, some of the new relevant contents which were introduced during the summer, like robotics, programming, science education, financial education, and education for health. Several schools are choosing those topics as part of their *Curriculum Autonomy*, and this is quite relevant because it strengthens *Personal and Social Development* as well as *Fields of Academic Formation.*

In a similar way, schools may choose to focus in *Regional and Local Knowledge*. This is fundamental for the students to know their locality, their municipality, and their state. Therefore, it constitutes a fifth area of development for *Curriculum Autonomy*. You all know that in several parts of the country the school acts as a center for community organization, and this helps to enhance social impact projects which may be based at the school, and which may belong to *Curriculum Autonomy*. So you can easily notice the richness of *Curriculum Autonomy* for every school, which allows to adapt teaching contents and techniques to each community. Each school decides that portion of the curriculum, according to the general guidelines, and this strengthens the integration of the three components of the curriculum for basic education.

Next figure shows how in our presentation of *Key Learnings* for the curriculum, we relate the three formative fields through the whole cycle of mandatory education, from preschool to superior education. The net of interconnections can be easily noticed, relating preschool, primary school, secondary school, and middle-superior education. This is one of the great advantages of the new curriculum: the interconnection and integration of the proposal throughout the cycle of mandatory education.

We have based our new Educational Model in 13 pedagogical principles, with the aim that children and teenagers may *learn to learn* and *learn to live harmoniously in society.* For this purpose, we need better teachers, better schools, better contents, and a better pedagogy. Here I will remark an important point, which is that federal and state educational authorities must approach the classroom, since the student and his learning process must play a central role in education. We must consider the previous knowledge of students and walk with them through the learning process. We must know their interests and encourage the intrinsic motivation of each pupil, as well as acknowledge the social nature of knowledge and propitiate local learning. We must understand assessment as a process related with educational planning, and model the learning process by acknowledging informal knowledge. It is also important to enhance interdisciplinary connections, to favor the culture of learning, and to appreciate the diversity as a source of richness for learning. These are some of the principles in which our curriculum proposal is based.

So, how will we work in the following months? Today we are busy with all pilot programs, in order to be ready for the school-year starting in August 2018. We plan to accomplish this in

NEW EDUCATIONAL MODEL

This diagram interconnects the three formative fields throughout the whole cycle of mandatory education, from preschool to middle-superior level

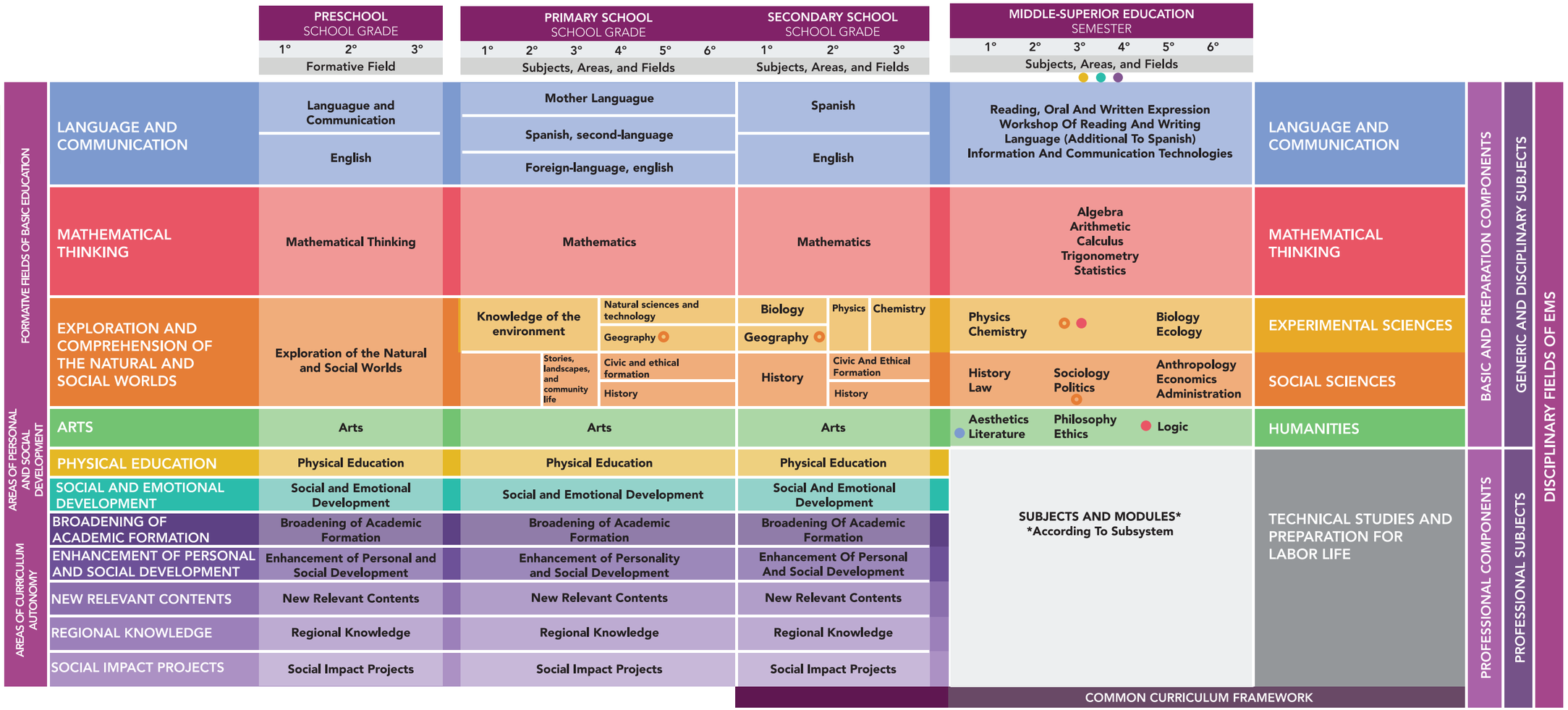

Figure 1. Outline of Curriculum Organization for Mandatory Education.

two phases: in the first one, during the school-year 2018-2019, we will start at all levels of basic education with *Personal and Social Development* and *Curriculum Autonomy*. That is why we are applying all pilot programs, so that at the beginning of 2018 we will have the corresponding guidelines and will be able to start working with preschool, primary school, and secondary school, in the activities of *Personal and Social Development* and *Curriculum Autonomy*, at all school grades of every educational level. Regarding the *Fields of Academic Formation*, which are *Language and Communication*, *Mathematical Thinking*, and *Exploration of Natural and Social Sciences*, including civic and ethical formation, the first phase will take place in August 2018, when we will start with first, second, and third grades of preschool, first and second grades of primary school, and first grade of secondary school. In August 2019 we will start with *Fields of Academic Formation* applying the new curriculum, enhanced by new educational materials, for third, fourth, fifth, and sixth grades of primary school, as well as second and third grades of secondary school.

We are working along with a team of experts in pedagogy and in the various disciplines, as well as with teachers and experts of superior education institutions. Currently we are focused in building new educational materials. We are doing this with the support of several academies, like the Academy of Language, the Academy of History, and the Academy of Sciences. In this way, we can apply a thorough revision of the new educational materials to have them ready for August 2018, where we will start at preschool, at first and second grades of primary school, and at first grade of secondary school. We are also already working in the materials to be applied from August 2019 onward, in third, fourth, fifth, and sixth grades of primary school, as well as second and third grades of secondary school.

We are accomplishing an enormous amount of work, since in addition to the creation of the curriculum and the diverse programs, as well as the building of new educational materials, this process needs teachers to be prepared. Our work would be wasted if we just delivered the relevant documents to the teachers soon before August 2018. Therefore, we have already written 21 documents for this first phase regarding *Key Learnings*, so that every teacher of basic education in the country, regardless of educational level, grade, and subject, may have the detailed explanation of the corresponding curriculum. The documents are ready, and will be delivered to 1,200,000 teachers of basic education throughout the country. In addition, since next January and during that whole first semester, there will be 21 courses online for teachers and educational authorities, including all three educational levels, with all information and materials corresponding to this new curriculum, as well as the way in which we will implement its three components, which are *Fields of Academic Formation*, *Personal and Social Development* for children and teenagers, and *Curriculum Autonomy*. We believe that we will arrive at August 2018 well prepared to begin applying this new curriculum with its new educational materials, and we will keep on working on implementation and revision so that in August 2019 we will be ready for the second phase of *Fields of Academic Formation.*

However, although it is important to talk about the curriculum proposal as the first axis of the Educational Model, it is not enough. Now I will briefly speak about the school, because the second axis of the Educational Model is *A Central Role For the School.* Today I will talk only about these first two axes. There are other important ones, like initial and continuous preparation for teachers, equity and inclusion, and management, but now I want to relate the curriculum axis with the school axis, because experience clearly shows that students have a better performance when school organization and environment favor learning, and that is why we have been working on the strategy of giving a central role to the school. In a similar way, the Educational Model encourages this strategy through a variety of actions, including intervention and the coordination of all people responsible of the Educational System, with the aim of continuously improve schools, giving priority to students' learning. *A Central Role For the School* is a strategy of implementing a more horizontal school organization, of encouraging federal and state educational authorities to approach schools, so that we may personally influence the development and learning of children. *A Central Role For the School* is not an end in itself, it is the aim of establishing the proper conditions for each school, as a community of learning, to be able to guarantee a quality education with equity and inclusion for all children and teenagers, independently of context, with the joint participation of teachers, students, and parents. This doubtlessly implies a medium- to long-term process, since we have to modify habits restricting the exercise of autonomy in school management, which constitute an obstacle to innovation in the classroom.

Regarding *A Central Role For the School*, we have five main lines of action, which I will briefly mention, since we have been working this whole year in implementing *A Central Role For the School.* For the first line, we established a National Management Council for *A Central Role For the School*, with the participation of every vice-minister of basic education in the country, no exceptions, who worked along with school principals of preschool, primary school, and secondary school. There we analyzed best practices for each state, considering the proposals subject to be interchanged, as well as those which can be implemented simultaneously. In such a way, we strengthened the school and its organization, so that each of them may function properly as a learning community. During this process, the work and preparation of school principals has been fundamental, especially since, as many of you already know, with the new law regarding professional teaching services we have more and more principals who have attained their position through open competition, instead of through direct appointment. This is extremely important; this preparation and leadership of school principals is truly fundamental. In a similar way, the preparation of supervisors and their work at the classroom, with systems of preventive alert and systems of classroom observation, in order to prevent students from falling behind or abandoning the school, is a basic factor for the system to work. This is a capital point, so we have been working with all state educational authorities so that all teaching positions are covered by prepared staff at every single school, thus strengthening all learning communities.

A second line of action has been to improve the infrastructure of schools, as well as their financial and material resources. It is clear that the program of infrastructure improvement of schools during the government of President Enrique Peña Nieto has been incredible, especially because it has focused on the schools having the greater needs, in the regions having the greater needs, particularly in schools for native people, in schools poorly connected, where it is more important to have a first rate infrastructure.

During this office, 300% more resources have been invested in the improvement of school infrastructure that in the two previous ones. We have a program called *Escuelas al CIEN* (Schools At CIEN; Certificates of National Educational Infrastructure, from their acronym in Spanish; also a pun since "cien" means "hundred" in Spanish), where we are improving the infrastructure of 33,000 schools in the whole country, by investing 50,000 million Mexican pesos, which is a rather substantial amount, and we will also keep on with programs like the Educational Reform and full-time schools in order to strengthen school management autonomy. Schools receive resources directly, with no bureaucratic involvement, which allows them to attend their necessities according to their own priorities through these federal programs. This strengthens their management autonomy, their decision-making, which builds upon *Curriculum Autonomy*. It is important to remark that we will keep on working at improving school infrastructure. We did it after the earthquake, which affected ten states, and also through programs like *Schools At CIEN* and the Educational Reform we are working on the improvement of the most affected schools, as well as those with partial damage, with the aim of offering children and teenagers first-rate learning communities as soon as possible.

A third line of action is for schools to have a closer relation with supervision personnel. It is clear that technical assistance at school is fundamental, so that each educational center may have the guidance, both in pedagogical and organizational aspects, to be properly strengthened. I also mentioned before how important it is to increase the number of full-time schools, since we have observed in several assessments, like the National Plan For Learning Assessment, that the academic performance of students who have been for three school-years in full-time schools is much better than that of regular students. Therefore, it is extremely important, as soon as we have enough resources, to increase the number of full-time schools in order to strengthen curriculum autonomy and give momentum to several educational programs. Moreover, those schools greatly support working parents.

The fourth line of action is about giving schools more power to make their own decisions. There is a very important element: School Technical Councils. Teachers and school principals at each school define, before the school-year starts (which is the time where said School Technical

Councils are busiest) some general guidelines, a working plan for the whole year and for each month. Thereafter, at the last Friday of each month they discuss their accomplishments. Therefore, for us it is fundamental not only to offer guidelines for the working pattern of School Technical Councils and their methodology, but to establish as well a program of collaboration so that best practices may be shared between School Technical Councils of a given area. Conversation and interchange of ideas is very important within a learning community, like a school, but also between two or three different learning communities, that is, between two or three different schools. The task of School Technical Councils is fundamental because they make the basic decisions regarding the learning of our children and teenagers, so it is of the utmost importance to increase school management autonomy and their power of decision regarding *Curriculum Autonomy.* Little by little, the power of decision of schools is increasing. Many of you may remember that in the last two school-years, it is the School Technical Council who decides the most convenient calendar for its school. No longer do federal or state authorities make such decisions, but each school is responsible for its own. In such a way we move forward, based on trust, towards the strengthening of decision-making at schools.

To finish, I will talk about the fifth line of action, which relates with an increased participation by families and the community as a whole. The participation of parents and families through School Councils of Social Participation is fundamental at each educational center. This is a capital point for those centers to become true learning communities, and for the work both inside and outside the school to be beneficial for the development, the learning, and the academic profit of children and teenagers. For example, parents have been increasingly participating in decision-making at schools, like in the best ways to invest federal resources and apply improvements. This is a very good symptom, but we also want parents to get involved in the different directions in which the school may evolve, and to work very closely with School Technical Councils.

We have already accomplished significant achievements in each of these five lines of action. It constitutes a strategic plan which is already being implemented and assessed in all five educational regions, along with governors and ministers of education of each state. We are moving forward, best practices are being shared, discussed, and interchanged. As I mentioned before, the aim of this strategy is to provide a fertile soil for the new curriculum, so that it can render better results. We will keep on working simultaneously and efficiently in the strategy *A Central Role For the School* while implementing the new curriculum.

To finish, I would like to mention that when Minister of Education Aurelio Nuño presented the new plans and programs, the Educational Model, and the various strategies, like the national strategy for English language, the strategy to strengthen teaching colleges, the strategy for equity and inclusion, as well as the document detailing the aims in education for the 21st century, we were not contented with a good intention or the mere formulation of a public policy, but minister Nuño was very specific regarding the way to implement such strategies. We established over 80 lines of action, chronological plans, and goals for each of the five axes of the new Educational Model. The way to implement the strategies will allow us to keep on working since, as you all know well, such a broad and ambitious Educational Model requires a long-term working plan, including aims, collaborative effort, discipline and, primarily, continuity, perseverance, and persistence in its implementation.

We have a very clear path to follow in the next ten years. It is very important to realize that we will not see results from one day to the next. We must work in the implementation of the new curriculum proposal, in keeping on strengthening the strategy *A Central Role For the School*, in making emphasis in both initial and continuous preparation for teachers, both inside and outside the school, in turning equity and inclusion into a reality through a new scholarship system, in strengthening the educational effort for native people, as well as for the children of agricultural workers who are migrating from one state to another. True equality for men and women is fundamental, so the various interventions regarding equity and inclusion require a continuous effort, require that we work perseverantly and persistently in the years to come.

Following this general path is the way in which the new management of the Educational System will render results for the benefit of our children and teenagers. They are the most important element in the whole Educational Model. At the center of our attention are children and teenagers. We must have an important impact in their learning process, so we will keep on working with several civil-society organizations, some as prestigious as INNOVEC, with which we work side-by-side in this very important effort to improve science education.

Thank you very much.*

** Transcription*

PANEL I

How does quality education privilege the development of people?

Keynote Speaker. Angela Fitzgerald
Panellists. Miguel Limón Rojas / Jorge Iván Ríos Rivera
Moderator. Leonardo Kourchenko

Angela Fitzgerald

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School of Teacher Education and Early Childhood
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INTRODUCTION

It is widely recognized and accepted that quality science education is underpinned by inquiry-based approaches. But why? What is it about inquiry that is so critical in informing science learning and teaching? This notion has become so engrained in our contemporary understandings of science education that we have long stopped questioning what it all means and why it matters. As we find levels of scientific literacy stagnating across the world, namely due to the socially and political challenging times we find ourselves in, it is time to take a step back from our assumptions and grapple with the why.

This paper, like the presentation preceding it, intends to respond to the question posed to me: why is teaching science through inquiry crucial for boys and girls in basic education? In providing a response, I will detail the current context we find ourselves in and what this means for learners of science before making connections to inquiry and the ways we can promote these qualities across basic education.

CONTEXT

In a fast-paced and rapidly changing world, questions are being asked about the role and purpose of basic education. Schooling has always had a place in preparing and educating children and young people for their futures, mainly focusing on equipping them the skills and knowledge-base to secure a job and/or engage in further education. Question marks hover above this intention, however, as we become increasingly aware that the realities of the nature of work and our understanding of what constitutes work are not the same as they were even a decade ago. Some key trends observed in the past fifty years or so that highlight the ways in which the workforce has changed (and is continuing to change) including:

- **Deindustrialisation** – less manufacturing-based employment and more service-orientated work;
- **Increased educational attainment** – more people with tertiary qualifications;
- **Technology and globalization** – the role in technology in significantly increasing the volume of goods and services traded globally;
- **Demographic change** – the workforce is ageing with more people retiring from employment than people entering employment;
- **Changing employment relationship** - more people are working in small (1 to 4 employees) companies with less people overall employed in the private sector;
- **Increased participation of women** – the number of women being employed is increasing; and
- **Decline of collective institutions** – union membership has dramatically declined.

With these factors and the rate of these changes in mind, projecting forward another decade, work will look and be enacted in significantly different ways again. This leaves teachers and schools in the unenviable position of educating their students for an increasingly uncertain future and workforce. For science education, this context challenges the function of science in the workplace/force and as a result the types of skills, knowledge and attributes that will be needed to engage in science-based work in the future.

In returning to the question driving this exploratory paper, it is hard to ignore the global presence of STEM (science, technology, engineering, and mathematics) and its influence on the ways in which we understand and practice science education. Regardless of how you define this interdisciplinary construct, the growing focus on STEM professions and the future-oriented role of STEM in the workforce is becoming ever sharper and more prominent. To illustrate this, consider the following insights from the United States:

- By the end of 2018, there will have been more than 1.2 million job openings in STEM-related occupations;
- Only 16% of Bachelor degrees obtained by 2020 will specialize in STEM-focused disciplines; and
- Within the next decade, 80% of jobs will require technology skills and expertise.

These statements become even more sobering for educators when considered in light of this quote from Alexis Ringwald, co-founder and CEO of LearnUp, "65% of today's kids will end

up doing job that haven't even been invented yet". The alignment of the above-mentioned knowns with this unknown is providing the impetus for STEM to have a presence in basic education. This is at odds, however, with what is happening at the chalk face in schools. STEM is not an acknowledged component of the prescribed curriculum in many parts of the world. Regardless, there is a global policy push for space to be found to accommodate and integrate STEM learning and teaching into classroom activities. The reality of this imperative is that school-based engagement with STEM capabilities and competencies is typically becoming the responsibility of science teachers (or generalist classroom teachers, the approach used in primary education). This is leaving science teachers' questioning what is required to ensure STEM education is enacted in meaningful and authentic ways to equip students with the skills, knowledge and attributes that will be valued and needed to be productive contributors in a STEM-focused future.

WHAT DOES THIS MEAN FOR LEARNING?

With the context in mind and an understanding of the kinds of challenges teachers, particularly those working in the sciences, face in preparing their students for an uncertain future, it is worth turning our thoughts to what this might mean for learning. Projecting into the future for both the science and STEM disciplines, it is recognized that a particular set of skills, knowledge and attributes will be required to experience success and be an effective contributor in the workplace as well as in the community at large. With the rise of automation, this success will no longer necessarily be about manual and routine tasks. Instead the focus is shifting to higher-level skills that go way above and beyond what can be achieved through robotics and production lines. These so-called 21st century (21C) learning skills are fast becoming the focus driving the purpose of education worldwide, which signals a move away from the learning of information to the learning of what to do with and how to apply this information meaningfully.

It is important to note at this point the construct of 21C learning skills is not without its critics. Some questions that are raised, for example, include 'Aren't we in the 21st century now?' and 'What are the skills that are actually needed for beyond this time and into the future?'. This paper does not intend to engage with this particular argument per se but would like to maintain the focus on what this approach means for learning more broadly. It is a push beyond learning as the attainment of facts by concentrating on moving thinking to deeper levels and bringing it to the complexities inherent in knowledge and knowledge sharing, which is a positive outcome from the introduction of STEM into the education sphere.

21C learning skills have been written about and defined in a number of different ways, but the following six attributes capture the essence of what classroom teachers, curricula documents and education policy makers hone in on in relation to the needs of learners across their basic education.

- **Information literacy;**
Ability to locate useful and reliable information that can be applied appropriately to the challenge at hand;
- **Collaboration;**
Working together to share, advocate, compromise and reach agreement on issues critical to the team succeeding
- **Comunicación;**
Ability to comprehend and present ideas in a variety of mediums and with the needs of the audience in mind
- **Creativity and innovation;**
Exploring the limits of the imagination to refine and improve original ideas and products
- **Problem solving;** and
Experimenting with new and familiar concepts, while processing and applying learning until a solution is found
- **Responsible citizenship**.
Demonstrating proper technology use, global awareness, ethical thinking and moral capacity in and out of the classroom.

In many educational contexts and jurisdictions, the 21C skills considered central to learners and learning are reduced and refined from the list above to the 4Cs: collaboration, communication, creativity, and critical thinking. These four skills are integrated within and across learning areas to not support their development, but better represent how knowledge is explored and expressed beyond the classroom in real world contexts.

WHAT IS INQUIRY AND WHERE DOES IT FIT?

In revisiting the question informing this paper –why is teaching science through inquiry crucial for boys and girls in basic education?– inquiry is an important component that still needs addressing. While inquiry is a word that is commonly used and understood in our daily language, it is often difficult to pin down and define in a pedagogical sense. This confusion often stems from a sense that engaging in inquiry processes in the classroom is about finding out an answer (usually through searching or researching on the internet), but it is much more than that. To think about inquiry in such simplistic terms is to undersell the value in the learning process. It is not just about accessing an established set of facts to find an answer or following a smooth, well established path to knowledge. The role of inquiry in the classroom is to spark students' curiosity about a particular problem or issue and ignite in them a genuine desire to want to discover a solution. The role of the teacher in this process is more as a facilitator and guide; it is not up to them to work out the answer or the path to get there. Instead, they should be posing the questions and bringing attention to the problems, then showing students the way by providing access to resources and materials that might assist in this learning journey. Equally, learners have a role to play here too. Rather than being passive receivers of information, engagement in inquiry-based approaches to learning requires learners to be active seekers of knowledge and even more active in working out how to apply this knowledge to generate thoughtfully considered responses.

This brief exploration of inquiry in the context of education starts to pick out some of the features of this approach broadly, but it doesn't specify what it means for science learning and teaching in particular. Drawing on the work of the National Research Council, based in the United States, there are five key ways in which inquiry-based approach to learning speak to and support science education. Inquiry enables:

- Engagement in scientifically orientated questions;
- Prioritizing the need to draw upon evidence when responding to questions;
- The formulation of explanations from evidence;
- Connections to be made between these explanations and scientific knowledge; and
- The communication and justification of the science-based evidence that has been gathered.

Drawing on the principles of inquiry makes pedagogical sense in a science classroom because it aligns directly with the contemporary understandings of and approaches to science education. Science learning and teaching has moved beyond science as a fix body of facts and a series of experimental steps that populate a lab report. Science in the classroom is now trying to imitate the skills, knowledges and attributes that practicing scientists use on a daily basis. School science has traditionally not represented how science is actually practiced, but being guided by inquiry-based approaches is helping to rectify this inaccuracy.

LINK BETWEEN 21C SKILLS, INQUIRY AND STEM FUTURE WORK FORCE

To summarize, three key ideas have emerged from this paper in response to the focal question that start from a big picture perspective and funnel down to implications for the classroom.

1. The nature of the workforce is rapidly changing and becoming increasingly STEM-focused, which significantly changes the skills, knowledge and attributes needed for success. Education systems need to acknowledge this and prepare students accordingly.

2. 21C learning skills speak to a world where automation will significantly reduce the number of manual jobs with the role of humans to instead think deeply and differently about the problems we face, locally and globally, and how to solve them. These higher-order skills can be collectively represented as collaboration, communication, creativity, and critical thinking.

3. Science as practiced by scientists has not been represented in the ways that approaches to school science tends value. The integration of inquiry-based approaches to science learning, however, is changing this and as a result we are witnessing in how science is taught.

This summary starts to capture what links the STEM-focused future workforce, 21C learning skills and inquiry approaches to science learning together – a recognition of the need to think and act differently in a world that faces a number of socially, geographically and environmentally complex and multi-faceted problems. To find solutions to these problems, there is a need to engage students in a different approach to learning science throughout their basic education, so that they prepared to be the leaders, thinkers and doers in their somewhat uncertain futures.

SOWING THE SEEDS: PROMOTING THESE QUALITIES ACROSS BASIC EDUCATION

If basic education is to make a difference, the focus needs to be on what is happening in classrooms around the world right now. The use of inquiry approaches in science education offer a potential portal into bringing about significant change in a short timeframe.

In terms of science teaching, inquiry-informed practices underpin quality. When teachers engage in effective science teaching, their students are more likely to be actively engaged in the inquiry process, developing their own ideas and using evidence appropriately. By positioning science teaching practices with the traditions of inquiry as a way for students of any age to investigate and make sense of the world, there is a greater likelihood of producing scientifically aware and literate citizens.

In regards to science learning, inquiry approaches require a shift from teacher-centered delivery of knowledge to student-driven exploration, which supports students to feel included and valued as science learners. Inquiry-based methods also emphasize that student curiosity, observations and problem-solving lead to more critical thinking about science as a set of knowledge, a process and a human endeavor. Furthermore, for learners, inquiry promotes ideas about and insights into science that are informed by lived experiences, rich discussions, targeted feedback and opportunities to represent learning in multi-modal ways.

As Carl Sagan proclaimed science is a way of thinking much more than it is a body of knowledge. The practices used in basic education to enable and promote science learning and teaching more than ever need to reflect this. At its most accessible level, inquiry-based approaches provide the framework in helping to make what might seem like a significant challenge an achievable reality.

Dr. Ange Fitzgerald
*October, 2018**

Presentation by Dr. Angela Fitzgerald. On the panel, from left to the right: Miguel Limón Rojas, Leonardo Kourchenko and Jorge Iván Ríos Rivera.

** Document for the Presentation*

Miguel Limón Rojas

Valora Consultoría S.C.

To be here with you in this forum makes me feel honored. I was invited by Guillermo Fernández de la Garza who, it must be said, is a Mexican citizen with a deep scientific vocation. Since a long time ago, even before I started to work at Secretaría de Educación Pública, he was already focused in the following topics: how to strengthen the awareness on the importance of science, how to better teach science, how to awaken in children and young people the passion for scientific learning. Therefore, I cannot avoid in any way a call from him involving solidarity with this cause, and I feel happy that he will be listening to this talk.

I will try to answer the following question: what must be done to build an educational system which provides children and young people with tools to develop their capabilities in the violent, complex, and dizzying society in which they live? The answer involves a construction process as challenging as it is unavoidable, as well as urgent, since the difficulties we face as a country are truly compelling in every sense. It is important to acknowledge that, in the search of the integral development of the human being, our educational system has sketched a clear picture of the aspects that must be changed, that is, Key Learnings, as well as the pedagogical and didactic practices needed to implement them. This transformation takes place at school, in the classroom, and in the relation teacher-student.

For this reason, the main part of the educational reform implemented since some years ago are the pedagogical principles supporting the educational model proposed; the remaining components of such model, that is, teachers, students, curricula, school, materials, infrastructure, funds, parents, syndicate, society, and government, must work in an integral and harmonious way towards the new methods of learning in the classroom. We start with the assumption that school practices greatly determine the quality of a student's learning. Therefore, we must leave behind the methods and procedures currently applied in our country: the teacher explaining vertically, with the aid of books, a big amount of information, like facts, dates, or formulas, which the student must learn by heart but not necessarily understand or appreciate.

The pedagogical basis of the model implies a deep transformation in the relation teacher-student. The teacher stops transmitting what must be learned and becomes an enhancer, an intermediary between student and knowledge, a guide who walks with the student through the fascinating path of the task of building his own knowledge. It is a new approach to interacting and processing, that requires collaboration and demands a systematic effort to clarify questions, for which it is necessary to acquire the habit of conducting inquiry and research, of relating and proving the worth of the findings which are the building blocks of this knowledge under construction. Success on this aspect will prepare the student for the requirements of the 21st century, allowing him to acquire scientific knowledge and, especially, enhancing the formation of human beings who are freer and better prepared for life, following the route of true awareness. In this kind of work, the student leaves behind the passive posture of waiting for information to be delivered in small chunks, worn out by repetition. Instead of this boring passivity, the student will activate the springs that stir up understanding through a variety of processes, allowing him to know the substance of reality and the way it behaves in its myriad of manifestations. During these practices demanding the mind to be alert, memorization becomes meaningful as a necessary part in the process of building knowledge. By learning in such a way, from the awareness awakened by the method, the student is truly learning to learn, so school becomes closer and more friendly, providing the satisfaction resulting from discovery, and rewarding effort with a sensation of wonder.

It is evident that, with these educational practices, students do not only acquire important information or store knowledge, but also develop a learning method, strengthen the muscles necessary for understanding, enhance their creative capacity, develop an always alert attitude which will conduct them to become autonomous and explore the reach of their capabilities. Human beings who are freer and better structured, who are not easily contented with answers they cannot prove by themselves, who do not expect to receive, since they will have learned the importance of activating their own abilities to get what they need. Similarity, they will not obey blindly because they will have learned to question themselves and others; they will have conducted the necessary practices allowing them to obtain a well-trained mind which can discern, decide, and act accordingly.

It is important to remark that it is not the first time these methods of learning and teaching will be applied in our country. Several schools, both public and private, have implemented them, making it easy to picture how great it would be for Mexico the generalization of this educational practices in all institutions responsible for the raising of children and young people. Reality will be very different when most Mexicans have a formation allowing them to use their full potential for their own well-being, as well as for that of their family and society.

As could be expected, several people have insisted in the importance of the role of teachers to reach these goals. It is perfectly understandable to doubt if the previous

formation and preparation of teachers will allow them to assume the appropriate functions for such pedagogical model. Active teachers did not receive a preparation compatible with this kind of learning, and even the formation currently imparted at teacher training colleges does not follow such pedagogy. Therefore, it is extremely important to undertake as soon as possible the great organizational effort leading to the appropriate change. Teacher training colleges must be updated, in order to provide an adequate formation to the people who will soon be in charge of a classroom. Most of the people who work in the formation of those who will work in the formation of children, in addition to the weaknesses they may have in their own area of specialization, do not apply in practice these educational methods. However, some of them have an innate vocation and have been constantly updating themselves; they may be fundamental pillars supporting and leading this transformation.

Regarding active teachers, it is easy to picture the high degree of difficulty of modifying principles and practices for over 1,200,000 individuals. In spite of the magnitude of the challenge, this is an unavoidable task, for which we must consider the diversity in abilities and knowledge of all teachers who will actually apply this new pedagogical model. Therefore, the formative strategy to be followed must address the huge variety of needs arising from a teaching corps with an enormous diversity regarding origin, profile, and context, which reflects the reality of our country. That is why the strength of the method will relay on its flexibility, allowing it to be adapted to each region, school, and teacher. This will be the greatest challenge of the new pedagogy, as well as of the whole pedagogical reform, but we must ascertain that the educational system is able to take it over. In addition to the political support which has allowed us to reach this far, we must consider all that has been learned by the educational system in order to be prepared for this unavoidable trip. A model positioning the school as a central element, recognizing its capacity to operate and its relative freedom regarding curriculum, as well as a new approach to school supervision, the creation of school technical councils and a system of technical assistance, are highly valuable elements when considering the capacity of teachers to take over this new challenge. It is not only to implement a wide offer of new subjects, but to clearly identify key concepts and start a dynamic involving both curricular needs and the exercise of the new pedagogical and didactic practices, based on the principle of learning to learn, stimulation of learning, and the building of relevant knowledge through cooperation. It is related with the effort of the teacher to reflect on his own teaching practice and on the way his students learn. As Pablo Latapí put it, "to be able to go beyond singular aspects in order to train oneself in the path of doubt". The practice of dialogue and peer-to-peer learning will allow to implement in our environment the idea of John Hattie: To build the attributes of teachers organized in professional communities, which analyze and reflect on the teaching practice, in order to become true intermediaries between knowledge and students.

The construction of good and varied examples will enhance schools to learn from other schools, and teachers to learn from other teachers. It is possible and necessary to take maximum advantage of technological platforms which allow to accelerate the multiplication of what is desirable. It is evident that all this demands the continuity of the organizational efforts that Secretaría de Educación Pública has been working in during these last years.

I must point out the energy and strategy which will be needed so that the government keeps on considering education its highest and most precious priority in the years to come.

To finish, I would like to remember a saying by the extraordinary thinker Baltasar Gracián, which allows us to appreciate both the antiquity and the strength of the principle of educating for life. Gracián said: "Knowledge is so long and life is so short, and to live we must know".

Thank you very much.*

** Transcription*

Jorge Iván Ríos Rivera

Ministry of Education. Medellín. Colombia.

Good morning, everyone. Distinguished professor and responsible of education since a long time ago, Dr. Miguel Limón, it is a pleasure for me to share this panel with you.

To begin with, I want to tell you that I am deeply moved by being on this land. It is the first time I touch this soil, but I have already walked through the lines of Octavio Paz.

I would like to answer the main question of this panel with six precise points, as well as share with you part of what is done in the city where I live.

The first step we should take, we are determined to take, and work towards it every day with our teachers since two years ago, when we started to work at the government, is to identify the three teleological directions humanity has followed in education. We believe that teachers should not be scolded or punished, but they should instead be taken care of and be given appropriate tools. And among these tools are concepts, since *a teacher without concepts is more dangerous than a razor blade at the neck.* A teacher without concepts is left wandering astray.

The three teleological directions are: to educate for perfection, to educate for adaptation, and to educate for contingency. Now I will explain these ideas. To educate for perfection is an educational model based on virtue. To educate for adaptation is based on industrialization. To educate for contingency, for the world none of us were prepared for at school, but is the one we live in. Therefore, we can still find in the classrooms some teachers who are anchored in virtue, the virtue of educating for perfection, of educating for the able, of exercising the difference between able and unable in the classroom, and I believe that would not be beneficial for the educational subject of today. Then, to educate for contingency is the great challenge, which involves a fundamental aspect: we teachers must unlearn many things, we must understand the time in which we are educating, and we must talk more deeply about what we must unlearn. There cannot be quality education, or education with quality, or education for quality, or quality in education unless we unlearn the teleological ideas in which we were engulfed. We probably were convinced of those ideas when studying to become teachers; we probably were educated to fit into an industrialized society, and maybe as students we filled all expectations, but today as teachers we must be aware of our current reality.

The first indication to all teachers in our city is to educate for contingency, for what is random, for the uncertain, for the world of connections, for a reality we cannot see and we have not yet understood. It is a process of understanding, of getting to know the society we live in; we live in the society of information and knowledge, but have not been able to understand that it itself gives shape to the society of risk. Quoting Niklas Luhmann in *Society of Risk*: What are the consequences of living in the society at risk? Why are we more abandoned? Why are we more fearful? Why are we more restrained? Why is it so difficult to reinvent ourselves in the middle of so much crisis and vulnerability? A teacher trapped in a region under siege by organized crime; for example, in my country and in my city, which is making great changes regarding education, teachers often have spaces where they can talk about fear, about loneliness, and that is why I am happy that school has been given again a central role. During the 90s the school was moved to the outskirts of the educational model, in the 21st century, with so much intelligence, it must be brought back to the center again.

I was just now telling somebody, "I am so happy to have come to Mexico, so when I go back to my country I can tell them that here the school has been given again a central role!" During the 90s, the school was set aside, it was cornered and forgotten, and the teacher along with it. Therefore we can say that here we acknowledge the school being rendered central again due to a humane approach. When we consider contingency, when we consider the fact that the teacher takes distance from such specific adaptation, from such notion of a stable, permanent, modern project, and takes a step towards contemporary times, managing to understand that work is now organized in paths and has to do both with uncertainty and with randomness, who among us can calculate the necessary funds? The condition of being a teacher becomes more flexible, it is incorporated in language and in a more fluent conversation, which is lighter, more diverse, and more precise from a human point of view. We believe that a conversation between different generations is only possible with the high degree of comprehension that at school human matters take place, since such conversation can only exist between human beings. We should remember Montaigne who, in the 18th century, already talked about pedantic attitudes from teachers, who mount on high horses, so to speak, rendering thus impossible conversation with young people. Now we live in the 21st century! But many are still in the same position and have not been able to establish the link between conversation and education. We must talk about all aspects of life, since it is important to teach children to not allow anyone to touch them or take advantage of them. All this must be explained at school, and that is science too. In Medellín we are accomplishing this task through a program called *Escuela: entorno protector* (School, Protective Environment).

We live in a very beautiful city, with 2,700,000 inhabitants according to the census, but with a real population of around 3,000,000. Therefore,

in the classroom we have to talk about what happens to us, and to turn that into science. Only when the teacher opens the possibility of talking about life, of talking about what happens in the city, it may be stated that we are truly working towards quality education, since quality in this context means to have a pleasant experience at school, which is the second task. Life at school must be enjoyable, and that can only happen if the children are able to talk about what happens to them.

Now I will mention six tasks which are responsibility of the teachers in my city:

1) To diminish the rate of child sexual abuse.
2) To diminish the rate of pregnancy in teenagers. In the city where I live, where we give our whole life for everything, from the mayor Federico Gutiérrez and my secretary Luis Guillermo Patiño, a teacher focused in the defense of human rights, all the way through we all who work from the other side in these issues, our priority is to diminish the rate: 6000 minors under age 14 in a city of 3 million inhabitants. We can see pregnant girls of age 12, so the question is, do you believe that schools must work into transforming such a reality? And the answer is "yes", because science must be just a branch of humanities. As Nelson Goldman states in *On the Mind, the Brain, and Other Matters*, science as a branch of humanities walks along with our children, asking itself questions regarding the underlying fundamental problems.
3) To diminish the hiring by dangerous organizations.
4) To reduce the use of psychoactive substances.
5) To diminish bullying and harassment at school.
6) To diminish violence among teachers, between students and teachers, and between administrative staff and teachers.

Then we had to make a decision, and we opted to take everyday events to science, as well as science to everyday events. How do we manage to do it? Well, 135 educational institutions out of 228 have teaching in problematic conditions as a central part of their pedagogical model, as well as research in the classroom, ABP, answering to questions, and that is what we call *STEM+H Territory*: Science, Technology, Engineering, Mathematics + "H", and this "H" includes literature, art, and narrations.

I would like to talk about a particular case: There is a neighborhood in the outskirts of the city, called Calasania, which is receiving the greatest number of people who have left FARC and reintegrated into society. The school in that neighborhood is called Olaya Herrera. There, girls of African origin were beaten and harassed because they use a particular hairstyle, requiring hours to be made with the help of their families, but when they reached school other students would undo the hairstyle and mock them. So, for those girls the greatest problem was not to learn, let us say, the cardinal directions, but to avoid being beaten and to preserve their hairstyles. Then the question for research in the classroom was: Which is the influence, or the role, of the hairstyle of African origin in school life? They discovered that it was necessary to teach the other students that it was not just a hairstyle, but the history of such people told with tresses, a narrative coming from the hair. In this way, when we take the decision to bring science to life, and life to science, I believe we are creating a path towards quality.

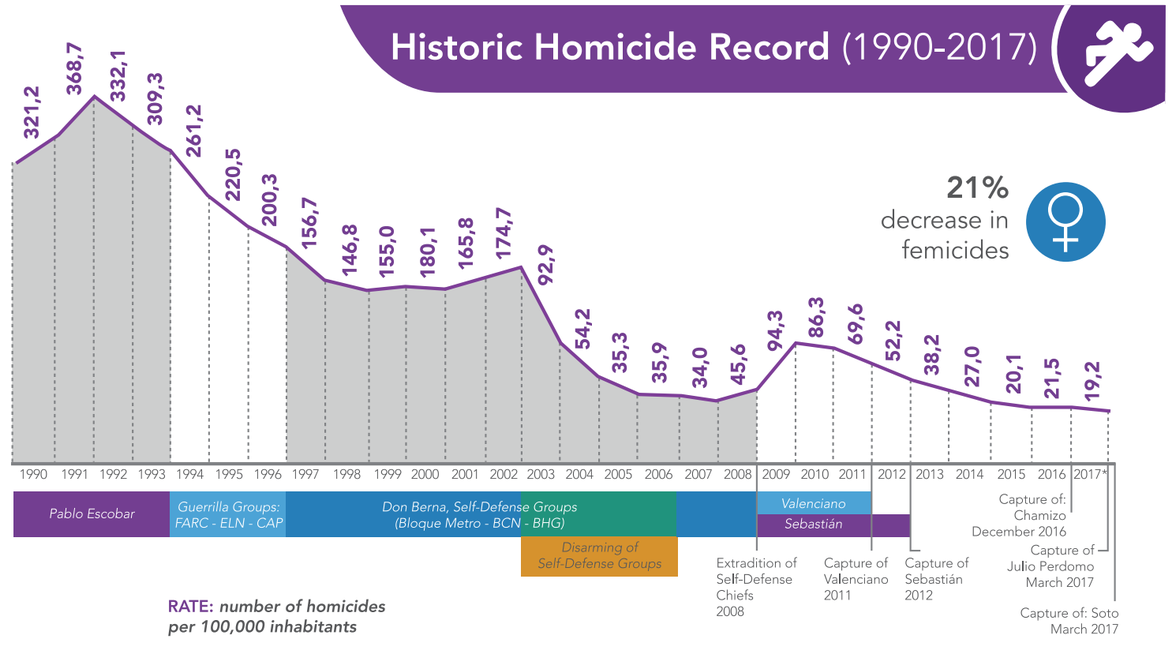
The fourth task is to state and believe in the direct connection between school environment and intellectual development. We believe that school environment is directly proportional to intellectual development, and that it is not possible to learn science if we do not work on a qualitative improvement of school environment at every level. For such reason, we started the program *Entorno protector*, with a psychologist in every school, as well as a group of artists with a program called *Mirarte* (To Look at You), the power of the symbol within the school.

The fifth task. Please take a look at the figure, so that you can understand a little bit the environment I am talking about, and why to talk about quality is to talk about life.

This is the historic homicide record from 1990 till 2017. In a city where, between 1989 and 1996, as many as 196 teachers were killed by their own students, the main problem was life. Take a look at the homicide rate when, 12 years ago, the city decided to give a central role to education; what it was actually doing was to give a central role to life, to take science to life, as well as life to science.

The sixth task is to recognize the worth and to give support to the teacher who is pedagogically bold. We believe in pedagogically bold teachers. We asked all teachers, "how will you teach in a country that has just signed a peace agreement? Will you keep on teaching as you have been doing it up to now? If you say 'yes', then you have a problem, because if you do not know thoroughly agreement pedagogies, then you do not belong to a country which has just signed a peace agreement." Even if half of them said "no", because half of my country's population said "no"! So, I should be ashamed of their behavior, but instead I work every day so that my city and my country, through school and through teachers, may understand that we are building peace together, a culture of peace, agreement pedagogies. We are not a society living after the conflict, because for us the conflict is latent, it can be found when we turn the next corner; conflict cannot disappear because we need it, and if we get rid of it then school would become meaningless in humane terms.

Therefore, it is important to acknowledge the value of pedagogically bold teachers, who in my city are all those working in the outskirts. There are less opportunities in the outskirts, mostly



because access is difficult, since slopes range between 45° and 55°. We recover and register all experiences where the teachers invent once and again new ways of life, of staying and connecting, similar to the way Italo Calvino does it in *Cosmicomics*, on the relation between the equation of the hypotenuse and the writing of a tale, literary creations, science, gastronomy, and art, directed towards coexistence. One of the craziest projects involves bicycles, small carts, and the culture of peace. That is, we reach our goals by mixing several elements, so we decided to found an Innovation Center for teachers. We are the only city in our country with such a center, where pedagogically bold teachers may formalize their proposals from a scientific ground, based on the knowledge coming from pedagogy, sociology, and other related areas.

Moreover, school and city must be connected. Our city started, 12 years ago, to build parks and museums. In this regard Mexico is way ahead and, in fact, I believe we learned it from you. Just now I walked four blocks and I was already lost, because there are so many things around. This country gave culture a central role and that is very beautiful.

Today, our city is full of scientific parks, like *Explora*, as well as library-parks, so our greatest task is to build a single circuit connecting school, *Explora park*, library-parks, and *life unities*, linking them all. In this way, we bring quality to that integration of educational and scholarly matters. According to our view, education and school are not the same, because education is inherent to the human species and its culture, while the school, a great invention of modernity, has to work a lot to insert itself functionally into such mechanism. Therefore, from the approach of the couple education-school, the city becomes the best ground for our work. And I am not talking only about Medellín City, but including other cities of the world too, because our students (120 children from the outskirts) went in 2017 to foreign countries with special projects involving robotics and nanotechnology, to tell other cities what is being done. That is why I talk about other cities in addition to Medellín City. We believe that getting to know other cities broadens the views and enhances the potential of our children.

This is, then, the task we must accomplish regarding the first question.*

** Transcription*

Comments
REFLECTIONS
Answers & Questions
ANALYSIS

Panel İ. How does quality education privilege the development of people?

- **How does quality education contribute to developing the potential and capabilities of individuals in a global society?**
- **What do we have to give priority to in children education for them to be successful in society?**
- **How do good schools work?**

Leonardo Kourchenko
Jorge Iván, you touch very sensitive points for Mexican people, since we have a lot of regions and communities heavily suffering from violence. Both in the north and the south of the country, we have many cities and areas living in a climate of violence every day. Therefore, this education for equity, for the culture of non-violence, *education for peace*, is extremely important for us.

You mentioned something I found fundamental when you talked about unlearning what we have learned. In Mexico, we are applying a powerful program for the preparation and formation of teachers, encouraging them to live the new model and to learn again what they had previously learned.

Miguel Limón Rojas
I feel very near to what Prof. Jorge Iván said, and I definitely agree with him. This conference shows the enormous power of communication, the extraordinary importance of learning from others, because each person, as a human being, lives in a unique way; each of us experiences things differently, so this interchange is quite meaningful. This strengthens the idea of learning while learning. Teachers will unlearn whatever is necessary and learn what is new, as well as exercise the new way of learning, much more challenging and requiring more work because it is more creative and needs a greater effort. This concept is so powerful that I consider it to be in the center of the construction of the human being we need to form.

To the words of Prof. Jorge Iván I would like to add something implicit in several of his sentences, and present as well in the new curriculum. This is about socio-emotional education, related with a great principle we inherited from classical Greece. During that time, before being admitted in any learning center, people had to read the sentence *know yourself*. This has to do with the world of emotions. If we do not understand the substance of emotions and the way in which they behave, they take control over us and we become their prisoners. Prisoners of our impulses, of our cultural complexes, of our own irrationality. Therefore, self-knowledge helps us develop the capability to regulate ourselves, the capability of being empathic, that is, to be able to consider what others are experiencing and feeling, in order to understand their behavior. This exercise that makes the mind approach the heart, and consider the buzz of the liver, can help us have a better behavior as human beings.

Prof. Jorge Iván exposed a very beautiful idea regarding how the school, after peace has been signed, must not be an after-war school. It must be a school abhorring violence, so that it will not be repeated, it must abhor abuse and impunity, which are the great enemies of a harmonious social life. The school must encourage understanding, comprehension, dialogue, and discussion. We are still a highly dogmatic society. We switched from middle age dogmas to 19th century dogmas, but we have not stopped being dogmatic. This disposition to accept what is vertically imposed on us is exactly what must be transformed through our educational effort, through dialogue, and through continuous learning.

Jorge Iván Ríos Rivera
The words of Dr. Miguel made me remember that last Sunday I was present at the graduation of the first group of ex-militants from FARC, at Manrique, in the Colombian highlands. We do not call them "ex-militants" anymore, but "people reintegrated into society". Such graduation gave us a lot of hope. They finished fifth grade of primary school with an exposition, after following a special program for adults. A man of age 40 brought a miniature of a house to his exposition. It was very heavy, almost 10 kg. I asked him the reason to bring such a heavy object, and he answered: "The weight, because I want my formation to be this solid and strong". It made me remember the first chapter of Gaston de Bachelard[2] in "Daydreams": *The house as a being, the being as a house.*

At Medellin City we received around 3000 people who had been militants of FARC. We implemented a formation process for them, which has been going on for more than six months. Then the question arises, why are such people so happy? Is it due to scientific formation, humane formation, social formation, economic formation? My God, it has to do with all that together! There is a lot of hope in such process, and that is why STEM education must be applied in the whole territory.

All agreements resulting from this forum regarding scientific formation will be taken to our country. I claim to have come in search of a mission to be taken to the Center of Scientific Innovation at Medellín, so that all these reintegrated people may be educated, and their technical formation may be improved. The horizon of science and scientists is today closer that ever to human development, social development, and the development needed for a harmonious social life, in order to avoid violent conflict.

Leonardo Kourchenko
Several very interesting topics have arisen. If you agree, we will have a brief interchange of points of view before opening the forum for questions from teachers, academicians, and the general public present here today.

Regarding inquiry and curiosity. Miguel, what can you tell us about the new reform regarding science education? Are we transforming the old models and the old ways of teaching science, mathematics, and engineering into this new approach, this new model based on inquiry, this new model of creative thinking? Are we following the right path?

Miguel Limón Rojas
We are following such path, we are committed to it, we can learn from isolated experiences from schools in different areas. However, we need to do much more than that. A very positive aspect of the new Educational Model is the necessity to adapt learning to the vocational interests and the environment of the regions in which each school is placed, so that our efforts may yield better results

[2] Gaston de Bachelard (June 27, 1884-October 16, 1962) was a French philosopher focused in poetic theory and philosophy of science.

which are meaningful and significant for the students, which are related to their necessities and to their life.

To learn by doing is an aspect we must strengthen enormously. To accomplish that, we must go over traditions which have yielded few or no results, forcing school, teacher, and student so that the latter learns a lot of useless facts. For example, to know the names of the battles fought by Napoleon in Europe gives very little to the student. Well and good if we know it, but there are so many things which are more important than that. Learning must be linked to practice, must be brought back to what is useful. The student must know the value of the technology he is using, and must build scientific learning through the exercise of curiosity and research. This is only one point, but it is a fundamental one.

Leonardo Kourchenko
I agree with your point of view. I have always sustained that we did something wrong with science learning in our Mexican Educational System, so that we took away curiosity from the children. Science learning took the form of presenting formulas to solve problems, instead of, as Angela mentioned, just pose the question and generate a process of research and reflection in the classroom. This is what you were talking about at the beginning, to let the student build his own knowledge. Instead, we just focused in finding the answer, in getting the result by applying a formula. In such a way we killed the curiosity of the students. I do not know what kind of experiences you have had in Colombia. Jorge Iván, could you briefly tell us how is science education in Medellín?

Jorge Iván Ríos Rivera
Well, for two years we have been learning from significant experiences of teachers of science, technology, and humanities. We were very pleased to discover that teachers have adapted quite well the principle of David Parkins, the pedagogy of understanding, according to which knowledge must be related to life. Then one of the characteristics of the 135 educational institutions is that they apply inquiry in the classroom related to everyday problems, and this is fundamental. I am not sure to be explaining clearly our approach. We know that our city has several difficulties and that the educational approach of STEM+H territory will allow us to reorganize classroom practices. We recognized 135 institutions which will be certified. Teachers will keep on working on their own formation, and students will have economical support for their projects. We state a situation and we encourage to apply the scientific method to it. Problem, question, framework, inquiry question. In the same classroom, children of ages 9, 10, and 11 work with youths of 8th and 9th grades, of ages 14 and 15, under the guidance of a teacher who studies a master degree with economical support from the government, and whose thesis is related with encouraging such kind of practices.

Leonardo Kourchenko
How does a good school work? How would it be an example of a school with all these characteristics we have been mentioning, with learning to learn, with the new role of the teacher, with the building of knowledge in the classroom, with an active student who does not act as a mere container of knowledge? Considering all this, how is a good school?

Angela Fitzgerald
Thanks. I think just briefly in response, I think we need to be telling the good news stories we need to be telling what's happening out there. But I get concerned about scale, we have a lot of individual things happening but how do we bring all that across regions, countries, societies? We need to start somewhere but I think that it is a bigger picture that we need to be working towards as well.

Miguel Limón Rojas
To begin with, at a good school there is a series of rules which are observed: teaching staff is complete; the principal applies a pedagogical and moral leadership, and has the leadership capability to coordinate everyone properly; teachers attend all their lessons, use their time in the classroom in the best way possible, and keep alive the observance of the fundamental values which allow a harmonious social life. For me, the basic and most important value is respect. By being respectful we can accomplish a lot of things, but without respect all our efforts will be wasted. The collaboration principle must be active, the capability of organization which allows the student to have the highest expectations of himself, in such a way that the teacher, the school environment, and the curriculum allow him and encourage him to attain such expectations. Regarding diversity, the school must have the capability of individualization, so that everyone may fit in and there is no discrimination. It is also necessary a spirit of collaboration which allows those learning faster to work with those having more difficulties and requiring some support in order to go forward. That is, it is not enough for the right to education to be a formality allowing everyone to go to school, but the obstacles to learning inside the school must also be superseded.

Jorge Iván Ríos Rivera
This question is very beautiful because it allows an extremely organized answer. I will mention four basic aspects:

1) Formation based on the experience of the teacher. We believe that we cannot go forward without this specific change. For us, the formation of teachers is an exercise on transformation, that this, to move in a direction proper to science, society, and ethics. That is why we stopped the lectures for teachers. At *Centro de Innovación del Maestro* (Center Of Innovation For Teachers) we have a "kitchen" where we will work in a certain "gastronomy", not to cook actual dishes but to encourage the reflection on how much we actually know regarding science applied to real environments and everyday life situations. It is an excuse for conversation, a place where teachers will have formative experiences. Therefore, the model of formation for teachers has changed, as we switched from lectures, talks, and courses to formative experiences. Later this formation model is put into practice in the classroom as well.

2) Another important aspect is, as Dr. Miguel Limón mentioned, to insist once and again in socio-affective capabilities. The new school must follow this approach. Why do we learn at school? Why do we work on science at school? In brief, why do we go to school? To live better, to feel better! Who with? With ourselves and with others.

3) Without the participation of parents, the city cannot move forward. We must diminish the cognitive, cultural, and affective gap between parents and school. We must invest so that parents support school. As stated in the report by UNESCO, parents are too far away because the school expelled them from the classroom, and they do not have any more the necessary "code" to participate in such an environment. Therefore, it is fundamental to incorporate parents again to the school. I ask you to read the report by UNESCO from last year.

4) We must work on improving school environment. For us, school environment is directly proportional to intellectual development, and we all want school to help students develop their cognitive abilities. School environment must be a learning environment.

QUESTIONS FROM THE AUDIENCE

Member of the public

There is a specific part of Mexican population without access to education. I am talking about native people, children of country workers, and immigrants. The government has taken some measures to address the issue, but it has not been enough. The question for Dr. Limón is, what must we do to work urgently on a solution to this problem?

Member of the public

Teachers working currently were not prepared in the humane aspect or in resiliency. Which steps is the government taking regarding this issue? How could we "unlearn" and be strengthened as teachers?

Angela Fitzgerald

Thank you for those great questions. Question one with issues around literacy. I guess in Australia we have been working and seeing science as a vehicle to increase literacy and in fact you can engage with science without having to be tied down to the written word and also science gives children and young people something to write about. So, it's not a fantastic answer, but we do see science as something that helps improve literacy skills.

The third question about resilience and what the Australian government is doing, look, we're in very early stages of trying to make sense on how to develop those skills. Some of the things we are doing, and this have been mentioned a lot this morning, about social and emotional programs so we can help students to understand themselves and to be more aware of others a swell. So, we do have particular national programs and they are started to be implemented in schools, but we have a long way to go there. It's a big issue and it's something that has to be improved. Because we are findings, and it's the same in Mexico, that our young people are anxious, there are high rates of depression, they are not resilient, what is this about? and this is something that is a societal issue and have to keep working on it for some time.

Miguel Limón Rojas

Regarding inequality, I do believe it is very important that the educational system puts the value of fairness at the center, that is, the issue of inequality must be a main priority instead of a mere subject of isolated programs and actions, even if those may be quite meaningful in certain cases, when the methods applied are adequate. However, fairness in education is fundamental, since otherwise education itself will reflect inequality, which represents a major problem.

I believe the notion of inclusion and the actions taken to reach it are fundamental. Law establishes that education is a universal right, but such right is not fulfilled by the mere admission of everyone at school. The educational system must breach all obstacles to equality, so that all students may have the highest expectations at school, the best possible learnings according to the capabilities of each student, and we must still work a lot to achieve that. This notion of inclusive education, which we took from UNESCO, is truly powerful. To assume that in the educational process there are people with disabilities who must be acknowledged as much as any other student, as well as native people, immigrants, children of country workers, and people in situations of risk. That is, school should address the topics of expulsion and desertion, identifying students at risk and taking action to keep them as part of the school community. However, as everything regarding education, this will be built progressively, there is no other way.

Jorge Iván Ríos Rivera

Regarding the first question, that would probably be for us the aspect requiring more urgent attention. The idea is not to take children with different capabilities to school to be treated exactly as the others by teachers. The idea is for the school to learn from those children and to accomplish a transformation on that regard. This is a paradigmatic change which Armstrong addressed in his text *Neurodiversity*. This researcher stated that the issue is much more complex than simply managing that all native children attend school. In Colombia, we have several different groups, like native, those of African origin, and several others. So here the question is, what are they teaching us? Instead of, what can we teach them? In Medellín City there are 13,000 children with some disability, and that is only one of nine special minority groups of population, and in each case we ask ourselves, what are they teaching us? That can give us a hint of which transformations are most important at school.

I make an open invitation to all of you to read the text by Armstrong called *Neurodiversity*, where the main question is not what do we teach them, but what do they teach us. As an example, let us consider a person with autism who finishes high-school but is not accepted at the university. Then we wonder, what do we need to learn from them, to be able to free ourselves from the rigid frame of the institutions? Because otherwise, being honest, we are not really trying to be inclusive, but only pretending to try.

PANEL ii

A scientific education for the development and commitment of individuals with their society

Keynote Speaker. Roberto Martínez Yllescas
Panellists. Héctor Escobar Salazar / Salvador Jara Guerrero / Miguel Rubio Godoy
Moderator. José Luis Fernández Zayas

Roberto Martínez Yllescas

Organisation for Economic Co-operation and Development (OECD)
for Mexico and Latin America

DEVELOPMENT OF CAPABILITIES AS THE BASIS FOR SCIENTIFIC LEARNING IN THE 21ST CENTURY

Nowadays, science plays a fundamental role in countless decisions of our everyday life, from medication and the proper way to have a healthy and balanced nutrition, to the evaluation of the consequences of acquiring a given vehicle, which emits polluting material at a certain rate. Therefore, the scope of science is not limited to test tubes and the periodic table. Currently, science is present in all machines we use and in most of the solutions to our practical problems, from a can opener to the information rendered by satellites. Following this approach, science must not be a field restricted to professional scientists, but part of the knowledge we all apply to have a better every-day life.

In the current context, of an ever-changing reality and an incredible flow of information, every citizen must be able to think "as a scientist", that is, to evaluate data rigorously and to draw conclusions from such analysis; to understand that scientific knowledge is not an immutable truth, but is constantly updated according to new discoveries and new interpretations, as humanity understands a little better the laws of nature, as well as the capabilities and limitations of technology.

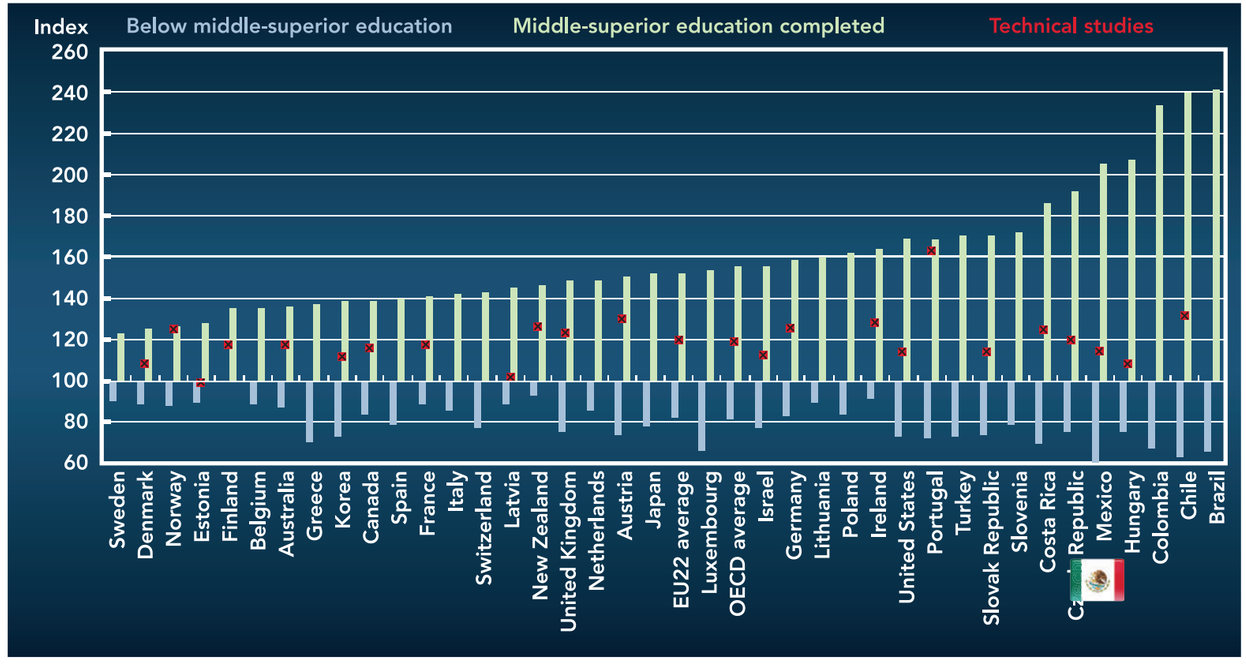


Figure 1. Relative income of adults with full-time jobs according to their maximum educational level (2014). Middle-superior education = 100

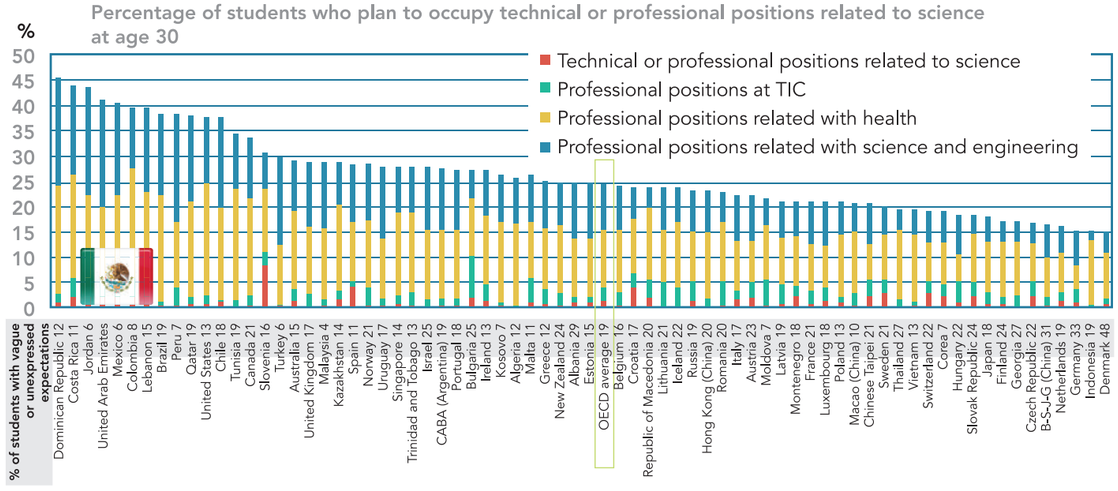
This approach, that all students must acquire scientific capabilities, is very different than traditional education regarding the teaching of science. That is especially remarkable in middle-superior education, where the traditional model focuses the teaching of science to a reduced number of students who plan to undertake scientific superior studies, instead of opening the opportunity to all pupils of getting to know and experiment with science and related questions.

Knowledge of science and technology, being the second based on the first, is not only necessary for people who use it in their professional life, but for every citizen interested in making informed decisions regarding the several controverted topics subject to debate today, from having a healthy diet to managing the refuse of a big city, ponder costs and benefits of genetically modified products, or mitigate the catastrophic consequences of global warming. Science is always present in our lives.

The results of PISA tests, applied by OECD in 2015, focused mainly on scientific capabilities, leaving reading comprehension and mathematical reasoning as secondary subjects. PISA defines "scientific capabilities" as the ability of the students to manage scientific problems, including the ability of making decisions in science-related topics. A person having such capabilities is able to reason regarding scientific and technological questions, to decide and evaluate experiments and research models, as well as to interpret scientifically data and evidence. According to PISA, a basic knowledge of science is an ability needed to establish a pertinent and reasoned dialogue regarding science-related topics. Scientific capabilities depend both on the appropriate knowledge and on the attitudes towards science.

To have a good performance regarding the learning of science is not only important for those who plan to develop a professional carrier in related topics. Any student who learns how to "think like a scientist" is capable of distinguishing between objective evidence and mere speculation, as well as to understand that science does not produce absolute and unquestionable truths.

Students who plan to undertake scientific superior studies



Now I will present some significant results.
The first relevant result is to be aware that what people know, and what they can do with such knowledge, has a major effect in their lives. Highly qualified adults have twice the probability to have a stable job, and almost three times as much the probability of earning a high salary, than less qualified ones. In short, to have but few capabilities severely limits the access to more gratifying and better paid jobs.

On the other hand, highly qualified workers are usually more participative regarding volunteering, since they consider themselves as belonging to a society in constant change, instead of only being part of a political process. This means that people with better capabilities have a higher tendency to trust others and to participate actively in community and civic life. Therefore, trust is not only related with patterns of behavior or with the people around us, but depends as well on our own capabilities. This suggests that trust and the sense of community may be strengthened by granting every citizen the capabilities needed to improve their life standards.

In seven of the eight Latin American countries participating in PISA test, between one-third and two-thirds of the students do not reach the minimum level of basic capabilities in science (level 2). In Dominican Republic, more than 80% of the students are in such situation. In contrast, only around 20% of the students from countries belonging to OECD have a scientific performance below level 2. At this minimum acceptable, students are able to address basic scientific contents and procedures in order to identify an appropriate explanation, interpret data, and understand the purpose of a simple scientific experiment. All students should obtain level 2 of capabilities when they finish mandatory education.

Each edition of the PISA test puts the emphasis in either science, mathematics, or reading comprehension. It is focused in the corresponding area, while the other two are considered secondary and complementary. The emphasis was put in science both in 2006 and 2015, so those are the tests to be considered when making a comparison over time. On the average, there were no significant changes overall during those nine years, although some countries improved remarkably, like Colombia, Israel, and Portugal, while the performance of some others decreased, as is the case of Finland, Slovenia, Greece, and New Zealand.

The commitment and interest of students in their own performance and results is mainly a consequence of two factors: One of them is their own perception regarding capabilities and interests on what is most beneficial for themselves; the other one has to do with their perception of the importance, usefulness, and joy related with scientific activities. Around 25% of all students involved picture themselves working in topics related to science, and following a scientific professional career. Naturally, interest and desire to follow a science-related professional career has to do with the presence of the appropriate capabilities. Therefore, only 13% of the students ranking below level 2 in the test have interest for a scientific professional career, while the same is true for 40% of those having the best results (above level 5 of the test).

Education for everyone is a necessary condition for a system granting quality education. In most countries with results above OCDE average, more than 80% of the population of age 15 attends school, which reflects a high proportion of school attendance overall. The countries obtaining better results have, in addition to a high academic level, a high percentage of school attendance and a low proportion of students presenting a poor performance. However, both attendance and results vary significantly according to socioeconomic level, to the point that 13% of the variation regarding performance may be due to such factor. Correlation between socioeconomic level and performance diminishes as the results of the country get higher than OECD average. Therefore, students having a high socioeconomic position get better results in the test, in the average. In conclusion, the material conditions of the everyday life of students have an important effect on their performance at school.

The importance of a home without socioeconomic hardship is reflected as well in better expectations for students. Students under socioeconomic hardship have a higher probability of getting worse results than the minimum acceptable in science-related learning at school. Those poor results explain the lack of interest for such topics, as well as the low probability to follow a scientific professional career. The disadvantage is also explained based on the difference in material

resources to which the student has access. For example, students of a higher socioeconomic level have, in the average, 35 minutes more of science lessons each week at school, while a pupil under socioeconomic hardship has almost twice the probability of having to repeat a course. In the case of Mexico, socioeconomic status has become less predictive of a student's performance, while the overall result of the country has remained stable from 2006 to 2015, significantly below OECD average. Therefore, to improve expectations and increase interest for science, we must take care of socioeconomic status and promote public policies to improve it.

IMPLICATIONS REGARDING PUBLIC POLICIES

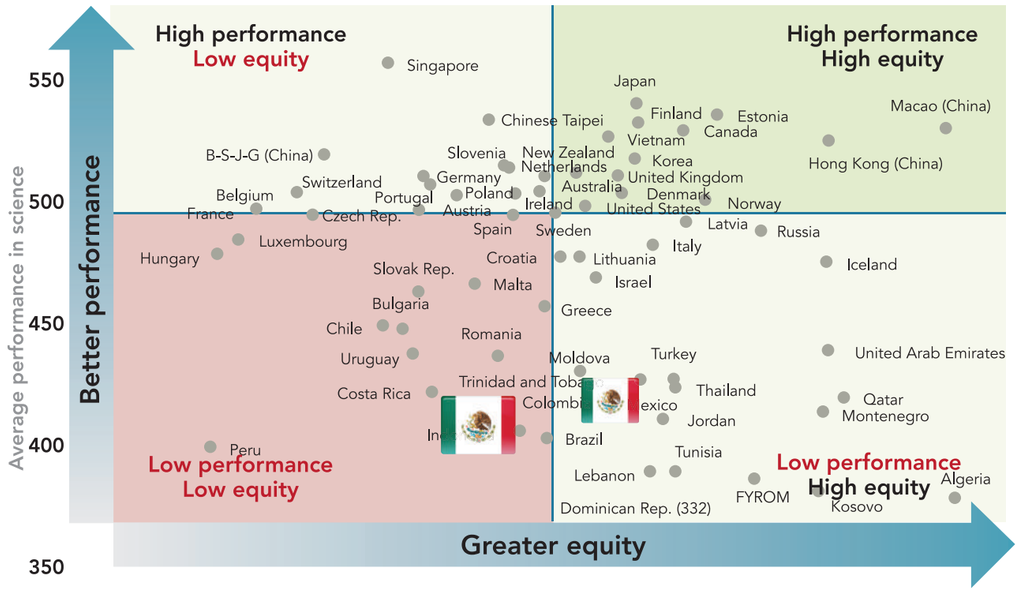
The implications regarding public policies shown by the results are quite significant. Results of the test show the interest and recognition that most students have for science. However, only a minority actually performs science-related activities. Gender differences regarding what is "appropriate" for men and women seem to be more accentuated in science-related topics that regarding general interests and abilities.

Changes related to technology and the labor market render more and more important every day to promote an inclusive and positive transformation regarding the way to teach science at schools. The path of science education must stop being considered as exclusive and reserved for those pursuing a professional career in science, to become a basis for new kinds of interest and satisfaction in life for everyone.

FINAL COMMENTS

Previously, when a small number of people with a good education were enough, it resulted efficient for governments to invest a lot of money to educate a reduced elite which would run the country. However, the social and economic cost of a low educational performance has increased significantly, so

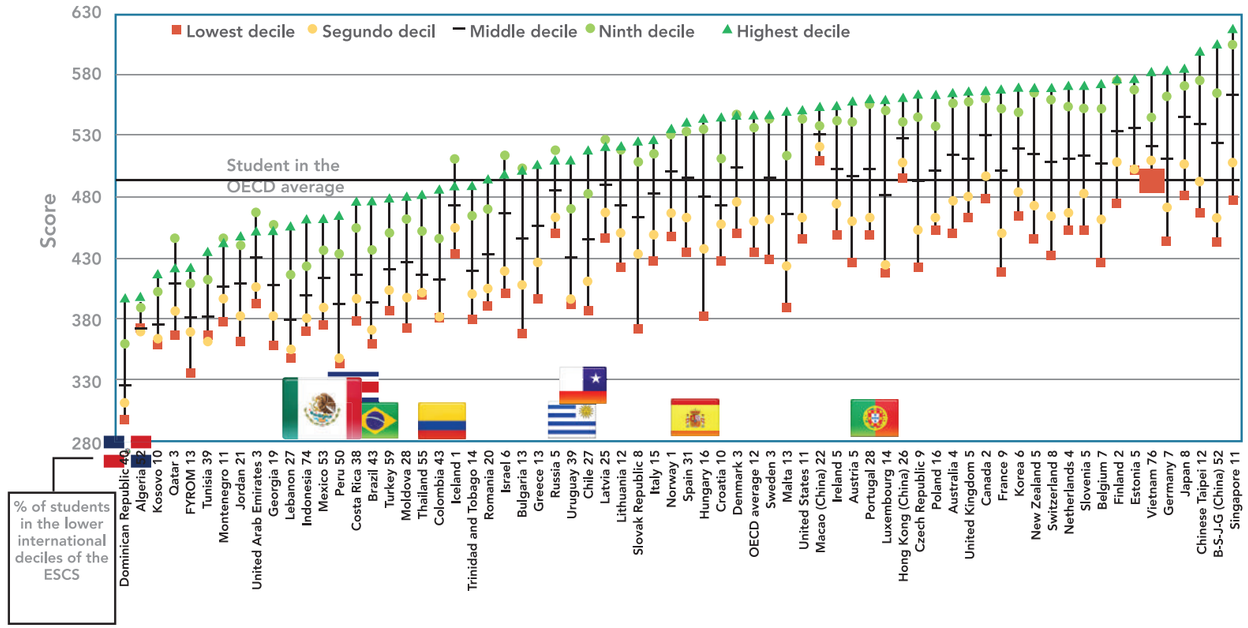
Performance in science versus equity in PISA (2015)



Mexico improved regarding equity from 2006 to 2015

Performance in science,

stated in international deciles of index for socioeconomic, social, and cultural status (ESCS) from PISA



today it is necessary for all young people to finish school having a solid basic formation, as well as the corresponding capabilities.

When it could be assumed that knowledge obtained at school was enough for a lifetime, education was centered in information and regular cognitive capabilities. Today we can get all the information from the Internet, and regular cognitive capabilities are digitalized and open to everyone. At the same time, the nature of available jobs changes at an accelerated rate, so education is today focused in preparing people to learn continuously, and to be able to perform complex tasks and reasoning which are still out of the scope of computers.

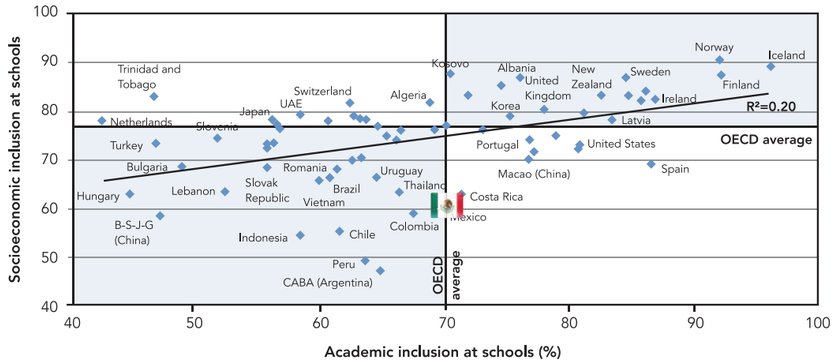
In old times, teachers frequently had studied only some years more than their pupils. Being the average preparation of teachers so low, educational authorities told them exactly what they should do and how to do it, using Taylorist methods of administrative control and surveillance, in order to get the desired results. Today the challenge lies in transforming education into a profession for highly qualified people.

However, such people would not like to work in a school organized following a Taylorist frame, with strict administrative control and surveillance, where their teaching efforts are subject to strict bureaucratic systems.

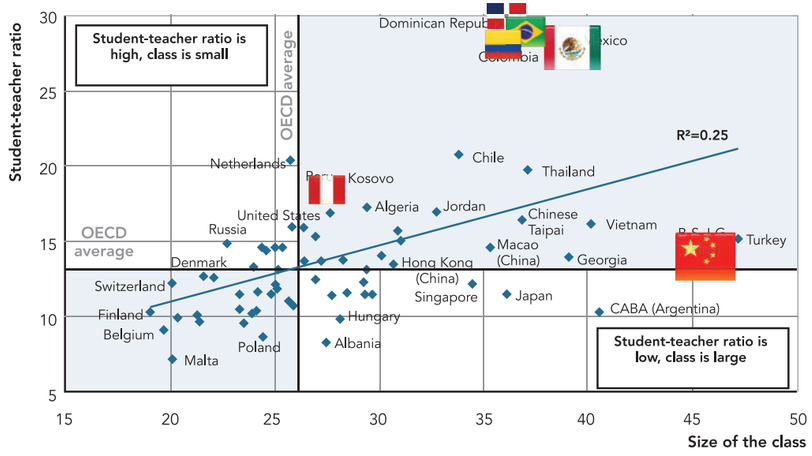
To cope the kind of staff they need, successful educational systems have transformed the organization of school work in a professional way, so that forms of control under professional organizational criteria complement traditional administrative and bureaucratic control frames.

Now I will summarize some important points in schematic form, useful to implement strategies and public policies oriented to the improvement of education, focused on the development of better capabilities for the assimilation of scientific knowledge:

Academic and social inclusion at schools



Student-teacher ratio versus size of the class



IMPLICATIONS REGARDING PUBLIC POLICIES

Commitment with universal performance

- Universal educational standards and personalization regarding the approach to the differences among students. Clear formulation of responsibilities on guaranteeing the success of students and everyone involved.

Resources assigned in a strategic and focused way

- Investment of resources where they make the biggest difference.
- Correspondence between resources and key challenges (for example, to bring the most talented teachers to the most difficult classes).
- Efficient budget decisions, giving priority to highly qualified teachers instead of small classes.

Support at school

- Attract, prepare, and keep highly qualified teachers and administrative personnel, as well as an organization that allows them to bring out their potential.
- Educational leadership and management of human resources at school.
- Manage to keep teaching as an attractive profession.
- Professional development in the whole educational system.

Governance, incentives, supervision, and knowledge management

- Correlation within incentives for all participants.

- For students

- Allow students to have incentives to attend more difficult courses.
- Increase incentives to strengthen the educational system.

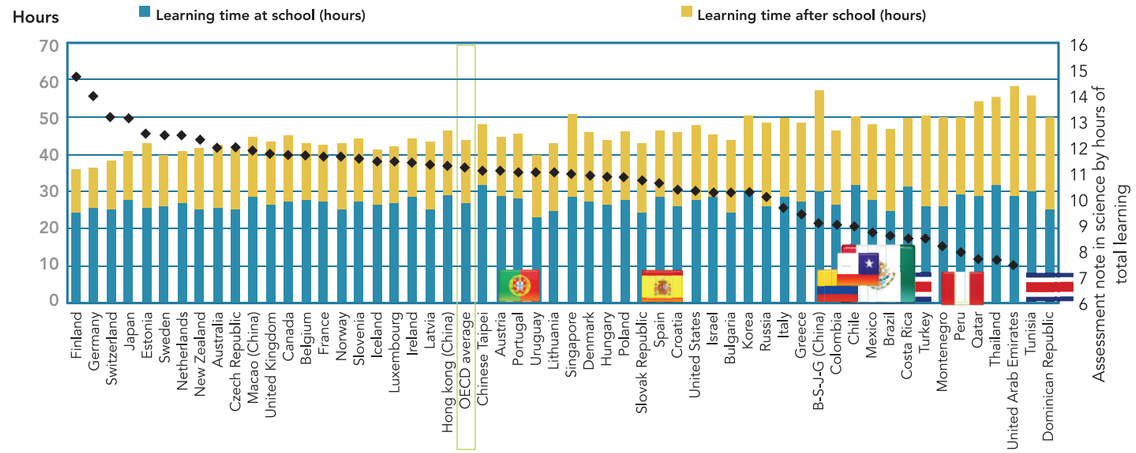
- For teachers

- Innovation regarding pedagogy and organization.
- Improvement of one's own performance, as well as that of their colleagues.
- Profit from opportunities of professional development leading to stronger pedagogical practices.
- Balance between vertical and horizontal surveillance.
- Efficient tools for managing and sharing knowledge, as well as spreading innovation: Communication within the system and with surrounding interested parts.

Coherence among public policies and practices

- Correlation of public policies regarding all aspects of the educational system.
- Coherence of public policies throughout long periods of time.
- Consistency when applying public policies and practices.
- Fidelity of application (without an excessive control).*

Learning time versus performance in science



* *Document for the Presentation*

Héctor Escobar Salazar

Secretary of Education of Tamaulipas State. Mexico.

Good afternoon. It is a pleasure for me to greet all panelists present. I am very happy to participate in this forum, in this historical building, and specially to share such participation with personalities who are so relevant in the fields of science and education.

To begin with, I would like to talk a little bit regarding the context of Tamaulipas, how we found its Secretaría de Educación (Ministry of Education) and the actions we are at present undertaking.

When we started working at Secretaría de Educación de Tamaulipas[3], our first action was to evaluate the whole institution. In general, the statistics of the state were not particularly encouraging, but something we noticed to be functioning well was the life-based science program that is applied along with INNOVEC[4]. It is very important for me to be here with you because, even though we believe to be doing a thorough effort, we still have to further strengthen this program. We must be able to reach the 43 municipalities conforming our state, the more than 5000 schools of basic education existing, in order to speak of equity in education.

Just now, Dr. Limón talked about the importance of bringing education into context for each region of the country. Therefore, it was fundamental for us to develop a document well adapted to the reality of our state. We were living under very special conditions, which had to be considered from every angle, but education was one of the best tools to reach society. Then we talked with the authorities of Secretaría de Educación Pública, who gave all their support to develop an appropriate document. A fundamental aspect for us was the restitution of the social fabric. How can we work on the restoration of the social fabric, which has suffered so much violence during so many years in our state? And how can we work with our children and youths towards such a goal, through education and science?

Therefore, we developed what we call Educational Method chapter Tamaulipas (MET, from its acronym in Spanish). We evaluated it with pedagogues, researchers, parents, and students. The document we built together addresses the main concerns of society, as well as the way to solve them through education and science. Since the school year 2017 we have started applying several programs and lines of action to help develop in our students both critical thinking and divergent thinking. It is important that our students are able to identify the aspects where technology is fundamental for the development of life itself. For that purpose, science education, and especially at the level of basic education, needs to enhance the development of abilities, attitudes, and values. A capital point is for our children and youths to learn how to identify reliable information sources, since today we can access in the Internet tons of content with no scientific basis. We want our students to be able to make this distinction when searching, organizing, selecting, and analyzing information.

We must work so that our students learn how to make decisions, since that is doubtlessly basic and fundamental in all aspects of life itself. So we have implemented several lines of action. Something that fills us with hope is to have started applying DIDE (Desarrollo Integral del Educando; Integral Development of the Student), where we selected 100 educational institutions which either are located in areas where violent events have taken place, or present a height rate of bullying. Those schools are extremely important for us, so we identified them and extended the time students spend at school. Something similar to the full-time program from Secretaría de Educación Pública, but with emphasis in restoring the social fabric. During this additional time, with the aid of DIF Tamaulipas, we give lunch to all students, and later work with them on the development of science, arts, culture, and sports, which are essential for an integral formation, about which Subsecretario Javier Treviño was speaking just now. Through curriculum autonomy we will be able to work in this way with the more than 800 full-time schools. It strongly encourages us to work on something so much in the line of the needs of our state.

A little time ago, Jorge Iván recalled the experience in his country. There is so much we have to learn. I would like to make an agreement towards the construction of that kind of experiences, since we in Tamaulipas need it so much in order to help our children and youths but, most importantly, our teachers. How to apply science in our everyday formation? How can we transform our reality into the one we would like to live in, with peace and full of hope? Thank you.*

** Transcription*

[3] His office had started one year before.
[4] The program Sistemas de Enseñanza Vivencial e Indagatoria de la Ciencia (System of Life- and Inquiry-Based Science Education; SEVIC, from its acronym in Spanish), which is applied in the state along with Innovación en la Enseñanza de la Ciencia, A.C.

Salvador Jara Guerrero

Undersecretary of Higher Education. Public Education Secretary. Mexico.

Thank you for the invitation, and I am grateful as well to all people present.

To say that something is "scientific" is almost trivial nowadays. We talk about "scientific thinking", about having to act "scientifically", and then we wonder what that is. What are we referring to when we say "scientific"?

I will start by stating a problem of our time. Today we have a paradox, because we have access to an amount of information incredibly larger than ever before. If I now ask any question, you will take out your cell phones and google it. However, are you aware of the percentage of false information you would get? Are you aware of the amount of false information we catch in the streets every day? How many medicines advertised in the streets have no beneficial effect, or may even be harmful? How can we know if our clothes actually have the percentage of cotton and polyester stated on the tag?

At the end of the day, how do we know what we believe? How can we defend ourselves of what we are told? How can we justify what we state we know? The method which can help us here is exactly science. What science has taught us throughout history, since the moment we can call it science, is that it is a good method and a good procedure to reach the truth. Even if it does not keep us completely "safe", it allows us to avoid several problems.

Unfortunately, today very few people have the scientific attitude of trying to justify, both realistically and objectively, what they believe they know, or what they affirm. Even in the media, as well as in public and private speech, we are invaded by a fallacy. Let us suppose that somebody says: "This economic model would be better for Mexico, since it would generate a lot of jobs". And somebody else intervenes: "Do not believe him, because he is a robber", or something of the sort. Of course I am now exaggerating the situation, but it is very common to see that in an argument, the idea is ignored and the person is attacked instead. That is a big mistake, because what we are discussing is the idea. For example, there may be a criminal with an excellent idea regarding a mathematical theorem. The fact that the moral life of such person is completely wrong, has nothing to do with the idea itself.

Therefore, one of the most important aspects, and one of the main problems in my opinion, is that in our everyday life we refuse to discuss ideas. We take the easy path, to disqualify our opponent, and we then reverse the situation. So easy: If we disqualify that person we do not have to take care of the idea. But where is this coming from, what is its origin? I like to talk about this because for some time it was my topic of research. It is very interesting because one of the roots of what we today call scientific research, or science itself, is theology. The theological argument, which emerged between the 16th and 17th centuries with the Protestant Reform, is a very beautiful one and goes as follows: If we observe carefully, we can notice that there are so many regular things in the world. For example, every day the sun rises and sets. Several processes repeat regularly, and are ordered up to a certain extent. In addition to that, it turns out that we are the only beings capable of noticing and understanding such regularities; animals are not aware of them, but we are. That is, we have an ability, the rational capability of appreciating this order of the world. Well then, since God created the world, and God created us as well, then He made an ordered world and gave only to us the capability of understanding it, and that cannot be purposeless. He made it so for we to understand it. Then the theologians of the time, who were not atheists, based on this principle affirmed that the best way to worship God is by studying the world, since he gave us the intellectual capability of understanding it. Then there is a large number of men, and surely of women too, who start studying the world because of religion, and that is very interesting!

There is another root of what we today call science, and it comes from law. Currently, many people study law because they do not like science, but they do not know that the origin of science lies partly in law. But where? In oral trials, around the same time as the other phenomenon I just explained, which is the 17th century. In Anglo-Saxon culture oral trials are very common, although we do not use them in Mexico. A popular jury is a group of people who, if not morally immaculate, at least do not present reproachful conducts; they must not have any personal interest on the trial, or any intellectual disability. They are common people, no particular studies or preparation are required. Then the jury is selected, and lawyers are appointed for prosecution and defense. Now, how will this jury decide upon the guilt of the accused? Because in this kind of trial the judge has no word regarding conviction or acquittal; the judge applies the law and decides the sentence, if necessary, but the popular jury, composed by common citizens, will tell if the accused is innocent or guilty. But how do we get to convince these people of our point? Little by little, two fundamental elements arise in this kind of trials. One is the concept of evidence, that is, how do we know that the accused is guilty? How can we justify our belief? As I was telling, there are two ways: one is by following a coherent argument, trying to reconstruct the facts, so that even without evidence we may reach our goal. However, the best and most important is evidence, to be able to say: "I saw it, and this is what happened".

Ultimately, this is what science does. Science helps us to understand the world with our

intellectual capabilities, and not only the natural world but the social world as well. On the other hand, it is not valid if the decision is based solely in our opinions. It is also not valid to attack the person instead of the argument. In science, we try to convince an impartial jury, composed of all other scientists, of our ideas, by using evidence and coherent arguments.

So this is very important and it would be great if we were able to practice it since childhood: In any conflict, where two factions have a different opinion, to settle it through dialogue, instead of through violence, as it is so commonplace today. "Let us sit down and analyze your argument and your evidence, as well as my argument and my evidence". To do it together and openly, allowing investigation and research, so that it is clear what is the real information, and we can choose the best hypothesis. This is basically scientific inquiry, and we should encourage it since childhood. Such procedure does not only help children to like science, but allows them to make proper decisions in their everyday life. How can we decide who to vote for? Whose program is best? Or how can we decide regarding any aspect of life? If we had a better education regarding critical thinking, we would be evaluating the argument instead of the aesthetics. We would think: "They are telling me this, but how do they justify it?" For example, "on which grounds do they affirm that this medicine cures everything?" However, we are sometimes incredibly surprised when educated people buy such medicine without questioning anything. People do not question what they are told, but just take it for granted.

In my opinion, this is the most important part of what we call scientific education, and we should apply it in our everyday life, since kindergarten. Since we have a social life and we have different opinions, conflict among people starts from an early age. If we manage to have teachers who follow this approach, and I truly hope so because I am quite optimist regarding the Educational Reform, I am sure that we will have much better citizens for Mexico and for the whole world. Thank you very much.*

** Transcription*

Miguel Rubio Godoy

Institute of Ecology. Mexico.

Thank you very much. Good evening. As all other panelists, I am very grateful for the invitation received from FUMEC and INNOVEC to come to El Colegio Nacional to deliver a speech. I hope to manage to address all the questions we were given, since they are fundamental questions.

Which abilities, attitudes, and values must be promoted when teaching science in basic education? Fortunately, I will repeat a lot of what others have said in this same panel. I say fortunately, because from different approaches we are finding several converging points, and this is fantastic. Because the idea is in the air and, as Richard Dawkins, the inventor of *memes*[5], puts it: ideas are there and we just have to grab them. Then it is very enriching to know that several ideas are there and we are now trying to get hold of them. Which abilities are necessary for science? As a scientist, one needs the capability of observation,

[5] Meaning of *meme*:
1. noun SOCIOLOGY. Cultural or behavioral element transmitted from one person to another, or from one generation to the next.
2. Text, image, or audiovisual element rapidly spread through the Internet, and frequently modified for humor.
Gran Diccionario de la Lengua Española © 2016 Larousse Editorial, S.L.
3. Unit of cultural information, like a concept, a belief, or a practice transmitted from one person to another in a similar way as the transmission of genes. Just as the genes which endure are those most helpful for survival through the process of biological evolution, cultural evolution is led by the most successful memes.
https://www.merriam-webster.com/dictionary/meme

the capability to formulate hypothesis, the capability of questioning what one is observing, of questioning the existing explanation; it is the fundamental capability of doubting, of considering that something may be wrong... it means to have a critical mind and not to assume the truth of everything we are told. There are other important elements, like perseverance, creativity, and some characteristics which are as important for artists as they are for scientists, like the capability of being very imaginative. "If this explanation does not work, if the result of this experiment is not what I expected, if I cannot understand this question which obsesses me, how can I look at them from a different approach? Because those tools and abilities do not only contribute to make a good scientist, but a good citizen as well. And the main task of public education is to form citizens. If any of them becomes a scientist, that is wonderful! But the main task is to form good citizens, and the tools which are critical for every scientist are also fundamental for every citizen.

Compromise. We were asked why science education since an early age helps the individual to have a compromise with society, with his environment, and with his culture. The answer is that humans have an innate ability to love what we can understand, so it is important to start understanding things when we are little children. Curiosity is extremely powerful. Science helps us to understand the way the world works and functions, and we like it as soon as we understand it, because we have something fabulous within ourselves. If we manage to awaken that, then we awaken the love for things as well, since people can only protect what they understand and what they love. That is why it is truly important.

It is also quite important what has already been mentioned: learning is easy. If we let children witness the wonder of a flower opening, the wonder of a fish swimming, the wonder of so many things in science... they naturally love those things. The difficult part is to unlearn.

It is also fundamental what our Colombian colleague said just now, regarding Montaigne stating that teachers used to mount themselves in their high horses. It is important for them to "dismount" so they are able to teach from the same height as their students, and here I am not referring to physical height, but to the fact of considering our intellects as equal and having an horizontal relation. If we do not do that, then we are not speaking the same language, and understanding becomes very difficult. Now just imagine, if teachers mount on their high horses, scientists mount into even higher ones. We are up there in our ivory tower, and we seldom deign ourselves to come down, but it is fundamental for us to start doing it. Here I will play a bit with words, because there are several scientists who pontificate and talk as if their word were sacred. They are in their ivory towers and speak the word of God: "Things have to be this way. I already burned my eyelashes getting my PhD, so now you must take my word as the truth...".

However, if we go back to the origin of the word "pontificate", the Supreme Pontiff is the supreme "builder of bridges". Then it is extremely important for us scientists to go back to the semantic idea behind the term and become builders of bridges between science and society. This is part of what has been done in this country. Even if it has not been put that way, it is part of what has been done since a long time ago, since the times of Universidad Real y Pontificia (Royal and Pontifical University), which later became UNAM (Universidad Nacional Autónoma de México; National Autonomous University of Mexico), and also through CONACYT (Consejo Nacional de Ciencia y Tecnología; National Council for Science and Technology), where I work. My job takes place in a public research center, and part of our duty is to try to establish those bridges, coming down from our ivory towers and starting the dialogue, similar to that of teacher with student, but in this case it is of scientist with society, so we are able to develop this important and urgent communication.

For this reason, I would like to tell you a little bit of what we do at Instituto de Ecología (Institute of Ecology). We are one of 26 public research centers in this country. After UNAM, which is undoubtedly that maximum authority and the greatest producer of knowledge, the second place regarding basic research and creation of knowledge is CONACYT. Those 26 public research centers combined are responsible for more patents, more innovative objects, more basic and applied knowledge than Instituto Politécnico Nacional (National Polytechnic Institute). This is a pride for our nation. It is part of the institutional and national investment, since science is not an expenditure, but an investment. And it is also our obligation, as scientists, to explain this to society, since we live from the taxes paid by the people, so it is fair and ethically correct to explain to them what we do.

In the institute I am proud to be the director of, we use several strategies to bring such knowledge to society. We have an event called "Casa abierta" (Open House), which emulates the opening of a private house so that others may come in and see what is done inside. In a similar way, I open the institute for everyone to visit us and see what we do, see how we are investing their money, the public funds, so they can ask any questions they like.

Since I am the director, I am acknowledged with all research projects in the institute. However, it is better for whoever wants to know, say, about otters, to ask directly to the person working on such topic. It is good for the public to notice that the diversity of what we do is enormous, because ecology is very broad, and includes from the use of electronic microscopes, which allow us to watch very small things, to the understanding of the way the basin of a river functions, the way trees incorporate water, and who eats who. Then it turns out to be much more complex. So, in addition to other strategies for bringing science to the general public, we believe to be very enriching for the people to ask the researchers directly about what they do. We owe this to society and we are ready to explain our work to everyone, from children to grandparents.

But here we are talking about education. It is very important to focus in children, so we have special programs for them. One of our programs is called *Fomento a la carrera científica y tecnológica* (Encouragement Towards Scientific and Technological Careers), and it has a variety of goals. The first one is encouragement itself, that is, for children to come and notice that "it is great to become a scientist!"; for them to know that it is an option for their lives, as good as a carrier as a physician, lawyer, or astronaut, economically speaking. Science may be a good career for some people, so we are happy that children come and take a look. On the other hand, we do this with second intentions as well, because when children work with scientists for a week, they witness what scientific method is about, how fieldwork is carried on, how data are analyzed, and how researchers try to make sense of their observations. Thereafter we organize and event, a small conference in the state theater in Jalapa City, where children are the ones presenting results, the ones establishing this link with society, instead of scientists. That is why I talked about second intentions, since we are actually turning them into ambassadors for the institution, as part of the task of trying to generate a scientific culture. And a scientific culture does not mean that everyone will be able to solve differential equations or to balance a chemical reaction, not at all. A scientific culture implies to understand what science is useful for, the kind of questions that can be approached scientifically, the tools used by science, the way data are analyzed.

That is what "scientific culture" means, and it is extremely important to enhance it.

We are also trying to do something bigger, and I hope we manage to do it. We have a program called *El semillero de premios Nobel* (Seedbed of Nobel Prizes). We would like to have much more "Marios Molinas" arising from this country, and especially from outside the capital city. Of course, most of science and research is accomplished in Mexico City, and it would be great if we managed to decentralize it. It would be very nice if the next Mario Molina came from Veracruz. Therefore, that is what we are trying to do.

Lastly, we also use our botanical garden as a tool to connect with society. Of course, it is a real botanical garden, a living collection where we conduct botanical research, like studies regarding the best ways to germinate different plants, etc. However, we also consider it a very beautiful and efficient way for the scientific method to be brought closer to young people. Then, every year, we do not invite the students, but their teachers, to visit us for at least two months, with the aim of making up small projects that can be worked with at schools. Why? Because the concept of perseverance is very important. Not everything worthy implies an instant gratification, and to understand that is very important these days. To be able to plan, to have the patience to continuously observe slow processes, etc., and it also works as a fantastic sounding board. This year, through the work we accomplished with around 150 teachers from schools in Veracruz, including training workshops, we managed to reach some 12,000 students. Then it is a wonderful way to profit from these sounding boards which are enriching both ways.

Now, let us remember that I work in an institute of ecology, and it was previously mentioned that we must be very clear on this idea of "educating for contingency", a very beautiful sentence by our colleague from Colombia. We have not yet understood, as a society, what "contingency" is about. We have been practically bombarded since several years ago with notions like climate change, desertification, and so many others that we either trivialize them or simply do not pay attention. It is very important for us to start becoming aware of what we are talking about. I do not know if you have already heard the word "Antropocene". I will explain its meaning very briefly. This very week, 75 years ago, Enrico Fermi accomplished for the first time, in the University of Chicago, the first controlled detonation of an atom, which was the seed of the atomic bomb. The atomic bomb itself was built later, in 1945, 72 years ago. We know all that. We all know, for example, about geologic eras: Cretaceous, Jurassic, and all those epochs. Now we are living in one called Antropocene. If you had not heard about it, it is a very simple concept: Since human activity has reached an incredible magnitude, it has already left trace in geological strata. Why did I mention Enrico Fermi? Because what validates Antropocene as a geologic era is the fact that it is already possible to detect significant amounts of radioactive material in the Earth's crust, effectively forming a geologic stratus. The trace is uniform enough to determine a new geologic era. In the same way as in Cambric or Cretaceous eras a certain amount of iron or carbon can be found, and such amounts determine the limits between geologic eras, the impact of human activity can be already detected in the Earth's crust, which defines the new period: Antropocene. And it is a monster with several heads, because this monster, this reality of contingency in which we happen to live and try to survive, has a head called climate change, another one called desertification, one more called loss of biodiversity, and another head called uncontrolled demographic growth. It has several different faces and it is extremely important for us to start to think about those processes as the heads of a Hydra. They are not independent problems, but connected to each other. They are united, precisely, by this Antropocene which is such a large, such a deep scar that we can perceive it in the Earth's crust from Manchuria to Petén. It is enormous. Therefore, considering this education for contingency, what we must do is to keep on studying science since, for example, ecology in particular can help to predict the biophysic limits of the planet: how much we can grow, how much timber can be taken from a forest without killing it, etc. This is one of the main applications of ecology, since it can tell us where the limit is, the encumbrance capacity of the planet. But what it cannot do is to increase such capacity. If we want to become a sustainable society then ecology is not enough; we also need economy and we have to consider education, politics, and several other factors, of which the most important is philosophy. Because we have to transform our approach, we have to say goodbye to Newton's world. Newton's world still helps us to send rockets to Mars, because the rules are good enough, but it will not allow us to reach the end of this century if we keep acting as we do now. Why? Because Newton's world was immutable, so it did not matter how much we dropped into the atmosphere, since the result would be negligible and the atmosphere would stay the same; it did not matter how much water was used, since there would always be sources of fresh water; it did not matter how many whales were killed, since the sea would always be full of them; it did not matter how many humans were in need of food and oxygen, it just did not matter. And why is this related to philosophy? Because that is our picture of the world and it comes from the Bible. God put humans on Earth to profit from it, and all creatures of God, and all minerals as well, exist only for our benefit. And such situation was true for so many millennia, when we could just take all the timber, coal, fish we wanted, and the change was not even noticed. Today we cannot indulge in such a luxury, because we are too many and our technological development allows us to generate a much deeper transformation than ever before. That is why we need to actively accomplish a philosophical change if we want to survive.

This transformation in our approach implies as well to question and analyze one of the fundamental principles of economy, which states: "Growth must be always present", based also in the Newtonian principle that resources are infinite in practice, so the machine can keep on working for ever, *ad infinitum*. But this is not true; from the point of view of biophysics it is impossible to sustain a constant growth rate, using more and more resources every year, when our planet has finite limits. It is simply out of the question. Then, why shall we transform our approach? Because we must start to realize that we cannot keep on following this "sacred" principle in all our activities. Because, of course, "money kills science", and it kills several other things as well... If something will generate an economic profit, then any other cost becomes negligible, we are readily willing to pay it. But then, it is time to start wondering, how much do the air and the weather of our city cost? How much are we willing to pay? And I am talking about the cost, not the value (and their value this enormous, because our survival depends on them). But to ask how much they cost is to ask how much we are willing to pay. For example, if we are planning to cut off trees in order to use that land to raise cattle, so that we can get milk and meat, we should ask how much we are willing to pay in terms of money. What is the cost of saving those trees in exchange of a small amount of milk and meat? And I am not saying that such food is not necessary, because our rate of demographic increase is very high, and we have not managed to reduce it. It is a very difficult problem for which, of course, science is needed.

As a last point, I would like to say that science is indeed a very powerful tool. It is the most

powerful tool we currently have, and the one most closely resembling a crystal ball, because it allows us to predict the future based on the evidence we have; up to a certain point, of course, since we are not magicians, but it lets us get a reasonable idea of what may happen. Considering the environment, considering the transformation in our philosophical approach to reality, it is extremely important to start acknowledging what the real value of our environment is, and for this purpose we may conduct an experiment which is as simple as it is horrifying. You have probably already heard about ecosystem services, and the fact of considering what forests, water, etc. contribute to society. However, up to now that has not been taken seriously, not only in Mexico but in the whole world, not even in Finland or China. In most places people disregard it completely. But we have a fantastic example of the benefits of natural capital; a very wise sentence by one of the members of El Colegio Nacional, Dr. Sarukhán. Natural capital must be considered in the same terms as economic capital. It is extremely important for us to start estimating the value of our natural capital.

I would like to close this speech with the example of Hispaniola Island. As everybody knows, such island lies in the Caribbean Sea, and its land is shared by two countries: Haiti and Dominican Republic. How many times, in the last few years, we have got news regarding natural catastrophes in Haiti? There was an earthquake which completely devastated the country; also several hurricanes causing incredible damage. I am truly sorry for what the inhabitants of Haiti have to suffer. However, we often forget that it is in the same island as Dominican Republic. This latter country suffered the earthquake as well, but there were no landslides destroying whole cities; the damage was not as severe, not in the least. Dominican Republic basically gets the same hurricanes as Haiti, but they turn out to be much less harmful. The fundamental difference is that Dominican Republic still has natural capital. They still have forests, and biodiversity, and that is what allows them to resist natural catastrophes. For example, when a hurricane strikes and huge amounts of water reach the country, there are natural sponges which can absorb it little by little, there are roots of trees which prevent landslides, there is a huge variety of microbes which help control natural epidemics, like cholera. So it is an example we have close by, and then we must decide if we want a future like that of Haiti or like that of Dominican republic. Because I can tell you, based on hard data, that we have devastated 97% of natural vegetation in the state of Veracruz. We only have the 3% remaining, which means that one of the richest states of the country is in a situation much closer to that of Haiti than to that of Dominican Republic. This is truly scary, but it is based on real data. It is very important for us, both as a society and as a country, to start considering how much we appreciate our natural capital, and how prepared we are to become the next Haiti. Thank you very much.*

** Transcription*

Comments REFLECTIONS Answers & Questions ANALYSIS

Panel İİ. A scientific education for the development and commitment of individuals with their society

- What skills, attitudes, and values should science education promote from elementary education?
- How do scientific skills, attitudes and values, influence the commitment of individuals to value their environment, culture and society?
- Why is it important to encourage the development of these skills from elementary education?

José Luis Fernández Zayas
Good morning. We will start the discussion on topic number two. After talking regarding quality education in the previous panel, we will now introduce the concept of science education and how to incorporate it to basic education.

A characteristic I detected in all three presentations is that the building of knowledge, the building of truth, takes place as a group effort. It is not in charge of a single individual, but of several people who share methods, respect each other, and who aim to reach the truth together. It is what we have also called the building of citizenship.

Héctor Escobar Salazar
It was a very good lecture, and the information shared by Prof. Martínez Yllescas is extremely relevant.

I definitely believe that we must take the context as a basis; to understand our place and be aware of our reality. Social commitment in the development of science through education is fundamental, as well as the application of science to our everyday life, to solve different kinds of situations, as you mentioned earlier.

A little time ago I was talking about the difficult situation present in our state during the last few years. There was a contest on innovation which took place in primary schools, and a student developed the model of a bulletproof backpack. This was extensively covered by the media. It is sad that science has to be applied to solve this kind of situations, but it reflects the current reality of our state, where every person working in the government has a commitment to make an effort towards the restitution of a healthy society. We know that the vast majority of people want our state to be peaceful and to develop, so we are working on that direction. It is truly impressive to see how science can improve our society, especially the life-standards in our different communities. Therefore, I believe it is fundamental for everyone working in the development of education to be committed on increasing our efforts towards better enhancing the development of science and, specially, the application of science to the improvement of everyday life. Thank you very much.

Miguel Rubio Godoy
I am very happy that economists have begun to assign a value to science education. We must immediately begin to undertake such transition. If people do not apply such change out of sheer conviction, now that the economic aspect has priority, it is great that OECD shows data proving that, by investing in science education, we can duplicate or even increase six times our gross domestic product. That is a very strong reason. It would be great for this information to be heard by congressmen; in fact, for them to have heard it last week, before deciding on the budget for next year. It is very important that, once we have such understanding, we also develop the will. We academicians never get tired of insisting on the importance of investing in science, technology, innovation, and education, since they are the foundations of everything. It would be great that, in addition to academicians, the topic were insisted upon by international organizations related with the best usage of public and private resources. That would be extremely helpful. To finish, I would like to make a very respectful suggestion: I know that economists talk about "spending", but such term somehow implies a waste, so it would be much better to talk about "investing" in education. Thank you very much.

Salvador Jara
Thank you very much. I would like to say something about each of the previous interventions, all of them very interesting. My first comment is that a scientific attitude in science education is not restricted exclusively to science, but is about integral education. If we experience the way in which science is created, in addition to learning we acquire several other important capabilities. One of them is communication, which in Mexico represents a major problem in several people, even after graduation. We experience difficulties when trying to convince other individuals. We have already seen that fact in the information provided by OECD. This kind of abilities must be developed gradually, through active participation of the students, since primary school or even since preschool. Active participation of the students helps to develop self-confidence as well, and that is fundamental for the success of every person, independently of gender. Other two very important abilities are tolerance and prudence. People must learn to listen to others. We are used to talk and talk and pay no heed to what others are saying. When we discuss with a scientific spirit, we keep silent and listen to what others are communicating, then we consider it and give our reply. Moreover, tolerance is fundamental, since otherwise we would never agree with others. Especially when discussing topics not strongly related with science, like religion or politics, we must learn to respect the point of view of other people. Therefore, tolerance is a very important capability. Another capital ability is reading comprehension. In a discussion we need information to sustain our ideas and to assess those of others, so we need to read and to understand what we read, in order to acquire such information.

About investing in science, technology, and innovation, it is fundamental in every country. In Mexico, a big problem is private investment. In several countries, private investment in science is much greater than public one, but that does not happen in Mexico, and it also has to do with science education. If a businessman does not know anything about science, he will not be aware of its importance in the development of the country and the welfare of the people, so he will not invest in science. There is a very important piece of information which is clearly shown in the diagram[6]: Regarding basic education, including students up to age 15, investment must definitely be increased. However, when considering superior education there is a paradox in Mexico, because investment has been steadily increasing, but productivity has not followed suit. This is a very important point which must not be disregarded. What happens is that in science and engineering we are forming people who, after graduation, cannot fit properly in the job market. That is a very important task for the future and we are already trying to correct it in superior education. My comment finishes here,

[6] See presentatiom by Prof. Martínez Yllescas.

and I would like to thank all my colleagues; it was a real pleasure to be here with all of you.

QUESTIONS FROM THE AUDIENCE

Member of the public
My question has to do with PISA results. I would like to know if there is any report or assessment related with ENLACE or PLANEA.

Member of the public
Regarding the global analysis of the PISA test, I would like to know which are the countries with best average results, which could act as a benchmark for us.

Member of the public
I agree in that a citizen with science knowledge is a good citizen, but which is the compromise of society to help science? A problem in Mexico is the lack of educational culture, especially regarding integral education. So my question is, what do you suggest? Who do we have to talk with? Which public policies must be fulfilled, not restricted to the educational area?

Roberto Martínez Yllescas

About the relation between the PISA test and the PLANEA test, OECD has not yet performed an analysis with emphasis in the comparison or validation of the consistency of results between the PISA test and other assessments which have been undertaken or are being applied in Mexico. One of the reasons for this is that we believe more evidence is needed for a methodologically strong comparison.

Regarding countries which may be taken as a benchmark or example for Mexico, there are some which were mentioned in the presentation. We should mainly focus in countries whose results were similar to those of Mexico some time ago, but which have shown a very rapid improvement. One of those is Chile, where some very good actions must be taking place, because their results have been increasing steadily. Going beyond cultural differences, we should also pay attention to the situation in Vietnam, whose results are outstanding, to the point that even the poorest students of that country obtained better results than Mexican students from wealthy families. So we should analyze what has been done in those two countries.

About the way in which society may cooperate to the improvement of scientific culture in everyday life, I believe that one of the best strategies, which fortunately has already been incorporated to the Educational Model by Secretaría de Educación Pública (Ministry of Education; SEP, from its acronym in Spanish), is that of inclusion. We must encourage girls to follow studies related with science and technology, as well as innovation. That is a best practice at an international level, already understood by progressive and rich countries. Therefore, it is very good news that Mexico has followed their example and has already a program by SEP, and supported by OECD, called *Niñas STEM Pueden* (Girls STEM Can). The idea is that women who are successful in the areas of science, technology, engineering, and mathematics, go to visit schools and establish contact with girls currently studying middle education, which are at a very important age to start considering which carrier to follow. In such a way, talent in those areas will increase. Of course, educational authorities and other academicians must also collaborate and give support. I believe that impact may be very strong in the following years.

Héctor Escobar Salazar

I would like to talk about the last question, regarding the way in which we could encourage the spreading of science. I believe it is fundamental for us to be able to establish such commitment. I think it is important to increase the possibilities of the general public to approach science, making an emphasis in digital media. As it has been already said, in technological spheres sometimes there is information without a scientific basis, so we must encourage students since basic education, and through middle and middle-superior education, to approach science and to look for the scientific foundations of technological facts. In such a way, society as a whole will be much more interested in the development of science.

Salvador Jara

In addition to what Roberto Martínez said regarding inclusion, as well as the effort of the Educational Reform to encourage women to study science and engineering, in teaching colleges we are also applying a strengthening plan focused in inclusion. Regarding this, there is a very important fact: A mother plays a very strong role in the vocational preferences of children. Therefore, it is very important to have more women with a scientific culture, even if they are not professional scientists. It is like going to a museum and, even if we do not actually draw professional paintings, we are able to appreciate the complexity, the aesthetics, and the beauty of an artwork. In a similar way, even if we are not all going to become professional scientists (and it is great that there are poets and people dedicated to all possible professions), it will be good when everyone is able to appreciate the value of science and is not afraid of it. If we truly manage to encourage more women to enter the world of science, to understand science, to appreciate scientific work, then we will have a real generational revolution, because then we will have children who do not flee away from mathematics, and who do have a passion for scientific activity as detective-like investigation. This is what we would truly like to accomplish.

Miguel Rubio Godoy

Obviously, as my colleagues have already said, it is in part our obligation to convince everybody, to spread scientific culture, to be efficient in communicating this message. However, there is something very important that we scientists and academicians have not always been careful about: To convince others with very good examples and very good results. Because that kind of examples and results also have economic value, and this is something that cannot be questioned.

At Instituto de Ecología (Institute of Ecology) we have a very good example of this. Up to the year 2004, Mexican avocado could not be exported to the United States of America, since such country stated that the avocado produced in the Mexican state of Michoacán was subject to a disease which did not exist in the United States of America. That was a perfectly valid reason for an economic embargo. The issue is that it was false, and we proved it using science. Institute of Ecology approached producers of avocado in the state of Michoacán, and proposed to conduct a scientific study which would cost them around one million Mexican pesos, which is not too much. The idea was to carry out the appropriate scientific experiments and show with a scientific basis that Mexican avocado is not a vector of disease. What followed was like a Hollywood movie. We went to a court in California, showed the results of our study, managed to take away the economic embargo, and since 2004 producers and packers of avocado in the state of Michoacán have earned 6000 million US dollars. So this is a very clear example of the utility of science and of the way in which it can be integrated with economy.

It is extremely important to publicize these academic accomplishments because, as Dr. Jara mentioned, it is very difficult to achieve the 1%[7] for an investment in science and technology without the participation of the private sector. In Mexico, the federal government

[7] Of the gross domestic product

has already done much, since we are close to the 0.5% of the gross domestic product, and we need an equal share the reach the 1% recommended by UNESCO. The question is that in most developed countries, around 70% of the total investment in science and technology proceeds from the private sector, and only 30% is provided by public funds. Therefore, we cannot expect the government to be responsible for the whole 1% needed for a desirable situation, but we need to find many more avocado producers, so to speak, many more people from the private sector who understand the convenience of investing in science, who understand that one million Mexican pesos may become 6000 million US dollars, which is an incredible profitable business! So we must make them understand that it is very convenient in an everyday basis, not only as an opportunity business. Avocado producers are so convinced in such regard, that at Institute of Ecology we have what may probably be the first patrimonial academic chair in this country.

In the United States of America and Europe there exist what are called *endow shares:* A company invests in a trust from which research positions are paid. As long as I know, in Mexico that only exists at Institute of Ecology. The money was invested by avocado producers, because they saw that it actually was a very profitable business, so they thought: "Let us invest there, because these people truly know how to perform research which generates actual profits and solves concrete problems". Therefore, Institute of Ecology has money to pay researchers whose results are useful for avocado producers. If we had many more companies with this vision and this real interest, not only to talk at a forum and say how much they value science, but truly willing to invest in a trust to support research, then we would be a power at the level of those we saw in the diagrams by OECD.

José Luis Fernández Zayas
We have talked about quality education and now, based on the principles of science, we have had a very interesting presentation. I believe we have been able to analyze the topic from different approaches, all of them legitimately valid. Thank you very much. I ask for an applause for the members of this panel.

PANEL iii

How does science education contribute to a comprehensive education that promotes innovation, respect for nature, and a harmonious social coexistence in a global world?

Keynote Speakers. José Sarukhán Kérmez / Carlos Galindo Leal
Panellists. Nuria Sanz / İrene Pisanty Baruch / Leah Pollak Lee
Moderator. Sissi Cancino

José Sarukhán

National Coordinator
National Commission for the Knowledge and Usage of Biodiversity (CONABIO)

Carlos Galindo

Director General of Communication of Science
National Commission for the Knowledge and Usage of Biodiversity (CONABIO)

I would like to thank INNOVEC for the invitation to come here. The second part of this talk will be in charge of Carlos Galindo, who leads the team from National Commission For the Knowledge and Usage of Biodiversity focused in the encouragement of non-professional science in Mexico. I will briefly introduce the topic and explain the reasons why we should start applying a different kind of scientific dissemination, not instead of science communication but as a way to enrich it.

In Mexico, there have been several important efforts regarding science communication, although it is always possible to do more. An example of this is the publication of the longest series of original works in Spanish language, dedicated precisely to science dissemination. Up to now, around 250 titles have been published. It was originally named *La ciencia desde México* (Science From Mexico), but that has changed to *La ciencia para todos* (Science For Everybody). Books written by Mexican academicians from every branch of natural, hard, and social sciences are being used all around. This shows the huge interest of Mexico and Mexicans for science dissemination. Even I have, since a very early age, suffered from "dissemination disease": When I belonged to Mexican Botanical Society, I used to gather groups at Bosque de Chapultepec and imparted lectures about botanic science. Another remarkable effort is the one undertaken by Jorge Flores at Museo de la Tecnología (Museum of Technology) with his *Domingos en la ciencia* (Sundays With Science), which have now extended and multiplied, and take place in several cities. It is true that we could have more science dissemination, but also that we have really improved on that regard. In addition, we have Sociedad Mexicana para la Divulgación de la Ciencia y la Técnica (Mexican Society For Science and Technique Dissemination; SOMEDICYT, from its acronym in Spanish).

However, I consider that it is time to start thinking differently, and switch from "doing science for society" to "making society do science", which is a perfectly attainable goal. This is nothing new; quite the opposite, it has been taking place in the world since a long time ago. Let us simply consider all people "hunting" extraterrestrial objects approaching our planet; they are amateur astronomers, "scientists from society" who, although lacking post-graduate studies in astronomy, dedicate a lot of their time to watch the sky, and therefore have ample knowledge on the topic. And this is just one example among many. Our task is to enhance and encourage activities which allow people to take a more active part in science, since the best approach to scientific knowledge is to do science, to understand it, to talk with people who do science as well, and so create an interconnected network of people with similar interests and the same desire of knowledge, who can share their experiences with each other.

Several different areas of science have been developed thanks to the participation of non-professional people. One of them is "naturalism", greatly enhanced by amateur scientists, some of the most famous of which are Humboldt, Darwin, and Wallace. Thanks to the love and appreciation for knowledge of these amateur scientists, some very important advances were generated, like the theory of evolution, which constitutes one of the greatest scientific revolutions in the history of humanity. Such theory, although developed by Darwin from his idea of natural selection, would not have been possible without the results of several others before him. Darwin put together the different existing pieces, bringing them to a superior level of understanding, but those pieces of knowledge by themselves are fundamental. The resulting idea was so simple that Julian Huxley (one of the staunchest defenders of Darwin), upon reading the manuscript, thought to himself "But, how stupid I am! Why did I not realize things work like this?" Because it is truly a very simple idea, but it could only be the result of observation, analysis, and the capability to synthesize, to compare, to identify patterns. And such a thing, a simple but great idea, can only be conceived when there is a lot of knowledge behind it.

Non-professional science has a very ancient origin. Practically all scientists from the times before universities existed were amateur scientists, who had to work as priests or something else to support themselves, since their scientific activities were not paid for, unless they focused in collecting specimens of living beings all around the world to sell them to museums, since at the time people were interested in collections but not so much in knowledge. Science developed in such a way, by people who had no salary and who did not belong to Sistema Nacional de Investigadores (National System of Researchers; SNI, from its acronym in Spanish), because there was no support of any kind for science and research, and something similar happened with all branches of knowledge. Astronomy, archaeology, history, and so many other disciplines have been developed by hard and unpaid work accomplished by several people. In contrast, today we have very different conditions, and scientists get paid for their work at some university or institution, which takes place in a relatively comfortable position. In our time, for their field-work, scientists have vehicles with separate traction at each wheel, and air-conditioning, but Darwin did it by foot, and practically walked along the whole South America. Although it is usually said that he traveled by boat, he actually got off at some point and walked for months in a row, interacting with people and collecting specimens, to catch the ship again at another port. But today we have a very different conception of how science must be done. People of old did not need sophisticated or specialized equipment, but a strong will, a lot of curiosity, and reasoning capabilities. The tools Darwin took with him were a microscope, pincers to collect insects, a press for plants, and a gun to hunt and to collect birds. That was his whole working equipment. However, the most important tool was inside his head, and that is precisely what I believe we must manage to encourage, starting from the natural interest and curiosity people have to know and understand their environment.

If we want to talk of a branch of knowledge particularly suited for non-professional science, we must forcibly give our attention to environmental sciences, especially to the knowledge of nature. This can be explained in a very simple way: We have it in our genes! We all are result of the evolutionary process taking place in this planet. We share genes with everyone, even with lettuces! Many people do not believe this, but when I show them the data proving such fact they become extremely surprised, since the idea that we only share genes with bonobos is quite extended, but is completely mistaken. We have this inside, we evolved in nature, we lived for millions of years in nature, but suddenly, in a 150-years period, we lost contact with it, we stopped being part of the natural world which allowed us to evolve and to reach the position we are in today.

The first collective effort on amateur science was the counting of birds after Christmas, which took place for the first time in the year 1900 at the United States of America. By common accord, between 50,000 and 60,000 people dedicated the day after Christmas to count different kinds of birds. We could ask, how can counting birds be useful? Well, it turns out that by counting birds, and knowing which kinds of birds are being counted, we start getting information we cannot obtain in any other way, like number of species, patterns of behavior, and patterns of change, which allow us to know what is happening with the distinct bird populations. Since then, such activity has been taking place every year in the United States of America (and later in the United Kingdom as well), and it has helped to understand and get information regarding several bird populations, which could not have been obtained in any other way, even with the combined efforts of all American ornithologists. These tens, or hundreds, of thousands individuals volunteering in such manner are perfectly aware of the importance of scientific knowledge, so they act accordingly. Such efforts have been extending with time, and they could be applied in Mexico without any difficulty, specially in Mexico City, where they could help understand some problems regarding pollution. More than one member of the government would be surprised if something of the kind came to happen. We would have people recording data at home and reporting them to a center where they would be put together, and then the understanding of what is happening in the city would be very different and much more useful than it is today.

There are so many areas where regular citizens can participate. It is only a question of organization and of starting to work following a different approach. Therefore, I suggest that science dissemination in Mexico and elsewhere must be organized differently. We must have academicians willing to invest time and energy to create groups, lead them, unite them, explain things and give lectures to them. The problem we have in Mexico is that SNI does not consider any of those activities as legitimate academic activities. Our scholarship systems, and even our universities, do not consider such activities as important either.

Another problem we face is that science development was completely dominated by physicists during the whole last century, leaving only one valid way of doing science, one valid way of evaluating and rewarding science. This happened because our physicist colleagues chose the simplest possible natural phenomena, those having a linear behavior, and in such cases it is very easy to develop models and equations allowing to predict with high precision the result of a given event. This way of doing science dominated, and keeps on dominating, the interest in science and the way it is disseminated. I do not know any hard physicist who works in earnest on science dissemination, and what is known of that area of science are mostly phenomena people are afraid of, because they have led to extremely complex technological applications. This does not represent accurately the actual development of science, and that is why I consider we must truly change it. The question is, how can we change it?

I would like to tell you about the work of naturalists when I was young, because I focused on that at the beginning of my career. To collect plant specimens, we used to go out at night carrying huge presses to heat and dry our samples, and we took with us a rifle with telescopic sight to bring down branches from a height of 45 m and take the flowers from them. The process of drying plant samples was very complex: We used to put them between sheets of absorbent paper, enveloped in newspaper and cardboard; then they were taken to the press to be dried using oil lamps, while we hoped not to start an uncontrolled fire, and once ready we had to take them to the corresponding herbarium. If it was about animal samples, the process was even more difficult: we had to hunt them, skin them, clean their insides, and later prepare them so they would not look too grotesque (using taxidermy techniques). Today, most of those processes are simplified by modern technology. I am not saying that there are new technologies for hunting, or that the animals are ready for exhibition the moment after they are killed, but modern technology allows us to localize specimens through GPS, to record them using high-resolution cameras, and to know precisely where a given sample was collected. That is, new technologies allow scientists to obtain more and better information, and that truly enhances our research capabilities, so we must make use of it.

Carlos and I will talk about the experience of CONABIO when encouraging activities of non-professional science, applied to natural sciences and to the knowledge of nature, and of the role of technology while moving forward in this area. Our main achievement through this activities is not only the amount of information that can be obtained, by itself a very important

factor, but the fact that the system we use allows two capital things: The first one is the generation of a culture which grants value to nature, and which had been lost in the last century; the second one is the creation of social networks sharing such knowledge, which leads to the formation of a scientific culture, not only in the individual but at all levels of society. As I see it, those are some of the most important and relevant aspects in a world where the proportion of urban population constantly increases. Human population is now crowded in huge metropolises, and each generation has a larger proportion of members with no contact with nature whatsoever. The natural world, which always played a major role in our development, has been suddenly left aside. I am no psychologist, psychiatrist, or social psychologist, but it is already being discussed the phenomenon of nature withdrawal syndrome, which is growing in big cities, and causes people to lack cultural or social connections, as well as to feel that they do not belong to any country. This nature withdrawal syndrome is aggravated by the huge flux of information coming from the Internet and from social networks, to which most people are submitted today.

This is a very important topic and I believe media is not giving it the appropriate priority. For most people, contact with nature is reduced to their visit to the supermarket. Therefore, they picture food as coming from boxes and packages, which arrive at the store to be unpacked. This is a very serious problem. I do not know how our species will keep on developing under the present circumstances, but for me it is very difficult to believe that we can all of the sudden get rid of all our evolution and our genetics without very serious consequences. I am not suggesting we go back to live like hermits, like mountain people of old, not at all; but we cannot lose the roots of our evolution, which we gained through contact with nature. According to some studies, most children in the United States of America are able to recognize a huge number of trademark symbols, but no more than six or seven animals and plants, and this is a terrible thing! I am not telling that meaningless accumulation of knowledge has any sense at all, but such result shows the huge gap between knowledge of artificial things and knowledge of natural ones, and we humans belong to this last category.

Another very important point is the development of technology. Not very long ago, say some 150 years back, most people living in cities of Europe and America knew how to milk a cow, since it was necessary to get milk to drink; they knew how to shoe a horse, since it was needed for transportation; they knew how to raise the level of water in a canal, since it was fundamental for irrigation. That is, they were proficient in a number of "techniques", which were the technology of the time. Everybody knew well how to apply a series of techniques which were vital for their everyday activities. As an example regarding my own life experience, some years ago, if the contact points of a Jeep were burnt out, I could simply take them out, sand them, and put them in place again: problem solved. Today, I do not have the slightest idea of how a modern car works, of the function of any of its parts, of the localization of the important pieces; but, on the other hand, I am not worried because I know that, if my car breaks down, somebody will come and fix it. So, again we are witness of the huge disconnection we have with objects and machines we use every day, but whose functioning we ignore completely. We are starting to have *magic items* (due to highly advanced technology) and it is all right, what to do, we just have them. But what would happen if we combined such magic with real life, with nature, which is where we come from, and which we must understand because there is where our roots lie?

Now I want you to picture two children, one of them is focused on his phone or tablet, while the other is caressing a bird. The question is, which of them is better connected? The ideal thing to do is to unite these to aspects, and it is perfectly possible. Moreover, we must be aware that technological development is not going to stop, and that the loss of contact with nature is a very serious problem. So here I grant the stage to Carlos Galindo, so he can explain to you what CONABIO has done regarding this important matter.

Carlos Galindo

Thank you very much, Dr. Sarukhán, and thanks to everybody for granting me this opportunity of sharing with you something I consider very good news, and something everyone of you may strengthen exponentially.

Last year it was published that non-professional science already contributes with more than 50% of the observations of biological species worldwide. The platform *Global Biodiversity Information Facility* (GBIF), which gathers all digital records of biological species around the world, has currently 874 million records of around 1,800,000 known species, and non-professional science has contributed with more than 50% of them. In Mexico, during the last 10 years we have contributed with around 40% of the records of Mexican species through non-professional science projects. At CONABIO we have a platform called *Biodiversidad mexicana* (Mexican Biodiversity), with a section dedicated

to non-professional science, provided with several elements and tools. I would like to talk briefly about three of them: 1) *A ver aves* (Let Us Watch Birds), 2) *Naturalista* (Naturalist), and 3) *Enciclo vida* (Encyclo-Life).

A ver aves is a platform created almost ten years ago. It is the first non-professional science platform making use of digital records, since it evolved from the simple observation of birds (as Dr. Sarukhán just explained, the day after Christmas) to perform electronic records, and it has truly been quite successful. This is the program rendering the largest amount of data. There is a huge number of bird-observers around the world. In fact, in some countries of North America and Europe it is a very profitable business, but in Mexico we have not given it the importance it should have: We have 1110 bird species, of which 129 are endemic, and that is what several bird-observers are looking for. It is well registered the way in which investment in bird observation has been increasing in the United States of America, reaching today 41,000 million US dollars, in spite of having a much smaller number of bird species than Mexico. Anyway, this platform has been extremely important, in spite of being a little too specialized, since it is designed for observers able to properly describe and identify the different kinds of birds. However, in the same website by CONABIO we offer materials and tools to help people identify bird species, like books, posters, links to other platforms, and networks of rural monitor training. As an example of what has been accomplished through the program *A ver aves*, using the data thus obtained we created a map simulating the migration of blue-winged teals (a kind of wild duck) in North America, and all that information was generated by non-professional scientists. We can watch the migration in real-time, since people are continuously recording data, so we can follow the path of these birds and of many others. Moreover, we have gained knowledge that it would have been very difficult to obtain otherwise, like the distribution of some bird flu viruses.

The second platform, called *Naturalista*, was created five years ago, and has been operating in Mexico for four years. It has a lot of different functions and usages. It requires a camera or a smart phone, and can be used in several different ways, as a social network, as entertainment, as an identification tool, etc. The platform started at Berkeley University and was later adopted by California Academy of Sciences, an institution with an extraordinary support, and with which we work directly. The platform can be used for fun, but in contrast with many others focused in sharing pics, there is a number of related institutions and information consortia, which provide it with a very solid basis. Basically, a user needs a camera, a pic, a location, and a date. In this case, as opposed to what happens with *A ver aves*, the user does not need to know about bird species, due to two reasons: to begin with, the social network is incredibly large and that helps with identification; in addition, six months ago was developed a tool for automatic identification of bird species, made possible because of the huge amount of images available today. A minimum of 500 good-quality images of a given species are necessary for its automatic identification, and we have already attained that number for a lot of individual species. Such identification is taken as a first reference, which is later validated by experts. Of course, we must acknowledge that the platform has some limitations, since not all species can be identified using only photographs; however, in most cases it is possible to determine the genus or even the species. In Mexico we have implemented the platform a little differently than in most other countries. Here we have sponsorship from Carlos Slim Foundation to grant scholarships to guides and curators. Guides are chosen among the people participating actively, and who understand very well that use of this technology, even if their biological background is not so solid. They help us train others in several regions of the country, so that they may become guides in the future. In order to accomplish this, we offer workshops free of cost in every state of the Mexican Republic at request, in charge of our guides, and every year around 12 courses and 228 workshops take place. On the other hand, curators are post-graduate students of taxonomy, who help with species identification.

The network has 589,000 members around the world, 26,000 of which are Mexican. Up to now, there are 6 million observations in total, 600,000 of which come from Mexico. That is, 10% of all observations come from our country, which means that the 21,000 species present in Mexico are already represented by photographs. For a lapse of four years, this is an incredible accomplishment. I would like to share with you some examples of successful data recording. I really like the first one because I worked for six years in the Sanctuary of the Monarch Butterfly, and we already knew a lot regarding the places where this species hibernates. But when the population started to diminish (as in the case of many other pollinators, due to the use of herbicides and insecticides) we needed to find out what was happening along the whole migration route, which was not well known because of its huge extension, comprehending half a continent. Today, through this non-professional science project, in a lapse of three years we have identified over 40 resting places, where the butterflies recover their energy after a flight of 50 to 70 km. Some of those places have already been visited several years in a row, and it is a wonderful phenomenon. As you well know, the migrating generation of the monarch butterfly lives nine months, while the others have a life-span of only one month. Then the butterflies travel to places they had never visited, which were also unknown by the previous three generations, but nevertheless they rest at the very same spots year after year. So, in three years we have already identified 40 resting places, which would have been an extremely difficult task for any researcher or group of researchers, and it would have taken much longer. Just by way of comparison, the person who discovered the hibernation spots worked for 40 years to accomplish the task, and he also made use of non-professional science through the addition of small stickers to the butterflies.

We have projects at all scales. The smallest one takes place in only 30 m², at the roof of CONABIO, where we have a green-roof project. The largest ones may include the whole planet. There are projects related with several protected areas. A very successful one is *Parque Nacional Cumbres de Monterrey* (Monterrey Peaks National Park), where 289 participants have already recorded 1700 species. All information in the platform is open to everyone. Any person can check who is participating, which state and city is that person coming from, as well as the whole list of species by region, city, or state. The states of Veracruz, México, and Coahuila have already uploaded all their protected areas, which is a great accomplishment since the information regarding them was not available online, but now it is open for everybody at our platform, and open to contributions from non-professional scientists as well. Today, each and every person can start a project. One which has caught my attention is called Mariposas azules (Blue Butterflies). It is an initiative of a group of girls of ages between nine and twelve, supported by an ecological group, with the aim of defending the natural reserve lying in the center of Monterrey City, like an island in a sea of concrete. They decided to collect information regarding such protected area, and have already recorded more than 300 species. The advantage here is that identification is in the hands of experts worldwide, so they have an incredible support and are decided to avoid this natural reserve to be swallowed by urban development.

Another recent successful story is that of *Francisco 3*, the observer having registered more records, with 27,000 pics uploaded to the platform up to now. He has 10 hectares of land in a dry forest area near Mazatlán City. When we first met him three years ago, he told us he was in the process of building on it in an environment-friendly way. His purpose was to sell the land. However, after being granted two prizes as one of the best Mexican naturalists, he decided to turn his land into a natural reserve, and he got the corresponding certificate from the National Commission For Protected Areas. Currently, he runs eco-friendly tourism in one of the best covered natural areas in Mexico. If I, as a biologist, wanted to get to know the species inhabiting the dry forest, with my apologies to Dr. Sarukhán here present, I would not go to the station of UNAM in Chamela, but to the land of Mr. Francisco.

We are also working at schools with very interesting projects, in collaboration with *Reeduca* (Reeducate), a network dedicated to environmental education. Several schools working with this civil society organization have orchards, so that the children can get to know the origin of some food items, and we support them by building such orchards, including gardens for pollinators. There is a very serious crisis in Europe because insects are disappearing; the problem is most acute regarding pollinators, so we must be aware that everybody can collaborate to maintain the diversity of such populations. Therefore, we have selected Mexican native species which produce nectar and are available commercially, so schools can include gardens for pollinators, and then teachers as well as students may take pictures to identify such pollinators through the platform *Naturalista*. Lately, I have been visiting those gardens in the company of my son, and we spend hours in a row observing nature in an area of 25 m² or even less.

Another example of scientific results is the following: In the year 2008, we finally managed to ban the commercialization of all parrot species in Mexico, since most of them were endangered exactly because of that reason. However, importation of monk parrots from Argentina started immediately, and by 2009 we were already receiving 60,000 specimens of that bird every year. But the fact is that parrots escape quite often. According to a scientific paper published by the Mexican Journal *Biodiversidad* (Biodiversity), in 2011 there were already seven localities where monk parrots were living free. Currently, as can be checked in our platforms, more than 50 localities register the presence of such birds. This information has come through non-professional scientists, who have posted their findings both in *A ver ave*s and in *Naturalista*. This means that we have significantly improved in six years. Moreover, this early alert regarding invading species is capital, since they are the second most important cause of extinction of native species in Mexico City. An important exercise on reflection is to wonder how many species are known in Mexico City. Up to date, we have registered 1715 species, 330 of which are birds. This means that almost one-third of all bird species present in the country can be found in Mexico City.

At CONABIO platform, in addition to common and scientific names, species can be searched by their names in several native languages, as well as by coloration, distribution, if they are endemic or not, and several other criteria. This provides a lot of opportunities for learning, since people do not need the services of a biologist: Everything is available at the platform.

According to my own point of view, one of our most interesting accomplishments using technology is that now our platforms *A ver aves* and *Naturalista* are connected to a third one, called *Enciclo vida*, which is itself connected to *Sistema Nacional de Información sobre Biodiversidad de México* (National System For Information On Mexican Biodiversity). This system includes 11 million records of species worldwide, of which 110,000 correspond to Mexican species. Upon accessing *Enciclo vida*, one can simultaneously check scientific records from university collections and non-professional records, all of them with an accompanying photograph.

To finish, I would like to comment that the participation of society in non-professional science has increased, particularly through these two platforms, which are the most important worldwide: *A ver aves* and *Naturalista*. Contributions are not only due to Mexican citizens, but to international scientists and amateurs as well. Moreover, I believe that in the future this kind of activities will be the greatest Mexican contribution to the knowledge of nature, since it is growing incredibly fast in comparison with fund recollection for scientific projects, as Dr. Sarukhán already explained. It has a myriad of applications, like vectors of diseases, agricultural plagues, forest plagues, endangered species, and many more. However, I agree with Dr. Sarukhán in that the most important aspect of non-professional science is the fact of society being involved in the acquisition of knowledge. A real social network has been born. We are all connected with each other, and if I go now to any state of the Mexican Republic, I can find people I know from the 23,000 participants in our platforms. The platforms allow us to know who is expert in which topic, how each person likes to work, and also there is a general attitude among naturalists of helping each other to learn. If you check the comments, you will find conversations where somebody asks how to identify a given specimen while several others take the time and make the effort of explaining what they know

in that regard, so that everybody can learn. The two naturalists having more comments in Mexico City are Poncho and Gonzalo, each with more than 10,000 photographs, who have already learned how to identify species. They help several other people in the platform, but in addition, without our knowledge, they both decided to organize photographic expositions in their neighborhoods. They print their pics and make expositions on the streets, so that people get to know and recognize what they see every day. Therefore, the platforms help create initiatives we had not even thought about.

Thank you very much.*

Nuria Sanz

Representative of the UNESCO Office in Mexico. Mexico.

Thank you very much. Good afternoon everyone. As always, it is a pleasure to be in El Colegio Nacional, an institution which should be multiplied. Now that we talk so much about cloning, I believe it would be very interesting to clone it in the whole country but, more importantly, in whole Latin America. It is very enriching for UNESCO to be here again with all of you.

Sissi Cansino, moderator of this panel, mentioned that binomial *education* and *science*. To start my approach I will change a little the order, and probably prepositions as well. We were talking about science education. My approach this evening will be aimed towards science by itself as a form of education.

I believe many of you have read the document Agenda 2030 from UNO, and all of us who belong to the world of science or to the world of culture (we are all interested in innovation, anyway) have been forced to, I am sure, practice a bit of archaeology while reading such document, in order to find some of the fundamental and central concepts of what we are and what we do for the construction of community and citizenship.

Since 70 years ago, UNESCO[8] is a specialized agency from UNO. Of course, upon hearing this we wonder what it specializes in. Because we are talking about basic science, social science, education, culture, and communication. Then, what does it really specialize in? Well, it exactly specializes in articulating all those fields

* *Transcription*

[8] United Nations Education, Science, and Culture Organization.

related to the production of knowledge, and such articulation turns out to be urgent and necessary nowadays, but not always easy. This is not a great moment for trust in multilateralism worldwide, but in Mexico it happens to be, and my organization celebrates this fact every day, which brings me and my partners constantly closer to each other.

I would like to recall a couple of facts regarding a relation of 70 years between science, UNESCO, and Mexico. When it was not yet decided how the distribution of activities was going to be organized after the San Francisco conference of UNO[9], where the institution as such was founded, Mexico sent an extraordinary delegation led by Alfonso Reyes and integrated by several Mexican scientists and intellectuals, like Jaime Torres Bodet. They were summoned by the Minister of Science of the United Kingdom, Ellen Wilkinson, who wanted the main foundations to be established, and who remarked that science must help to rebuild the concept of humanity. Then the Mexican delegation stated: "Yes, but to build a perpetual peace we need an agency specialized in education, culture, and science", and that is exactly what UNESCO is today. Therefore, I find it very important, from the place we are standing now and considering science the main subject of the sentence, to recover this first step, which is a very Mexican step. A second step, also extremely important, is that the first scientific commission from UNESCO was led by the Mexican delegation, which in turn was led by a Mexican female ambassador: Paula Alegría. I believe that tells a lot about the reasons why we are here, as well as the reasons why this discussion must, evidently, answer the questions that have been so kindly facilitated to us. Regarding those questions, I choose three different approaches. I will talk about the first question[10] from the standpoint of harmonious community life; about the second one[11] from the standpoint of integration; and about the third one[12] from the point of view of education.

The Age of Enlightenment brought many good things, but also some I consider reproachable. Among the latter, since 150 years ago, or even more, we mark a clear difference between the ways we approach scientific and non-scientific knowledge. Just as if creativity were the axis or the foundation of what we know as Fine Arts and culture, but were not necessary for science. We doubtless need science for several reasons; without science we cannot explain the human species, without science we cannot explain innovation. Humans as a biological genus is very special in nature: since 3 million years ago we innovate, build tools, improve them, take possession of them, and transform this technological knowledge into something that accumulates, being constantly repeated but slightly improved at each iteration, and that is what makes us truly human. To manage the development agenda, when I told you about the need of some archaeology, I meant that we people focusing in science, education, and culture really have to read the small print to find our disciplines in the development agenda. Those working on culture will notice that not a single objective in the development agenda of the United Nations is related with culture. Let us think if we can conceive a form of development which excludes culture in any kind of agenda, the national, regional, or international. Of course, there cannot exist a concept of development independent of a certain way to be in the world, a certain cartography, a steer of principles, of values, of beliefs, of practices, which is what we call "culture". However, if we keep on with our archaeology, it is not easy to find that term "science" in such agenda either. In Objective 16 "scientific development" is mentioned. It is as if, in this very long document, culture and science worked only as adjectives, not as the subject of the sentence. It is clearly not possible to build such an ambitious agenda, so extraordinarily participating and which will mark the beat for the people of the whole world, without joining those two points of view which the Age of Enlightenment separated: culture and science. Probably this agenda will help us discover, hopefully, that we are finally getting rid of this mistake we live under since the mid-18th century.

For UNESCO, science goes beyond what is known as basic science, engulfing social science as well. I believe this is a very important binomial. To think of social science as basic science is probably the only way of leaning towards fairer societies, with a principle of actually exercising citizenship, based on the fact that inquiry and its practice are human rights of every citizen.

I previously mentioned that I wanted to approach the first question from the point of view of harmonious community life. What is truly most alarming is that a substantial portion of the technological population (and I am not talking only about *millennials*) think that "science" is almost a synonym of "technology". The truth is that science, both social and basic, should help us keep on allowing an analogical harmonious community life, and put an end to fruitless debates (from the telematic, technological, or simply digital points of view) when we treat very important topics which still do not have a clear expression in the development agenda, related with artificial intelligence. And here I am not talking about the old question we can find in some books, regarding the possibility of a machine getting a Nobel Prize. Beyond all that, what will happen with those machines able to make decisions? What will happen with those machines which cannot be humans above all truth, but nevertheless are capable of learning? Technology must be at the service of social development, a development involving values, and those values must never get away from the capability of doing science.

Even though culture and science do not play as important a role as we would like them to in the development agenda, we keep our spirits up and do our job. I will mention two relevant examples. The first one involves a joint project of UNESCO with L'Oréal Foundation which has been extremely successful. Year after year, this is one of the events I enjoy the most, because I have the opportunity of meeting extraordinary women, who are powerful, very young scientists, getting this award from Mexico for the whole world. They prepare several disciples and generate great fields for practice, and they focus, precisely, in social development. I would like to mention that other topics are considered as well; for example, last year the prize was awarded to a research project trying to find out what happened to the substance of the universe just after its creation. However, several very young female Mexican scientists are trying to find improvement, prosperity, and social harmony through science. Some of them focus on auditory problems which, even while they affect hundreds of thousands of persons

[9] UNO San Francisco conference: the United Nations Conference on International Organization (UNCIO), better known as the San Francisco Conference, was a convention of delegates from 50 countries which were allies during World War II. It took place from April 25th, 1945 to June 26th, 1945 in San Francisco, United States of America. In this convention, delegates examined and rewrote the agreements of Dumbarton Oaks. The result was the creation of the United Nations Charter, presented for signature on June 26th, 1945. The president of such conference was Alger Hiss, a diplomatic from the United States of America.

[10] How does science education promote tolerance, equity, inclusion, and harmonious community life?

[11] What is the transcendence of science education on efficiently enhancing the productive integration of individuals in a global society?

[12] What is the usefulness of science education regarding the purpose of education for sustainable development and for global climate change?

around the world, a lack of systematization had traditionally led to a lack of attention towards them, and it is a Mexican woman who is working on the topic. Another female scientist is researching this year the movement of amphibians in what we call ecological floors, and its relevance to understand the rate of global climate change. Still others work on neuroscience, trying to find direct social causes to the aging of neuron cells, and that has drawn a lot of attention worldwide.

The second example I want to talk about is that, as it is important for us to approach the new generations, in this country we will develop a project with all children who have the curiosity of inquiring the meaning of biodiversity and its usefulness in Mexico. I would like to mention that, in this country, UNESCO has learned a lot from a great institution called CONABIO, and we heartily celebrate its anniversary. With some of those grounds and along with our partners of CONABIO, we have created this program which will identify all children willing to become ambassadors on behalf of biosphere reserves. In Mexico, there are 44 UNESCO biosphere reserves, and it is truly important for us that the young generation, children of ages 7 to 14, become the defenders of such reserves, practicing and communicating with their classmates, their families, and their friends from other reserves.

The second approach, which I will use to talk about the second question, has to do with integration. I believe that rivers of ink have flowed trying to find inclusive definitions regarding quality in education, as was mentioned this morning in the first speech, and also involving the topic of integration... integration as well as inclusivity. I think there are some points we must acknowledge in this panel. For example, how can we avoid restricting our measurement to the things that are different? Because that is not enough. What happens with difference? We always consider it a hindrance, either intellectual or physical, but what happens when the difference is an excess of talent? I believe it often goes unnoticed, and I consider that an inquiry in science, as well as an inquiry in all creative talents, should emphasize this 20% of student population mentioned by the Subsecretario (vice-minister) this morning. If the curriculum is optional, the 20% of highly talented student population, which really needs to find a more creative and adaptive way, would develop much more easily. Children who are not hyperactive but have this extraordinary intellectual activity often go unnoticed, simply because we have not been able to develop their curiosity, so we only see apathy. Because those children may get bored with the pace at which the majority moves. Therefore, I think that when we interpret difference and inclusion, we must also be able to identify those talents.

The third element of my approach, with which I will address the third question, has to do with education and learning. Every five years UNESCO produces a report of its activities worldwide. The last one was presented along with Dr. Sarukhán at the premises of CONACYT, to which I assign a feminine gender, as I do to every scientific institution. I am already known in Mexico for this practice and I will keep on with it. I will only talk about a certain percentage mentioned in such report. When we talk about mathematics, engineering, and other basic science studies, the percentage of women involved starts going down as we come closer and closer to PhD. We have already reached equality till the end of undergraduate level, but there are important differences. The first one is that, at the end of PhD less than 40% of the population is feminine. The second one is that the percentage diminishes even more when we look at women in decision-making positions at scientific projects, where it almost comes to 20%. These figures show the same as an analysis of UNESCO tests, like PERCE, where girls of age 6 who are very good at reading and writing but not at mathematics,

say the reason they got a low mark in that subject is because they "are girls". That is an answer we can simply not accept. It is a social debt, and that is why we have set ourselves the task of understanding that we can only address this question at the medium and superior levels of education if we start treating it since a very early age. For this purpose we signed an agreement with Siemens Foundation (here with us is Ulrike Wahl in its representation) to develop a program, along with INNOVEC, to identify what is happening since kindergarten, both to children and teachers. In such a way we can understand the origin of several issues, for example, when girls tell us: "In school icons I am represented with hair buns jumping rope, while the boys appear with a white coat and a test tube". So there is where we must start working to diminish the gap. Therefore, we have organized a national forum including four generations of Mexican female scientists, since the first woman to use the labs of UNAM (National Autonomous University of Mexico, from its acronym in Spanish) when its new premises had just been built, to the teenage girl who just won the Olympiad of Mathematics, and is Mexican. Along with these four generations and four inter-generational testimonies, we will make the presentation of a book with Mrs. von Siemens, with Ulrike (Siemens-Stiftung Foundation), with our partners from INNOVEC, at the premises of the United Nations, the day after tomorrow at 11:00 AM. All of you are invited. I will not talk now about the book and its conclusions, since that will be addressed at the presentation.

However, I wanted to briefly mention the topic because, in the first place, I would like to thank Mexico for keeping on organizing these meetings, thus making history; I think it was important to share this accumulated

knowledge today. In the second place, because it is important to me for creativity and inquiry to keep discovering talents we do not see, simply because they are different. And, in the third place, because to have a fertile and secure territory, able to guarantee a balanced development, we need girls who are scientists.

Thank you very much.*

İrene Pisanty Baruch

Faculty of Sciences. UNAM. Mexico.

I thank thoroughly the moderator, as well as the organizers for inviting me and providing me with this completely unexpected opportunity, for which I am truly grateful.

I believe that science is like culture. It is a part of culture itself. I do not know why we talk about science and culture; that is only a bad habit. We have a lot of art museums, we have a lot of libraries (more and more empty as time goes by, since there are other ways of accessing reading material), but we have very few science museums. In such a big city[13] I believe there are only two, among hundreds of museums of other kinds. This happens because we have been convinced that science is very difficult, reserved for people with very peculiar and singular characteristics.

Some time ago, when it did not mean to risk my life every day, I used to ask random drivers for a ride along Insurgentes Avenue. I was asked: "Where are you going?", and I would answer: "To the Faculty of Sciences", so they would ask again: "Political Sciences, is it?". "No, no: Faculty of Sciences".

There would always follow one of two possible comments: either "you are a genius", which I am not, or "how is it possible, being you a woman?". "So what?", I would reply. "Oh, right, you are a biologist; that is all right for girls". Those conversations were uncomfortable. The thing is, we repeat those scenes all the time. We have talked so much about how girls are not stereotyped towards science, how they are not dressed in a white coat, but in a princess

* *Transcription*

[13] She is talking about Mexico City.

gown. But let us talk about how there are less boys than girls studying biology, but much less girls than boys in studies involving a lot of mathematics. Let us talk about how science should be taught, and about the fact that nowadays, to educate has more to do with un-educating and un-teaching than with teaching itself. The task is mostly related with pointing out all the false information they have, because the amount is so huge that there is no time to teach the true facts we would like them to know. Those of us who work on environmental topics face this every day! But I am sure that everyone working in science, be it exact, natural, or social sciences, live this situation. Because knowledge, culture (and I consider science as a part of culture) are social constructs. Why are there less women with a PhD, or in a decision-making position? It is because of their families, since the idea that "that is not for women" is very widespread, as well as the idea that women are incapable. But also society makes it very difficult for women, to the point that in highly competitive areas, like pure and applied sciences, academics, and public service, a woman must decide individually between having a family are building a career. I do not understand why those two things must be incompatible, and why such a decision involves only one gender, excepting pregnancy and the first months after giving birth.

The whole society has marginalized women from science. I will give a very simple example, but I believe that probably several of you, perhaps prompted by curiosity, have watched or even followed the series "The Big Bang Theory"[14]. So, tell me, which female scientist appears in there? None! Well, that is not true, because there is one female scientist, the girlfriend of Sheldon Cooper: the one who is ugly and not sexy, and the one having a bad relationship. Everyone laughs so much with the series, but to me it just "gives me the chills", since the idea is pointless. After all, we are repeating and reinforcing in the classroom, since baby-care to post graduate studies, the vertical structures of decision-making and assignation of roles. What we need is an education where we do not reinforce what does not work, and where we enhance what actually does. For example, undistinguished creativity from men and women, the capability of men and women to work and cooperate together, to build science together, to stop despising applied science as if it were second-rate, to start respecting completely those branches of knowledge, and considering that publishing in the *Journal of Very Difficult Results* is as important as developing and managing a plan for a protected natural reserve, a mechanism to get clean energy, and thousands of other things I do not have the time now to talk about.

Science education must be as important as any other topic. From a scientific point of view, history may be more difficult that physics; the difference is that history can be learned by heart, while physics, when memorized, is not very useful in a test. But we have turned science into something reserved for a select group, which after all is not so select and not much of a group. By picturing science as something reserved for geniuses, we have left several people outside of an activity which is essentially ludic and highly creative, extremely enjoyable, and having two very important advantages. The first one is that science teaches us to enjoy effort, that is, nothing is more satisfactory than what we accomplish through hard work. It is not acceptable for children at school to complain because science is hard and not fun. I affirm that science implies hard work, but it is very fun as well, and the funnest things are those implying hard work. The second advantage is that science teaches us to put our work in the weighing scales every day. Scientific work is a collective task which first requires a great individual effort, and then those results must be put in the *weighing scales*[15]. That means to present our research at a group of second graders, at a post-graduate seminar, to send it to the editors of a journal, to submit it to a group of experts with the aim of generating a given public policy. To put our work in the weighing scales may not be comfortable, but it is utterly necessary, so necessary and enriching that it must be taught to students since they are young, very young. Another very important characteristic of science, according to my humble opinion, is that it teaches us to collaborate, to listen to criticism, to criticize properly, that is, it teaches us to establish a dialogue, and I believe that our society urgently needs dialogue, not only regarding politics, but also concerning science and knowledge. Some years ago I was listening as a famous ecologist ranted about the fuss taking place around a very beautiful lunar eclipse; he was telling: "How is it possible that they are spending money in astronomy? It is like spending money in poetry!". And I replied, "You have just put yourself an F-minus with a permanent marker. How can you ask why? Because it exists!".

Maybe what we need is to turn it into a life-based experience, to teach students that science is made, constructed, and does not just "happen"; it is fun to make it and everything matters. I am very worried because there is a very strong focus in technology (of which I am a fan, by the way), but it seems that other areas of science are not considered important because they do not render short-term economic profits. Whatever does not get a patent is worthless, and that is an idea I have heard repeatedly from official sources in the last few years. But the truth is that we can never know if the basic discoveries arising from the curiosity that defines us as humans will ever have a practical use. We will never be able to know that. Moreover, in the strict sense of the term, very few things have a practical use. I do not think that any literary exercise has turned any young writer into a millionaire, what is then the value of literature? I believe we need to reflect in how the curiosity that makes science work, the satisfaction resulting from scientific work, and the service to society rendered by the scientific process, are as important as any of our productive activities, and may greatly contribute to the quality of life in our society, from very basic topics, like medicine and the environment, to some as far-fetched as climate regulation, or the aesthetic beauty of nature, literature, or music. Lastly, science and art are both creative activities, but they are ruled differently. It is very surprising for me to find in *Google* that there exists an association actively supporting the idea that Earth is flat. The concept is just unthinkable, since there are so many photographs taken from high up in the atmosphere; there is no room for doubt. One would assume that a person who believes that will not get very far. But, what happens when somebody tells us that vaccines are harmful? We just have to check the data to notice that, since three years ago, we have been having epidemics of diseases we believed already controlled forever. Then we have to remember that science is a social construct, which makes us repeat social structures we do not want, like "women are not capable" (I am honored to share this panel with three women who have proved to be quite capable). We must remember that education is not about *trimming* neurons, but about nourishing them. We must not only prove how fun science is, but also how easy and gratifying it can be, and show the students how science works as an everyday activity. Everything we do nowadays is related, up to a certain point, with scientific and technological

[14] A television series created in the United States of America by Chuck Lorre and Bill Prady.

[15] In the sense of letting them be validated by colleagues and experts.

work. To finish, I would like to say that without sciences, and I talk in plural because there is not only one science, but several; so, without sciences we cannot go forward, but also sciences alone are not enough.

Thank you very much.*

Leah Pollak Lee

Chile Foundation. Chile.

Sissi Cancino

How can we turn science education more visible for all children, how can we bring it closer to them, especially in this context of sustainable development we all aspire to attain, and for which all of us work so hard?

Thank you Sissi. This question is very great indeed. You have raised the level of this discussion, as Irene and Nuria did as well. So I thank Guillermo Fernández for this invitation from INNOVEC. It is a pleasure and an honor for me to be here at this panel, along with all your other guests, in this day when we all are going to learn a lot, including me.

I come from Fundación Chile (Chile Foundation), which is quite unique in its nature. It is a private institution, but its owner is the Chilean State, and it has always been an international private institution. Nowadays its focus is towards technological transference for the development of the country through innovation, but at its beginning the main task was the creation of new productive sectors for Chilean society and later, as the ecosystem kept on strengthening itself with the new technological centers and the growth of the enterprising world, its focus turned into the great challenges of our country, which no single actor can solve by himself, like the challenges of sustainability, energy, water, climate change, food supply, and formation of human capital, both in the educational and labor environments. Such is then the context that brings me here.

I would like to quote a sentence by Andreas Schleicher from Organisation for Economic Co-operation and Development (OECD), closely related to our work, and which emphasizes the situation we are discussing here today, as well as the challenges we face. Personally, it truly moves and interests me. Schleicher said that: "Today, classrooms belong to the 19th

** Transcription*

century, teachers to the 20th, and students to the 21st". Then we need a bullet train to take us forward 200 years, and that is not all, because countries are dynamic entities; for example, we have South Korea, Germany, and the United States of America as reference points, so the question is, how can we take this quantum jump for the countries in Latin America, for which the diagnosis is extremely poor? Roberto Martínez from OECD put Chile as a benchmark, but if we analyze our results in the PISA test for mathematics, we notice that our students of age 15 from private schools have similar achievements than those of public schools in Shanghai, so the situation is quite dramatic. In the PISA test, Chile is in position 36 out of 44 participating countries from OECD, but we had the last place in the OECD test regarding critical thinking. If we talk about gender gap, although at age 15 men and women have equal results regarding reading comprehension, mathematics, and science, according to the PISA test, only 25% of the female population chooses superior studies strongly related with such topics. For example, in informatics and biotechnology only one out of five persons is a woman, while in mathematics and computer engineering, which are the most important trends for the future, only one out of ten persons is a woman. Therefore the question arises naturally: how to bring more women to get involved and participate in science? However, in Chile, as Roberto Martínez showed, we thoroughly invest in education and, relatively speaking, in science too. Moreover, we spend more time in the classroom that our partners from OECD; in fact, two hours more than most of them, but even so our output is terrible. Therefore, the solution is not to invest more money or to spend more time in the classroom, but to bring quality to education, and to do it properly. When we analyze the context, it is evident that the time to act is now, and not only that, but our challenge is the exponential technological change we are living today. Beyond our capability as humans to adapt to such transformation, as Nuria Sanz just mentioned, the challenge we face is to generate social capital and to take the right decisions because, for example, self-driving cars already exist, the discussion is if we will protect cars or the pedestrians who cross the street when the light is red. That is the kind of decisions we are taking now and in the near future. That is why the creation of social capital around those topics is critical nowadays. Moreover, as Angela just said, we must not only be concerned with successful cases, but the whole scale is what matters, to find out among what percentage of the population such successful cases take place.

If we take a look at what Chile and my organization are doing today, we can arrange it in three broad levels which feedback each other:

At the Latin American level we are working in an initiative called SUMMA[16], along with Banco Interamericano de Desarrollo (Inter-American Bank for Development, BID from its acronym in Spanish), for cooperation between education ministries of seven countries: Brazil, Colombia, Ecuador, Mexico, Peru, Uruguay, and Chile. All those countries believe that education must play a central role, and for such reason they are involved in deep educational reforms. However, the topic of decision-making based on evidence becomes critical, that is, we are not only interested in large scale policies, but when generating such policies we must question what truly works and how much it costs. We are focusing in that aspect along with BID, regarding policy makers and concerned with advocacy, with the aim of taking better decisions and, finally, having the necessary information as a basis when making decisions, so that they are not dictated solely in intuition.

At a national level we have been working for 15 years with the Chilean Ministry of Education in what is called the mother policy for development of educational contents: the website *EducarChile*. Today, 60% of teachers in our country use the website to help them make decisions regarding contents and curriculum for their classroom. The website is completely indexed regarding curriculum, and it is very encouraging to notice the creation of several communities around best practices, based on what actually works in the classroom. It has been quite gratifying to witness its development, and now we are working on version 3.0, but the best of it is that in addition to 60% of Chilean teachers, several people from other countries are using the website, and turning their sight towards what is happening in Chile, so the whole process has been very satisfactory.

At a local level we have the initiative of STEM territories, which are also called STEAM, since we include also arts and design, or even STEAM+H engulfing humanities as well. Previously we used to call them *integral sciences*. It has always been a challenge to decide which term to use and that is one of the topics we usually discuss, because we like to coin certain helpful terms but sometimes it is difficult to reach a consensus among everyone involved. Ultimately, as Guillermo Fernández mentioned, the important part is the notion of *engaging the mind*, that is, to become more critical and collaborative, and to be able to formulate the correct questions, to question the *status quo*, and to move forward. Therefore, at the territory level we are implementing everything related to project-based learning, by now as a pilot program, in all classrooms of the Arica Region, at the border with Peru and Bolivia. The content is developed around the topic of the sun, since Arica is a benchmark regarding solar energy, and the native communities regard the sun as an important symbol. So, following project-based learning they work with all beneficial aspects of the sun. This has been done as part of a larger program regarding human capital gaps in the labor and enterprising sectors, with the aim towards a huge territorial participation which would allow us to escalate and see what truly works. We would like to have a national repercussion by working with *EducarChile* and SUMMA, creating thus evidence outside Europe and other countries, becoming then part of a larger learning community and being able to participate in decision-making.

On the other hand, two years ago we made, in partnership with UNESCO, a Latin American referendum regarding what students told teachers about the way they preferred to study. Young people want to learn STEM, although they do not use such term. They say they want to learn enterprising, they want to learn within their everyday context, they want to be in a classroom where the teacher does not provide all the information, but acts as a facilitator, guiding them through those contents; they want to have more actual practice, and to be in charge of their development and their learning. We all have been talking about regarding the importance of the context we act in, and the context of the context, since what happens today, in our highly digital world (like Facebook), is that we all belong to international communities in our every day activities, so that is also a relevant factor, and it is important that we are able to discern among the information reaching us through all such spaces.

Another fundamental question which, I believe, has barely been discussed today, is the connection with the productive sector.

[16] BID and Fundación Chile have agreed to establish a program of technical cooperation with the goal of facilitating the creation of SUMMA, whose purpose is to strengthen the decision-making processes regarding educational policies in the area, through the improvement of the quality of the available evidence, the promotion of innovation, and the feedback between policy creators, researchers, innovators, and educational communities https://www.summaedu.org/lanzamiento-de-summa/

I am focused in that aspect as well. Last month I interviewed ten leaders in digital transformation, and not of companies that one would assume to be digital by their nature, but focused in mining, manufacture, retail, and even LATAM Airlines, which are having today deep technological and digital transformations to keep on maintaining a successful business. Companies have realized that, independently of their current sector, they may soon become a technological or digital company. This is an incredible situation because it shows that we are all experimenting the same, which represents an opportunity, since the ones adapting faster and better will have an edge. However, the gap regarding human capital is huge, and I do not talk about a gap on technical or scientific formation, but involving the intersection with other abilities, because the leaders I interviewed are not necessarily technicians, since the most efficient leaders are those able to communicate, able to generate social capital not only through their employees, but by managing to put in motion teams with agile structures (nowadays known as *tribes*), capable of solving problems, since their activities are no longer defined by fixed tasks, but by challenges. The people belonging to those teams must be able to work autonomously, but also collaboratively, and they must be alert of any tension this may provoke; therefore, they must be communities able to take decisions in a short time span and at a low cost, which for Latin American countries is not easy. All this takes place in the context of leaders being worried about their children as well, because they may not be aware of the intricacies of the labor market, but they know that their children will have to be proficient in programming, but also able to formulate good questions, and that is why inquiry-based education is so important.

This diagnosis of the most critical aspects is what took Fundación Chile, along with the Chilean government, and particularly Corporación de Fomento de la Producción (Corporation for the Encouragement of Production; CORFO from its acronym in Spanish), which is the agency in charge of economic development dependent on the Ministry of Economy, to constitute a coalition with focus on STEAM (to include arts as well). For seven months we held meetings with around 40 institutions, including participants from the public and private sectors, as well as from the third sector and organizations of petitioners, with the aim of reflecting how to turn this into a central topic for the nation, and to plan an agenda highlighting the six main points which will allow the new government to take control, since we will soon have a new government. What we happily discovered is that such a change may take place much faster than originally expected, because Chilean curriculum allows it and, in fact, we were able to map the whole national curriculum and identify the places where these transformations may be applied. Today, more than ever before, we are in need of an active and contextualized learning, and teachers are eager to participate in the change, but they require support. Therefore, during this process we must find a way to support them since, even if they are willing, that is not enough and it is fundamental to walk along the path with them. It is necessary to build a culture STEM-STEAM, based on science, going beyond an equally important factor which are spaces for divulgation, which allow people to take ownership of knowledge and learning in such a way that their families accept it and, at the same time, can be accomplished easily, since less is more. Another critical point is learning throughout life, since school is not the whole world, so this must be followed up into the labor experience, and it is very important to work on establishing such connection. That is why the work of backbone organizations, like INNOVEC and Fundación Chile, is fundamental. Institutional efforts may have a limited scope, but with the aid of backbone organizations our reach can be greatly increased. Thank you very much.*

** Transcription*

Comments
REFLECTIONS
Answers & Questions
ANALYSIS

Panel III. How does science education contribute to a comprehensive education that promotes innovation, respect for nature, and a harmonious social coexistence in a global world?

- How does science education promote tolerance, equity, inclusion and cordial coexistence?
- How does science education transcend the productive integration of individuals into a global society?
- How does science education contribute to the goals of education for sustainable development and global climate change?

Sissi Cancino

We have a very interesting topic, which is extremely important now that one of the characteristics we are trying to enhance in education is a global education, an education in which children learn from questions, from curiosity, from inquiry, in an absolutely global world where it is everyday more and more important to work as a team, and to build, through such work, patterns allowing us to research, explore, and grow regarding tolerance. How can we then find a better topic than this?

Leah Pollak finished her intervention with a very important point: Many people from several fronts are participants of this effort to improve science education. In Mexico, we recently worked very hard to develop the new Educational Model; research and diagnostics were performed, and the result is that the axis of this new model is clearly "to learn how to learn", which has to do with all we have been talking about. That is, education is not only to go to a classroom where a teacher gives a lecture and stuffs students with knowledge, but the teacher must guide students so they can know how to learn and become able to apply it to what they encounter at school. Within the framework of so many institutions and initiatives to enhance this educational transformation, I would like to ask the panelists which is the main challenge for science education in the global society of today.

Nuria Sanz

I would like to slightly modify the question, since I would like to account for the accomplishments as well as the challenges. Let us consider the most recent econometric reports. Within 15 years, we will face a labor market whose possibilities we ignore in up to a 65%. Considering the situation, we need creativity to know what we are going to do with our jobs and our profession in the future, but the greatest challenge will be for those who start their professional formation in 15 years. Therefore, science, culture, and all other disciplines need to become opportunities of creative learning, because only with that capability we will be able to face the huge and uncertain future labor market. I would even dare to say that we will need an "overdose of creativity".

Another challenge is to develop the proper infrastructure at schools to generate true learning spaces, with the necessary conditions to allow and enhance such process. In Mexico, with its 33,000 schools, this will be an enormous challenge. UNESCO and Instituto Nacional de la Infraestructura Física Educativa (National Institute For Physical Educational Infrastructure; INIFED, from its acronym in Spanish) are working on the matter and will present a report regarding the importance of schools having drinking water, services, and multipurpose classrooms. How can we develop and apply the 2030 agenda of the United Nations, talking about water sustainability, when we know that some girls stay at home because several schools do not have the hygienic conditions allowing them to assist and take their lessons?

Another topic I consider fundamental is the existence of scientific literature. Recently I visited the International Book Fair (FIL, from its acronym in Spanish), and I was able to realize that there are a lot of books for children, but there should be more books dedicated to oppose the idea that science is difficult. I do not mean books giving scientific information, but providing an active reading which helps to overcome the fear towards science. This is something that must be greatly strengthened.

I also believe that science needs to be closer and more interactive with all other disciplines; for example, to practice science when we are thinking about art. Science needs creative diversity, especially in countries with such a cultural diversity as Mexico. Here I would like to deepen in the topic of intercultural scopes. Let us consider Latin America, where 500 languages are spoken, 50% of which are not restricted to one single country. This presents a very important area for collaboration. Science will be able to respect itself when we manage that little children in the classroom can count using Maya numbers (as it is done in the Yucatán Peninsula), and editor houses publish native scientific thinking. Science must be multicultural and traversal, aimed to give answers to society; this is absolutely fundamental. We must understand that the existence of several languages is essential to science, since it represents different approaches to understand the world, which must have a certain level of transitivity, so that we do not remain at the level of a social science. I thoroughly respect teachers in the mountain ranges of Guerrero and Oaxaca who can speak two languages at the maximum, but work in classrooms with children of several ages and grades, who express themselves in four or five different native languages, and to whom their parents may have transmitted a recipe, a medical treatment, a piece of knowledge of nature in their own mother language. We must respect this 40% of children who are considered to have difficulties with learning, but only because they are forced to learn in a language they cannot speak well.

Irene Pisanty

I am pathetically optimistic. I believe that it is possible to improve, but it is very difficult to notice our achievements because reports only state what is good and what is not at a very large scale. One of the challenges, and therefore one of the opportunities, we have to face is to focus in slightly smaller scales. Nuria Sanz has pointed out a very widespread area presenting a remarkable backwardness, where teachers have huge difficulties to reach their schools, and work in classrooms with children of different ages, grades, languages, and religions. Once survival is assured at age 5, education is the first priority. In several Mexican villages we wonder how, with so much scarcity, children manage to learn how to read and write, how to perform additions and subtractions, and sometimes even get to finish post-graduate studies. This is truly incredible.

I believe that we have great opportunities. Based on the universal access to education,

we must work to homogenize quality, and generate a better education for everyone. We must manage to have quality at all instances of public education. We have to make a great effort at several different scales, to be able to generate strong enough criteria so that everyone is able to distinguish between a scientific concept, a pseudo-scientific concept, other kinds of knowledge worth exploring, and mere quackery. Moreover, access to information is highly irregular, very different at a rural school than at one in Mexico City. But the problem is not only access to information, but the tools available to judge it, which are also highly dissimilar. If we enter the word "diabetes" in an Internet search engine, we get at the very same level publications from Mayo Clinic[17] and from the supplement "Salud para la mujer" (Health For Women) from the magazine *Vanidades*[18]. Nobody has the obligation to understand the technicalities appearing in the articles published by Mayo Clinic, but everyone involved in education, or having access to massive communication media, has the obligation to generate the necessary tools to discern truth from lies, to judge the quality of the information at our disposition. After all, the most important aspect of science is to question ourselves if what we know is really true. What if Aristotle, or Newton, or Lamarck are wrong? And that is how human scientific knowledge has advanced and moved forward throughout the ages. Probably the most difficult obstacle for people who have studied following traditional systems is not being able to question what they are told, or to accept being questioned themselves. In a professional dissertation at a very prestigious school, I once heard a student question a given result, and the synod asked sarcastically if he believed he knew better than somebody who had been awarded a Nobel Prize. I could not judge how pertinent the question of the student was, since it was a topic related with economy and I do not know very much about that, but the truth is that the educational system prevents students from questioning the information that is given to them; it is limited to produce answers instead of challenge students to build their own knowledge and their own answers. I definitely believe that is one of the greatest obstacles.

I insist in that one of the advantages of scientific knowledge is that it creates a common language; in fact, a very precise common language, which can be taught to everyone, whatever their mother language may be. I coincide with and celebrate the comment by Nuria Sanz, and that is why UNESCO has so much international prestige on that regard, but the fact is that science, regardless of mother language, generates a common language which allows us to understand each other; I mean that 2+2 = 4, not 4.5, not 8, not 88, but 4! Therefore, we must use this common language to promote both the acquisition of knowledge and the segregation of knowledge, because the access to information that we have nowadays is incredible, but we must use it wisely. The goal is not for more and more people to be aware of the minute details in the lives of celebrities (and I hope nobody will get offended by this comment); the goal is for more and more people to have high-quality information that allows them to make better decisions, and this goes from the everyday life of common people to the persons who get to decide how to manage a country, using real and not fake data.

[17] Mayo Clinic is a non-profit organization dedicated to medical practice. Its headquarters and research facilities are in Rochester, Minnesota.

[18] *Vanidades* is a magazine for women published in Spanish language, covering topics related with fashion, beauty, royalty, celebrities, health, travel, and cuisine. It is available at Latin America and the United States of America. It was founded in February 1937 at Havana, Cuba, by Editorial Carteles, S.A.

Leah Pollak

Something very positive nowadays is the existence of several organizations applying different kinds of effective interventions, but the challenge is to manage to take them to the classroom. In Chile we witness an over-intervention at some schools, and an almost complete lack of it at rural schools. It is not only about quantity, but about quality as well, because when too many new techniques and methods are applied at a given school, it is impossible to know which of them are effective and which ones are not. In this aspect, the role of the school principal becomes critical, not as someone who keeps order and structure, but as a leader who encourages teachers, moves forward the agenda, and fulfills the challenge of inserting the school into the community. It is very important to support school principals so that they are able to choose wisely among the available methodologies, considering that several times it is not a new technique what is needed, but a good feedback. There are several methodologies which can be applied at a low cost, and which can become incredibly effective, but their efficiency depends precisely on a good feedback. A good teacher who in addition provides us with a good feedback, generates high-quality learning in us as students, but also helps us to be able to give a good feedback ourselves to the new generations like, for example, our children. Therefore, it is as well fundamental to compromise parents with the educational project, and to manage that the school becomes an integral part of community development. Everyone, and this includes students, teachers, managing personnel, and parents, must be able to assess which methods are truly working, and to judge the available information.

Sissi Cansino

I thoroughly thank Dr. José Sarukhán Kérmez and Dr. Carlos Galindo Leal. This was truly such an interesting talk! The examples of amateur science platforms supported by CONABIO in Mexico show that, as Dr. Sarukhán mentioned during his exposition, the best approach to learn science is to work on it actively, and nothing can be more wonderful than this because it gives us the opportunity of getting to know it. These amateur platforms involve society in the knowledge of nature through science, and make people truly love it.

QUESTIONS FROM THE AUDIENCE

Member of the public

This is a comment and a question at the same time. I worked in an institution as head of a department. Once my boss asked me to make contact with Instituto Nacional de Energía Nuclear (National Institute of Nuclear Energy). The project my boss had in mind was for such institution to give us a small quantity of some radioactive material, so that we could attach a bit of it to the bees when they were leaving the beehive, so they would leave a track allowing us to localize the plants they used, in order to make a map and be able to better locate our bee-colonies. So the question I would like to ask is, how dangerous may such a radioactive trail be for plans, birds, the bees themselves, and other entomological species?

Member of the public

What kind of behavior or collaboration would you expect from the private sector in the different working areas you are involved in?

Member of the public

How is CONABIO managing to involve schools and ministries of education, so that they participate actively in the formation of teachers and students, for them to become active allies in this excellent effort you are developing?

Nuria Sanz

Regarding the first question, I will not talk much about the radioactive part, but I will try to answer it from the point of view of the reactive approach. I do not know how

necessary or efficient it may be, but to play with uranium or plutonium is often dangerous; probably physicists and chemists may be able to answer this question from such approach. I would answer it from the reactive point of view, and in this case reaction means culture. As we have undertaken some extraordinary projects in Yucatán Peninsula, and considering the teachings and the knowledge pool of CONABIO, now that we face an alarmingly decreasing number of pollinators and the necessity to enhance new sites of world patrimony, as well as to strengthen and unite several biosphere reserves in order to preserve such places, I can tell you that maybe scientists need uranium, but the communities in Yucatán, and especially the women in such communities who are working since years ago with melipona bees and developing their pollination, do not need any kind of radioactivity, but to be supported by the reaction of all those who could, for example, consume honey in a more informed way. On that regard, our reaction (not our radiation) is to be able to develop plans of community collaboration and distribution of products, whose label and bar-code do not only describe the extraordinary qualities of the honey itself in order to strengthen European markets, but also inform regarding the cultural effort involved. Therefore, I believe we need much more culture before we start to think about radiation.

Regarding the second question, I believe the private sector is absolutely necessary, but we need a private sector which is detached from the idea of personalized philanthropy, which is able to follow processes with an idea of continuity, which is involved in mid- and long-term projects, and most importantly, which is committed to fulfill the needs of the population. Lastly, I would like to comment that in this country, with its huge industrial capital, it would be desirable to develop a commitment with such sector, not only towards a social corporate responsibility, but also towards a *cultural corporate responsibility*, and for that we definitely need the support of the private sector. Thank you very much.

José Sarukhán
Regarding the first question, I am sure that your boss was a physicist, and I say this with full affect and respect (in fact, several of my best friends are physicists), but I consider that maybe he ignored that no radioactive elements are needed to trace the movement of bees and the routes they follow: It suffices to be a good beekeeper. Beekeepers in Yucatán Peninsula do not need radioactive substances in order to know where to place their beehives. I believe this is an example of a huge disconnection between the real world on the possible solutions to a problem, developed by people who do not understand such world. Therefore, the best solution to a problem of this nature is in the knowledge and the experience of beekeepers

Sissi Cansino
Thank you very much, Dr. Saruhkán. Nuria has already partially answered the second question, but I would like Irene Pisanty, as an academician from UNAM, to give her point of view regarding the importance of private sector collaboration for the development of educational projects, especially regarding science education, since I am sure that her comments will be extremely enriching.

Irene Pisanty
I believe that the participation of the private sector behaves as much everything else: When it is good, it is very good; when it is not, then it is not. I feel that we still cannot relay in its support permanently, but I am very happy that it has come closer regarding two aspects. One of them is to open and enhance long-term job opportunities, like those given by Eng. Carlos Slim in areas like Cuatro Ciénagas. The second one involves scholarships, and that seems extremely relevant to me for the scope of this forum. I witness this at UNAM, but I consider that Mexican students need scholarships even from nursery age, which allow them to get involved in activities like those we have been talking about, because such activities do not require special talents, but several years of preparation. On that regard, I believe that the private sector has a great opportunity in Mexico, and has already made an important difference, because those scholarships, although involving modest amounts, have allowed several youths to reach university, or simply to have a whole breakfast which keeps them awoken and active all morning. It is true that we have accomplished so many things without the aid of the private sector, and that in Mexico the incorporation of such sector to educational and research activities has been extremely slow; in fact, the private sector was much more efficient to find public support to the development of private enterprises, than to invest a little bit of private funds into the development of science and technology. This support from the private sector should involve a good dose of humanities, since such a situation would ultimately rebound in the benefit of the private sector itself. So, I still hope to be able to say one day that the private sector has made an important difference in Mexico at a large scale, because when it has done it at small or medium scales, the results have been very good.

Sissi Cancino
This message may reach the right people. Let us hope it does. Do not forget it: Scholarships so that everyone is given the opportunity to access quality education.

Leah Pollak, from the point of view of NGOs, which would be the importance of the private sector?

Leah Pollak
To begin with, the private sector gives meaning to the kind of initiatives we are encouraging. Secondly, it contributes with the idea of urgency, gives the momentum. In the third place, it helps to counter the inconsistencies due to changes in the government, since it allows to maintain initiatives for long periods even when public funds are taken back. Therefore, public funds help as seed capital, but it is private funds which allow projects to develop at a large scale. In the fourth place, although private funds are granted with the underlying idea of profit, as time goes by we see a qualitative change, where this benefit is not only considered from the economic point of view, but also taking in account the community and the labor world. On that regard, in Chile this process is only beginning, but at a global level is already taking place, and I hope it soon will be important in Latin American countries as well. To finish, the private sector plays an important role regarding innovation, which at the end of the day is the applied part. Even if today in Chile public funds represent the 80% of total investment in the area, we expect the situation to revert so that private funds will reach that 80%. Therefore, I believe we are in the right path. Thank you very much.

Sissi Cansino
Thank you very much. Then we may conclude that the support of the private sector is of the utmost importance, as long as their commitment involves mid- and long-term projects, is pertinent, goes beyond changes in government and, of course, includes scholarships so that everyone has the opportunity of a quality education.

Let us answer now the third question, how does CONABIO involve schools and communities in this huge and enriching project of amateur science platforms?

Carlos Galindo Leal
In this government office we had the opportunity that the Ministry of Education (SEP) got to know all the material we have developed. We have specific materials for preschool, primary school, secondary school, and a magazine intended for

superior-middle education. All of them have been incorporated into the resources that SEP has included in laptops and tablets. We have also uploaded and organized the curriculum of SEP so that teachers may easily find whatever they need, arranged by year and block, directly from the home page. The site "El país de las maravillas" (The Country Of Wonders) easily adapts to different kinds of electronic devices, like tablets and cell phones, and has a lot of material, not only regarding amateur science but also including songs, games, and trivias, among many other resources. A very important aspect of this page is that we work along with Consejo Nacional de Fomento Educativo (National Council For the Development of Education), so that all materials may be downloaded in rural areas, for teachers and students in the whole country to have access to them. Moreover, in the site there is material available in 14 native languages. Regarding environmental education, even though we do not have the financial resources to implement projects ourselves, we support and guide several NGOs which work on the topic. As a final comment, although we work directly with SEP, I believe it would be great if several of the materials developed by CONABIO where present in the new Educational Model.

Sissi Cansino
I thoroughly thank all panelists. Thank you very much for having brought us closer to nature, and therefore the science.

PANEL IV

How to assess progress in the development of scientific skills and competences in students?

Keynote Speaker. Eduardo Backhoff Escudero
Panellists. Kristina Reiss / Felipe Martínez Rizo / Carol O'Donnell
Moderator. Cimenna Chao Rebolledo

Eduardo Backhoff Escudero[19]

President of the Board of Métrica Educativa, A.C. Mexico.

EVALUATION OF SCIENTIFIC COMPETENCIES IN MEXICAN STUDENTS: SCOPE AND LIMITATIONS[20]

Science and technology play an essential role in the productive system of a country and in the daily life of its people. The best scenario would be for all citizens to have a basic scientific and technological culture, which allowed them to understand the complexity of our world, so as to know how to relate with the environment and to develop the capabilities required for modern labor. Scientific knowledge and technological abilities have become indispensable tools to interact effectively within contemporary society.

On such grounds, it is important to reconsider the way science and technology should be taught at the various levels of compulsory education. Our first concern is that scientific education should not be reserved to an elite but become accessible to everyone so that every Mexican is able to acquire basic knowledge and capabilities.

Considering the role that science education must play in our country, the main purpose of this talk is to try to answer two fundamental questions: 1) What can we learn from international evaluations (PISA)[21] regarding the scientific competencies of Mexican students? and 2) What can we learn from teacher's assessment regarding the learning process of students?

PART 1: WHAT CAN WE LEARN FROM PISA RESULTS?

The teaching of science in basic education intends to make students understand that science is part of the culture developed by humans throughout history, and that scientific knowledge is considered both a conquest and an asset of human society. The teaching of science allows people to develop intellectual abilities to understand and properly relate with the natural world, to take decisions in favor of the environment, and to solve a variety of personal and social problems.

Considering the importance of scientific knowledge and science education for Mexican children and youths, it is natural to ask some questions regarding scientific education in our country: Why does the average Mexican have a *magic* way of thinking instead of a *scientific* and *rational* one? Why are the learning achievements of students so poor regarding natural sciences? Why is the demand for science-related superior education steadily diminishing?

Although I do not intend to fully answer these basic questions, I will try to hint towards important aspects which may be helpful, mostly based on results of standardized scientific assessments, like PISA. Other elements will have to emerge from specialized research on the topic. So, what can we learn from PISA regarding the development of scientific competencies by Mexican students? We can learn a lot indeed, but first we must understand what this international assessment is.

PISA is a comparative study on educational achievements coordinated by OECD (Organisation for Economic Co-operation and Development), as had been mentioned earlier. Currently, over 70 countries and economies participate in the program, not all of them belonging to OECD. Its main purpose is to determine up to which point have students of age 15, independently of their specific educational achievements[22], acquired the

[19] When the talk was delivered, he was president of Junta de Gobierno, INEE. Currently he is president of Consejo Directivo de Métrica Educativa, A.C.
[20] Talk delivered on December 5th , 2017, at the 9th International Conference on Life- and Inquiry-Based Science Education (organized by Innovación en la Enseñanza de la Ciencia, A.C. and El Colegio Nacional).
[21] Program for International Student Assessment.

[22] As long as they have completed primary school.

fundamental knowledge and abilities to effectively and competitively participate in a globalized and highly technological world.

The project PISA started in 2000, with the participation of 28 countries (Pajares, Zanz, and Rico, 2004). It currently assesses three main areas: natural sciences, mathematics, and reading comprehension. The assessment process takes place every three years, with emphasis in one of the said areas. In the year 2015 the focus was on natural sciences. In addition, PISA occasionally evaluates other abilities of interest for participating countries, like problem solving, financial education, and cybernetic (digital) literacy.

Since the focus of this conference is scientific learning, it is important to know exactly what related aspects PISA evaluates and how are specific contents selected. To begin with, I must state that PISA is not based on the curriculum of any country, but in the opinion of international experts, who decide the knowledge and abilities (or competencies) considered basic for any student of age 15, independently of country and curriculum.

According to OECD, such scientific competencies are related with:

> *"...the ability to use scientific knowledge, identify questions, and reach conclusions based on evidence, which allows them to understand and take decisions regarding the environment and the changes it experiments due to human activity."*

Therefore, PISA is not useful to know the achievements of Mexican students regarding specific goals established in the curriculum they follow. However, as will be explained later, the competencies measured by PISA help us to compare what they learn in relation to what students from other countries learn. This allows us to assess the quality of our own curriculum, the pedagogical practices implemented by teachers, and our national educational system as a whole.

The conceptual framework of PISA is shown in Table 1, where it is easy to appreciate its distinct elements and components. For example, to explain scientifically a phenomenon related to life systems, be it at a local or regional level. Similarly, it is important to remark that such conceptual framework involves attitudes towards science as well.

On the other hand, it is important to understand the way in which PISA results are presented, in order to interpret them properly. The assessment makes use of a scale ranging from 200 to 800 points, with a mean[23] of 500 and a standard deviation of 100 points. The results are arranged into six levels of achievement, which describe the competencies of the students. Table 2 shows a summary of such levels, with their corresponding descriptions and range.

It must be remarked that a Level 2 of competence is considered the minimum for any student of age 15. A person at such level:

- Is able to use daily knowledge, as well as basic procedural knowledge, to identify a proper scientific explanation, to interpret data, and to identify the question that a given simple experimental design is addressing.

- Is able to use daily knowledge and basic scientific knowledge to identify a valid conclusion from a simple data set.

- Shows basic epistemic knowledge, being able to identify questions which are subject to scientific research.

[23] For countries belonging to OECD.

Element	Description/Definition
Definition	Capability of the student, as a citizen, to get involved in scientific topics and ideas.
Processes	• To scientifically explain phenomena. • To assess and design scientific research. • To interpret scientific data and evidence.
Knowledge	• Related to content. • Related to procedures. • Epistemic.
Content	• Physical System. • Life System. • Earth and Space Systems.
Context	• Personal. • Local. • Global.
Attitudes	• Interest in science. • Assessment of scientific thinking on research. • Environmental awareness.

Table 1. Summary of the conceptual frame of PISA. Source: INEE (2016)

Level of achievement	Competence description	Range
5 and 6	Capability to perform activities involving high cognitive complexity; with potential to occupy leading positions, scientific or otherwise.	> 633
3 and 4	Above the minimum and therefore considered good, although not at an optimal level to perform the most cognitively complex activities.	484 a 558
2	**The minimum required for the student to fit properly into modern society, and to be able to engage in superior education.**	409 a 484
1a and 1b	They possess some important abilities, but do not reach the minimum needed for superior education, or to fit properly in the society of knowledge.	260 a 409

Table 2. Generic levels of achievement in PISA. Source: INEE (2016 and 2018a). Shown here with proper authorization.

With this background in mind, let us take a look at the PISA 2015 results of Mexican students in the area of science, published in the official report of Instituto Nacional para la Evaluación de la Educación (National Institute for the Evaluation of Education; INEE from its Spanish synonym): México en PISA 2015 (Mexico in PISA 2015).

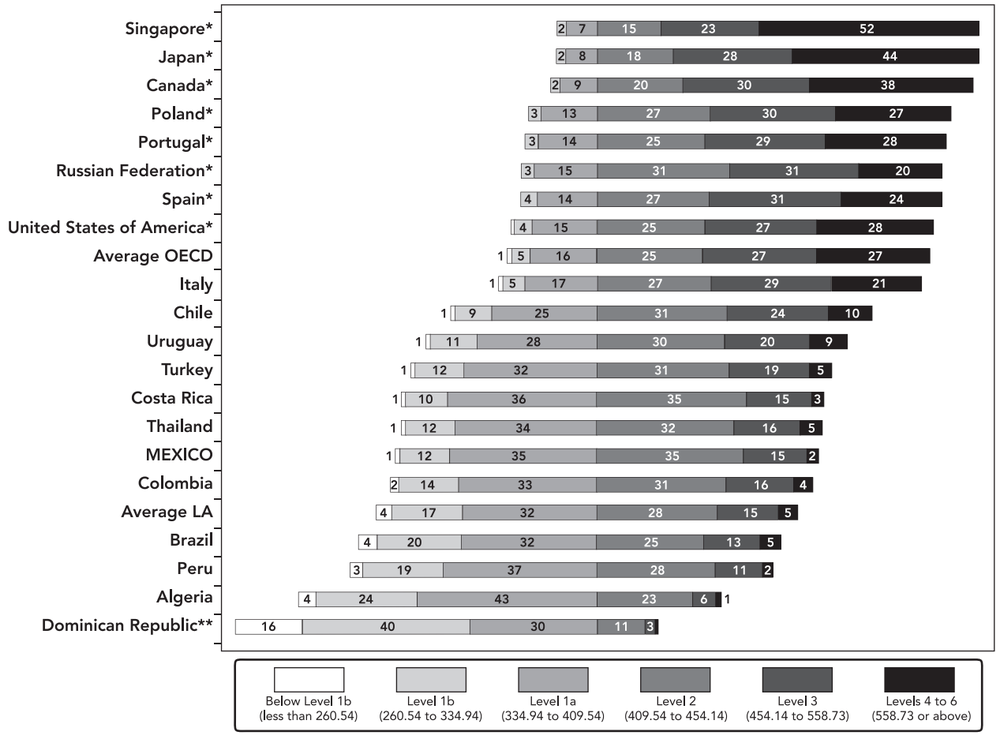


Figure 1. Percentage of students from Mexico and other countries at each level of competence, according to the scale for science in PISA-2015. Source: INEE (2016). Shown here with proper authorization.

Figure 1 shows the percentage of Mexican students at each level in the area of science, compared with only some of the 72 participating countries: those most important for us, like all belonging to our continent and some others from Europe, Asia, and Africa. It can be easily noticed that 35% of Mexican students reach Level 2 (the minimum), 17% are above that basic level, but 48% of our students of age 15 do not have the basic competencies in science, that is, almost half of our students are at Level 1 (a or b), or even below.

Figure 2 shows the position of Mexican students in relation to those of other countries participating in PISA-2015. As can be easily noticed, Singapore and Dominican Republic are in the first and last positions respectively, while Mexico stays in position 56 out of 69 participating countries[24].

[24] Although 72 countries participated in 2015, three of them were unable to assess the minimum number of students required by OECD.

Abbr	Country	Average	ee
SIN	Singapore	556	1.2
JAP	Japan	538	3.0
EST	Estonia	534	2.1
CHT	Taipei	532	2.7
FIN	Finland	531	2.4
MAC	Macao-China	529	1.1
CAN	Canada	528	2.1
VIE	Vietnam	525	3.9
HKG	Hong Kong-China	523	2.5
BSJ	B-S-J-G-China	518	4.6
KOR	South Korea	516	3.1
NZL	New Zealand	513	2.4
SLV	Slovenia	513	1.3
AUS	Australia	510	1.5
UNK	United Kingdom	509	2.6
GER	Germany	509	2.7
HOL	Holland	509	2.3
SWI	Switzerland	506	2.9
IRL	Ireland	503	2.4
BEL	Belgium	502	2.3
DEN	Denmark	502	2.4
POL	Poland	501	2.5
POR	Portugal	501	2.4
NOR	Norway	498	2.3
USA	United States of America	496	3.2
AUT	Austria	495	2.4
FRA	France	495	2.1
SWE	Sweden	493	3.6
CZR	Czech Republic	493	2.3
SPA	Spain	493	2.1
LAT	Latvia	490	1.6
RUS	Russian Federation	487	2.9
LUX	Luxembourg	483	1.1
ITA	Italy	481	2.5
HUN	Hungary	477	2.4
LIT	Lithuania	475	2.7
CRO	Croatia	475	2.5
ICE	Iceland	473	1.7
ISR	Israel	467	3.4
MLT	Malta	465	1.6
SLK	Slovakia	461	2.6
GRE	Greece	455	3.9
CHI	Chile	447	2.4
BUL	Bulgaria	446	4.4
UAE	United Arab Emirates	437	2.4
URU	Uruguay	435	2.2
ROM	Romania	435	3.2
CYP	Cyprus	433	1.4
MDA	Moldova	428	2.0
ALB	Albany	427	3.3
TUR	Turkey	425	3.9
TTO	Trinidad and Tobago	425	1.4
TAI	Thailand	421	2.8
CRC	Costa Rica	420	2.1
QAT	Qatar	418	1.0
COL	Colombia	416	2.4
MEX	**MEXICO**	**416**	**2.1**
MON	Montenegro	411	1.0
GEO	Georgia	411	2.4
JOR	Jordan	409	2.7
IND	Indonesia	403	2.6
BRA	Brazil	401	2.3
PER	Peru	397	2.4
LBN	Lebanon	386	3.4
TUN	Tunisia	386	2.1
MCD	Macedonian Republic	384	1.2
KVO	Kosovo	378	1.7
ALG	Algeria	376	2.6
DOM	Dominican Republic	332	2.6
OECD	**Average OECD**	**493**	**0.4**
LA	**Average LA**	**408**	**0.8**

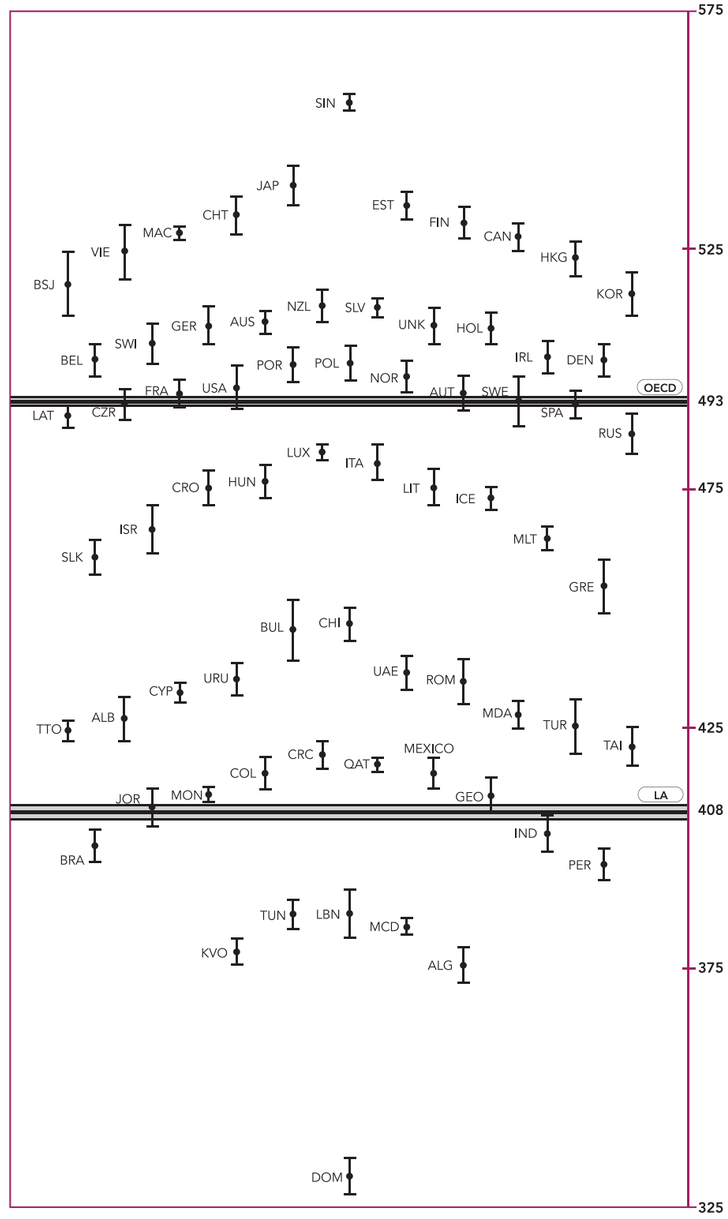


Figure 2. Position of Mexico in PISA 2015, Science. Source: INEE (2016). Shown here with proper authorization.

On the other hand, Figure 3 shows the results of Mexican students during the period 2006-2015, where it can be clearly noticed that there is practically no variation (0.3 points every three years). That is, there is no significant change regarding the learning of science.

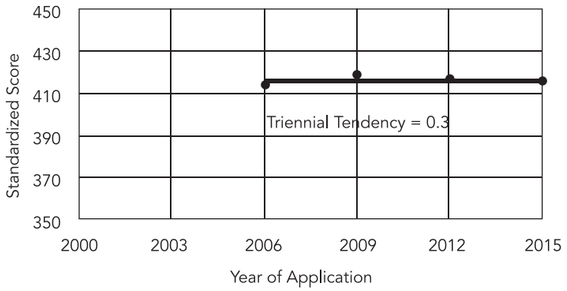


Figure 3. Tendency regarding the learning of science by Mexican students. Source: Backhoff, Vázquez-Lira, Contreras-Roldán, Caballero-Meneses, and Rodríguez-Jiménez (2017); INEE (2018a).

Factors Related with Learning

In addition to the level of achievement of students in the area of (natural) sciences, it is important for the Mexican educational system to know the social, personal, and educational factors related with the acquisition of scientific competencies. Therefore, PISA applies at least two different surveys: 1) regarding the specific characteristics of schools (which is filled by the principal), and 2) regarding the individual characteristics of the student and his family (which is filled by the student himself).[25]

The survey for schools includes questions involving: 1) academic level of the students; 2) specific characteristics of the school (the way it obtains funds, geographic localization, size of the premises, ethnicity of the students); 3) educational policies and teaching-learning processes.

The survey filled by students includes questions about: 1) attitudes towards the study of science (will to succeed, well-being at school, beliefs, and learning strategies); 2) personal characteristics (sex, age, level of studies, socioeconomic status).

As socioeconomic level (NSE, from its Spanish acronym) plays a major role on educational success, special attention is paid to it. Since it is not possible to measure it directly, PISA calculates it from related factors, like job and educational level of parents, as well as household goods. Since the relevant information comes directly from the students, the calculation of NSE is not precise, but in spite of this limitation it is still the best indicator to predict success at the science learning process. Figure 4 shows the relation of this factor with the results of PISA for Mexico and some other countries.

In this figure we can readily appreciate that there is a direct relation between socioeconomic level of the students (expressed in decile units) and their PISA results regarding science.

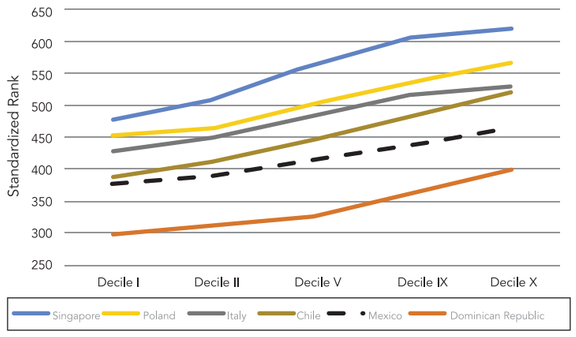


Figure 4. Relation between socioeconomic level of students and their PISA results in science: Mexico and some other countries. Source: Adapted from INEE (2016).

[25] Optionally, parents can also contribute by giving their opinion on household matters.

Attitudes of Students Regarding Science

A student's learning does not only have to do with school processes and daily life conditions but is also a result of the attitudes the pupil has in general towards learning, and specifically towards the learning of science.

Research in psychology and education has rendered solid evidence showing a positive relation between students' attitudes and their achievement in the learning of science. However, PISA has detected that the answers of students in the survey have a cultural bias and are subject to social desirability.[26] There is scientific evidence showing that students from Latin America tend to answer all questions optimistically, while those of the far East have a pessimistic approach. Therefore, one must be careful when interpreting the results of PISA regarding students' attitudes.

Figure 5 compares the attitudes and science results of students from Mexico, Japan, and Dominican Republic.[27] Theoretically, those with better attitudes towards the study of science should achieve better results. However, by observing the right side of the figure, it is easy to appreciate that such correlation is only true for Japanese students, while in the case of Mexican and Dominican pupils we notice the inverse situation, that is, students stating to have better attitudes are the ones getting worse results. As it was explained earlier, this may be due to a phenomenon of social desirability, were less capable students report being more motivated towards the study of science, which seems paradoxical.

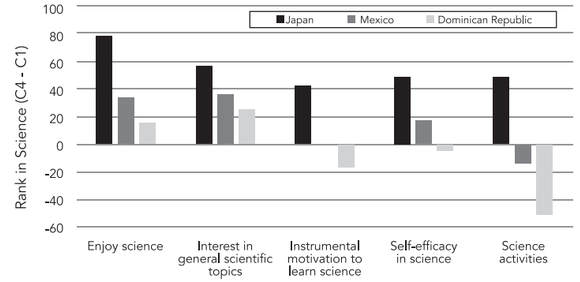


Figure 5. Relation between attitudes towards science and PISA results: Mexico, Japan, and Dominican Republic. Source: INEE (2016). Shown here with proper authorization.

PART 2: WHAT CAN WE LEARN FROM THE ASSESSMENT OF TEACHERS REGARDING THE ACHIEVEMENT OF STUDENTS?

It is important to remember that the goals of a given assessment determine its design, its application, and the interpretation of its results. For the teacher, the most valuable assessment is the one he or she designs and applies in the classroom. This kind of evaluation has a different focus than those developed to know the learning achievements of the students in a whole country, and to compare them with those of other countries, like the assessment conducted by PISA.

A good teacher makes use of various ways of assessing students: tests to measure acquired knowledge, written essays and projects, as well as direct observation of students and their interactions. Since the goal of this kind of assessment is to improve the learning process of students, giving them feedback on their academic performance, it is called *formative assessment*. Its usefulness as an element in the learning process is widely documented in several specialized studies, which show that

[26] There is a tendency to express what the student believes to be socially acceptable, instead of showing his true opinions and feelings.
[27] The results shown in Figure 5 represent the difference between the achievements of the 25% of students with better attitudes (quartile 4), and those of the 25% of students with worse attitudes.

pupils learn better if they receive detailed feedback on their achievements at school.

Mexican teachers of middle-high education (EMS, from its Spanish Synonym) use a variety of tools to assess their students, the most relevant of which are shown in Figure 6, based on a study carried out by INEE. Bars indicate the percentage of teachers who use the given kind of assessment, while diamonds represent how useful is the given tool in the teacher's opinion. As can be easily noticed, according to teachers, the two most helpful tools are active participation in class and exams based on memorization, being the second one considered the most useful by far.

According to international publications, there are three main reasons for teachers to assess their students: 1) to encourage them to increase their learning effort; 2) to obtain helpful information which allows teachers to improve their teaching strategies; 3) to be able to communicate the learning achievements of their students.

However, Dr. Anderson (2018) concludes that none of those reasons has proven effective enough as to justify the use of assessment in the classroom. According to this author, the results of a given assessment may have a very different meaning depending on the teacher. For example, some give priority to the capacity to accumulate information, to the possibility to apply such knowledge, or to the ability to critically analyze what has been learned. Therefore, the notes given by two different teachers at the end of the school year do not have the same meaning and cannot be thought of as equivalent. Depending on the moment and the student, a given teacher can be more or less demanding, according to the expectations regarding the learning process of each student.

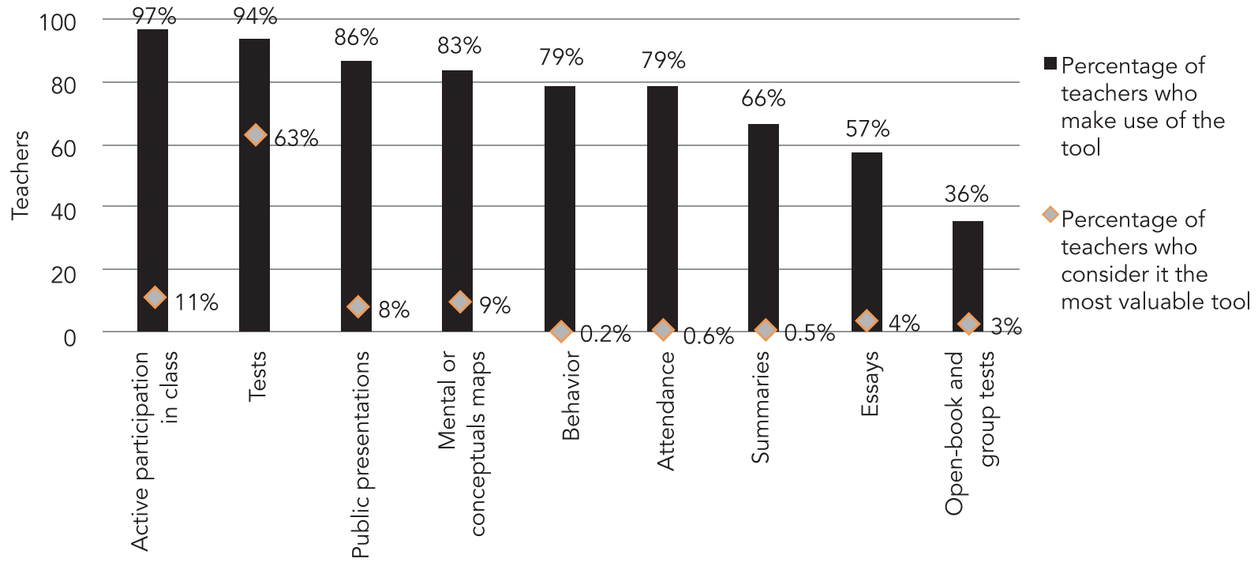


Figure 6. Tools used by teachers to assess the learning achievements of their students. Source: INEE (2018b). Shown here with proper authorization.

For this reason, the results two students get in standardized measurement may differ enormously, independently of their final notes. Studies conducted by INEE (see Backhoff et al., 2018) show that such differences may be of up to four grade points for 6th Grade students and of up to six grade points for 9th Grade students (middle school).

In their book *Knowing What Students Know*, Peregrino, Chudowsky, and Glaser (2001) state that there are three key elements to design an assessment model that efficiently measures learning achievements: a cognitive model, an observation model, and an interpretation model.

The cognitive model must have two distinct levels: a general one focused on the way people learn, and a specific model for each area of knowledge (for example, science). The observation model must be based on the beliefs and assumptions regarding the kind of evidence on the abilities of students that the assessment should provide. Finally, the interpretation model must be helpful to understand the information resulting from the assessment.

Unfortunately, in Mexico there is not a culture of scientific evaluation among teachers, and that is why the model I just talked about is unknown. Therefore, teachers use intuitive models to assess the learning process of their students.

CONCLUSIONS

Given the role of science in modern life, its teaching is of great importance and has to be considered seriously. In a world where scientific and technological developments are apparent in everyday activities, it is necessary to be well informed on these topics, to be able to interpret them correctly, and to find both meaning and social worth in them. In a country with a poor scientific and technological development, like Mexico, it is of vital importance to arise the interest in science in next generations.

As any other wide scale test, PISA measures what students managed to learn on a given topic during their whole life (since they were born till the moment of the test), both at school and elsewhere (home, community, and from the media). In addition to their performance in science, PISA measures other abilities needed to complete a test involving a high cognitive level, like reading comprehension, abilities for logical reasoning and abstraction, as well as working with numbers and problem solving.

PISA may be considered as a sort of thermometer for the educational level and the scientific culture of a country, which measures national "temperature" through the competencies of its population of age 15 who form part of the educational system. The abilities needed to solve the problems appearing in PISA go beyond what students learn at school. This explains why the ranking of Mexico at PISA in all three main topics (science, mathematics, and reading) is very similar (positions 54 to 56) and does practically not change from one year to the next.

PISA results work as an educational compass, sketching to us the direction in which we must sail in order to reach safe port. However, it does not tell us how to undertake such a journey. That we must find by ourselves, based on our starting point, the power we have to change our course, and the best ways to deeply transform both the educational system in general and the teaching of science in particular.

On the other hand, the strength of classroom assessments lies on its correspondence with pedagogical theories. Their limitations become apparent when they do not manage to capture the breadth and richness of the abilities being assessed. It is important for classroom assessments to engulf the complexity on learning which is currently emphasized. Unfortunately, a lot of them do not focus on the cognitive aspects suggested by research.

In a similar manner, they are not designed to detect critical thinking on students and are not based on scientific evidence.*

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** Document for the Presentation*

Kristina Reiss

TUM School of Education. Germany.

Thank you so much. Fortunately, we heard a lot about PISA yesterday[28] and so I just have to add a little bit. PISA is not about Knowledge so much it is about literacy. And I think this is something we have to consider. It is literacy, science literacy which is the ability to engage with science related issues and with the ideas of science as a reflective citizen.

This is very much apart from what just knowledge is. It is applicable knowledge, it is knowledge that children are supposed to learn because they are supposed to understand what they are doing.

PISA tells us that scientific competences comprehend explaining phenomena scientifically, evaluating and designing scientific inquiry, interpret data, interpret evidence scientifically. This is one thing that is necessary to understand. On the one hand, there is contents, definitely, physical systems, or living systems, or Earth and Space systems. There is a context in which children are supposed to answer content-based questions for example, health and disease, which is very important for them, or natural resources or environmental quality, topics which were very prominent yesterday. In addition, PISA gives some ideas of how competences are, so we should know there is a base line level in science, which is a proficiency level associated to certain points. I won't argue about these points, but it is just to mention that at certain level, students are expected, at least,

[28] For more information refer to the Magisterial Conference of Theme II presented by Maestro Roberto Martínez Yllescas, Organisation for Economic Co-operation and Development OECD for Mexico and Latin America.

to elaborate experimental designs of simple quality, to understand and to give information about these contents.

In addition, we are facing a new challenge: computer-based testing. Sometimes schools are not able to perform it because they don't have the equipment to do so. This is something, in my view, that we can learn from PISA.

The first thing I want to point is, do we take the challenge to understand literacy? Do we get into that literacy concept? Do we understand and accept that education aims at literacy and not so much at knowledge alone but at competences that make students able to master situations in a globalized society? To implement these elements in the national curricula is important, and it is important to support teachers to implement them in the classrooms.

I think the first thing we can learn from PISA is that it's not only about numbers, 400 or 500, or whatever, it's about a way to understand classroom teaching and classroom knowledge. So, this is one thing.

The next thing to point is that PISA is an International test. However, countries, societies, nations are very diverse. So, for example, in Latin American countries we face other problems than we face in Europe or in the US. We have many low socioeconomic States students and we know that these States predicts students' low competences in many countries. Fortunately, not in Mexico, according to the good news we heard yesterday. But for example, in Chile or in Peru. I tell you this because it is interesting to understand what our neighbors do, not only in terms of a worldwide testing. We heard a little bit yesterday about Shanghai, Singapore or about Vietnam. It is also important to understand what my expectation is and what my neighbors' expectation is. We have to consider that this expectation has to be embedded in the society. We must see what we can reach as realistic goals and how can we reach theses realistic goals. So, PISA provides goals. We have to understand what is realistic in my country, in your country. This is something that we have to analyze. We should accept international comparison and we should accept our numbers in this number line. But comparing results doesn´t mean that we have to compare our country with somebody who is like Singapore, in a situation which is economically privileged, and which is, on the other hand, imbedded in a totally completely different society. So, it is important to compare results always with countries which are in a similar economic situation, with a similar cultural background, and for me the latter is even more important. Understand your cultural background and understand what PISA means in this context. It is important to implement reforms embedded into society otherwise we would never get the support of the society and we need the support of our societies to understand the results and to go into reforms.

My third idea is about what do data tell us besides points, besides markings on a number line. It is important to analyze those data in depth. Yesterday we heard a little bit about students' attitudes about science and if you remember our OECD colleague told us a little bit about Korea's expectations in science and engineering. It is a very interesting topic because there are nations like Korea which are very, very, good in the PISA test. However, the Korean expectations of the children are far away from being like the ones in Mexico. We heard that close to 20% of the students in this country (Mexico) do have career expectations in science and engineering. Our colleague presented detailed information on the topic, so I won´t repeat it. However, the percentage of boys is 27.5 and the percentage of girls is not even 9%. So, in my view, it is important to understand that in some countries there are gaps. There may be gaps between SES (socio economic status), there may be gaps between different parts of society and there may be gaps between boys and girls. We have this boys and girls gap showing something different. Just a couple of days ago, at the end of November, results from 2015 were presented. With respect to collaborative problem solving, students were asked to solve problems with other persons. Worldwide, girls were much better than boys in this collaborative problem solving. Unfortunately, the difference in Mexico is low. Girls perform better but they do not perform that much better compared to the international standards.

I hope you see what I mean. It's not about points, it's going into the data qualitatively to understand what these data tell us with respect to what we can change. And this "boys and girls" data, is something we can change in our societies. So, fostering students independently of their socio-economic status and independently of the agenda is something that we could really face in all societies even those that do not that good results. So, I think initiatives to foster girls are important, very important and not only for the individual but also for the society.

PISA is an international endeavor and I will shortly add on this. It´s not only about the literacy concept or about competences of what we're doing in schools. PISA is embedded in a context which tells us that there are good conditions for learning, which foster learning situations and I think in the Science classrooms we have a lot of empirical evidence of how this should be.

Yesterday, somebody mentioned that it is all about the teacher, that is correct. But there are some other things in the classroom that are important. For example, we know very well that the active involvement of students is most important for success in science, that the quality and quantity of activities is very important but definitely supported by the teacher. There is good evidence that we should take this into account: successful work, problem solving behavior of the students and teacher explanations play a very important role into science classroom. So, we know a lot more than just the points obtained at PISA. We know about things that are interesting for all societies because they are not dependent on cultural context. Going into the classroom and doing something like process-oriented learning or like active learning is important. We can implement it and we know that the learning gains a higher level if students are taught in such a way and are able to learn in such a way. So, I think implementing active classrooms in which children participate is something we can all learn from PISA, because results in our country can be improved. We are able to improve results in our country. We can make children aware that learning is an activity. It is not only the teacher. It is not only the teacher that can do something. Students' active involvement is indispensable for learning, for understanding, and to get insights into knowledge, into competences and into literacy.

We heard a lot about this yesterday and I think it is very good. Reform processes are excellent, reform ideas are very good, the implementation is on its way. However, we need to know that education is a long-term endeavor. There is always a time gap between initiating reform processes and getting evidence of their effectivity. Changing education systems needs patience. We have to do so much to change not only curriculum, not only documents and ideas, but to get these changes into society, into the classroom, into teachers' routines and practices, not only in their minds.

I know this from our own experience. In Germany we started and reform process on education around 2000 – 2001 and now, after nearly 15 years, somethings are working, and others are still not really working. We need patience and we must learn from studies like

PISA. Patience is also a factor that must always be considered. We cannot go from 0 to 100 like a car. Fortunately, students and teachers are not cars, they are human beings with their ideas, with their willing embedded into society and with their cultural background.*

Felipe Martínez Rizo

Autonomous University of Aguascalientes, Mexico.

I will address the second question, but first I will make a comment regarding the first one, and I will refer to something Kristina said, and with which I agree almost completely.

I have always been absolutely in favor of the application of PISA in our country. I was appointed responsible of that since its beginning, and I consider that PISA has a number of positive aspects, but I also believe that it has not been used in the best way possible. I think that the frameworks from PISA, since the original one and the one used in 2006, up to the new one from 2015, are very good, since they give us a complete and coherent vision with the most enriching approach I know regarding science education. Science education is considered important not only for people planning to follow scientific studies, but for the formation of every citizen, including theoretical knowledge but also skills and procedural knowledge, as well as attitudes.

I believe that the tools used by PISA are very good, clearly much better than most tests we apply in our countries, since at least half the questions are open-ended. Moreover, it has a computer app. So, we are certainly moving forward. I think that our countries have learned a lot on this regard thanks to PISA.

However, the part which is not a test but refers to attitudes is much weaker, and I believe most of us are not fully aware of that. When we see, for example, that students from Mexico and USA have very poor results but are the most willing to follow scientific studies, and claim to have very positive attitudes toward science, then we should reflect on what is happening.

But in particular, I think the results have not been used properly. The focus has been in comparisons between countries in a highly critical way, without considering the cultural differences, as was mentioned by Kristina, and

** Transcription*

ignoring several other aspects. For example, PISA 2015 allowed a much better analysis of tendencies, but since there was a change in methodology, even the PISA report warns that, although comparisons in future will be more solid and precise, the opposite happens with previous comparisons.

A serious problem is what we were discussing yesterday, when tendencies are included. For example, the city of Buenos Aires was excluded from comparisons because Argentina, in contrast to what it had been doing previously, did not send a representative sample of the whole country, but only of its capital city. The results obtained by those students were, as could be expected, better than the average of the whole country.

Another problem were the differences observed in several Latin American countries, like Uruguay, Colombia, and to a lesser extent Peru, due to a change in the way an empty answer is assessed. Well, tendencies are a delicate topic. Another example which should make us think is the fact that Finland was the country moving backwards faster than any other from 2000 to 2015. Then we wonder, was not Finland a benchmark? I believe that the educational system of Finland keeps on being very good, even if the result in 2015 was slightly worse than that of 2000. Of course, if the result in 2000 was especially good, the decrease will be reflected in the statistics.

Then I believe we must be very careful. I also think that OECD has sometimes had a negative influence. For example, when it says that improving our PISA results in science would increase Mexican gross domestic product in 550%. I believe that a scientific approach should make us a bit skeptical, and in particular I am quite skeptical... It seems to me that such a statement has no basis whatsoever, and I would like to take a look at its grounds. Therefore, such an affirmation drives decision-makers, who often are not knowledgeable on the topic, to make harsh decisions based on non-solid information. With this I finish my comment regarding the first question.

Concerning the second question, what can we do for the assessment of scientific capabilities to become an everyday task? Since several years ago I have been working closely with teachers, not only on science but also on literature and mathematics. I have witnessed a lot of changes in education. Sometimes we have a negative vision and say that nothing has ever changed. I definitely do not agree. So many things are different now. If I remember my primary school and compare it with the reality of most primary schools today, I can perceive a transformation: Regarding the way children are treated, how they are respected, etc.

But, on the other hand, some aspects have not changed at all, and particularly concerning teaching practices for the development of the most complex capabilities; there we have not improved so much. The main reason is that it is a very difficult task. In our work with teachers we have witnessed that both teaching and assessing practices are extremely poor. This is due to several reasons. We have also noticed serious problems regarding the knowledge of teachers on the contents they are working with in the classroom, as well as their pedagogical preparation, and their attitudes. Yesterday somebody mentioned that certain people believe Earth is flat, and there even exists a *Flat Earth Society*. However, if we go a little beyond the surface, we notice that several people do not understand the matter thoroughly. If we ask any child, the answer will be that Earth is "round", because that is what they were taught. But if we inquire a little bit, most of them cannot tell any reason for it to be so. Still many people believe the 19th century legend that Columbus was the first one brave enough to affirm that Earth is a sphere, so his ships would not fall anywhere... but even the Greeks already knew such fact. So, there is a lot of ignorance on this topic, and not only among uneducated people. The anti-vaccine movement is very strong in California, especially among highly educated people who are, curiously, very skeptical on this regard.

I believe it is convenient to distinguish at least three different meanings in the term "constructivism". One of them, which to me seems unavoidable, pretty clear, positive, and supporting several pedagogical theories is the idea that the child is not a passive container to be filled with information, but an active agent who builds his own knowledge. I completely agree with that. But then comes the second step, which is very delicate, since we may think "then we must leave the child to do everything by himself, and the teacher must only encourage the student". That is extremely risky. The child needs help to move forward, and it is a very complex help. The jump from naïve notions to scientific concepts is not easy, and the teacher must have pretty complex capabilities to help children make it.

A third meaning, even more negative in my opinion, is the one taking us to the field of philosophy of science, with the idea that science is not a special form of knowledge, but as valid as any non-scientific form of knowledge. This leads to people believing in alternative medicine, and to the anti-vaccine movement. If science is a social construct, then the measles infections in California are a social construct too? If it were so, there would not be any reason to worry: We should simply construct it differently and the problem would be solved. However, a law has just been approved in California, stating that a child without vaccines can be rejected by any school. Some people say that the rights of the child are not being respected, but a child without vaccines may jeopardize the health of all other children. It is very serious because if the child gets measles, it may die; if it gets poliomyelitis, it will live but in a very poor condition.

This third meaning of the term "constructivism" seems very dangerous to me. I do not approve Comte's approach to positivism (very different than the one from others, who were extremely rigorous, like Mag). His approach was quite naïve, presenting science as a third step in knowledge, after theology and metaphysics, considering that the world was perfect and then scientific theories were absolute and definitive. I do not accept that at all. But I also avoid the extreme posture considering science as valid as any other form of knowledge, with no advantage over less rigorous methods. If it is so, why do we teach science to children if science and non-science are equivalent?

I believe such meaning of the term is unacceptable. I also dislike the idea of constructivism as a method of just letting children play. I mean, in such a case at least they will not be as stressed as under a traditional educational method, but they will not learn, they will not develop a scientific mind or rigorous attitudes, etc.

Then, how can we turn the assessment of scientific capabilities an everyday task at schools? This implies a substantial improvement in the professional capabilities of the teachers, both to teach and to assess. The two aspects are very important. But there PISA does not help us much. PISA helps us to understand our position, which is very important and that is why I support such program. However, it does not help the teacher to decide what to do. For that we need a different kind of work, similar to the one INNOVEC has been trying to do for several years. It is a task that, as Kristina just mentioned, needs a lot of time, since it implies a deep transformation in teaching colleges.

One of the aspects we have studied is the way students of teaching colleges are taught to teach science. The result is very sad. Of course, there are around 450 teaching colleges in the country; half of them are public and the other half are private; some are extremely bad and

others are quite respectable. I believe that the best ones make a very good work when teaching how to teach language. That has changed a lot recently, and now reading is much more encouraged, and suggested texts are more carefully chosen. Teaching of mathematics has also changed a little bit, thanks to the work of people like those from the Department of Educational Mathematics of CINVESTAV[29]. Not so much as language, because it is more difficult, but at least something... while in science we have not seen any change at all.

They have told us openly in several teaching colleges: "Look, we put the best people we have two teach didactic of language, as well as didactic of mathematics, but for the two courses of didactic of science, which are taken in the second and third semesters, we just put anyone, because nobody is knowledgeable in the topic". Therefore, those courses are always very poor. Then a deep transformation in teaching colleges is urgently needed. It seems that now it will start taking place. Let us see. It does not seem easy.

On the other hand, another deep transformation is needed regarding professional development for the hundreds of thousands of active teachers, because professional development activities have always been very poor. They have not triggered fundamental changes in teachers, so we need to modify the concept of professional development for teachers, which currently is mostly based on their own assessment. Teachers try to get a good result in their assessment, and are not worried about their own teaching practices. Then, what do we need for the assessment of scientific capabilities to be a reality at schools? Well, first of all, to substantially improve the professional level of Mexican teachers when teaching and assessing science, which is a fundamental task involving several years of work, but we have to start it as soon as possible.

This is what I had to say. Thank you very much.*

** Transcription*

[29] Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional (Center For Research and Advanced Studies of National Polytechnic Institute).

Carol O'Donnell

Director of Smithsonian Science Education Center. USA.

Hello. My name is Carol O´Donnell and I am from the Smithsonian. How many of you have you have heard about the Smithsonian? Ok good. We are in Washington D.C. in the United States and we are a very, very big museum complex. We have 19 museums and nine research centers, but we also are deeply engaged in science education throughout the globe. I direct what is called the Smithsonian Science Education Center[30] And I have been working with INNOVEC for... I think it´s about 15 years we've been working together.

And what I would like to talk to you today about is the third question, which is whether or not we have evidence that the types of learning that have been described by my colleagues[31] and have also been assessed by PISA[32], whether or not while we implement inquiry science education in classroom, do we have evidence that it actually works?

And so, I want to point out a few things that my colleagues mentioned. When Dr. Reiss talked about the PISA, she mentioned that PISA is asking whether or not students can

[30] https://ssec.si.edu/
[31] Agenda of the 9th International Conference on Inquiry-based Science Education in Elementary School.
[32] Programme for International Student Assessment (PISA), it assesses the extent to which 15-year-old students near the end of compulsory education have acquired some of the knowledge and skills that are essential for full participation in modern societies. http://www.oecd.org/pisa/aboutpisa/

apply knowledge. Can they interpret data? Do they understand the content? Can they put their ideas into context? Do the literacy skills increase with science? And as Dr. Martínez Rizo mentioned, can we also improve teacher learning and teacher practice?

And so, the question that the Smithsonian set up to answer was whether or not the work that we have been engaged in over the past 25 years and 15 years here in Mexico through INNOVEC, whether that actually has an impact. So, we call our work LASER. And it is an acronym, it stands for Leadership and Assistance for Science Education Reform. Laser is a model. You heard the Undersecretary for Education from the Ministry of Education, yesterday speak about the importance of pillars as support of reforms. For INNOVEC, as well as for the Smithsonian Science Education Center, LASER has five pillars. So, the first one is we have to put in place good curricular materials that are inquiry-centered and that are based on the research of how students learn.

The second is that we have to provide the materials to teachers, the objects that students need to learn science through inquiry. Yesterday we saw a wonderful image of a little boy with an iPhone and then next to him a little boy with a bird in his hand. We believe in the power of object driven learning, we are a museum, we believe in the power objects and so the idea is the second pillar. So not only good curricula materials but also materials that teachers need in order to teach inquiry-based science.

The third pillar as Dr. Martínez Rizo mentioned is teacher professional development. We have to improve teachers content knowledge as well as their pedagogical knowledge. So that is the third pillar.

The fourth pillar is: you have to have administrative' support. From the school system, from the state and hopefully also from the Ministry of Education. Administrative support and community support are important, partners like INNOVEC, or as Leah mentioned yesterday, a private partner that might be supporting your work. So that's the fourth pillar: community and administrative support.

And the fifth pillar is good assessments, so not just assessment that are multiple choice, that test your content-based fact knowledge, but as you noted, also open ended assessment items that test students critical thinking skills, as well performance based tests, that tests whether or not students can develop questions, design experiments, engage in analyzing data, interpret the data, communicate their findings to others and apply that knowledge to new situations as PISA expect students to do.

So what the Smithsonian set out to do within the five year randomized controlled trial study funded by our Ministry of Education, was to work with three states in the United States: New Mexico, North Carolina, and Texas, to determine whether or not, if you put these five pillars into place in schools: Curriculum, Materials, Professional Development, Administrative support and Good assessments that have performance based tasks and open ended tasks, do you actually see stronger results from the students who engage in inquiry-based learning, compared to students who learn through traditional means which for us is text book-based learning. And what we found out after a five-year study, after testing 60,000 students a year, 16 School districts, 125 schools, whether or not those students actually ended up learning.

And what we found out are five big results. The first result is that students who engaged in this kind of learning, actually did better than their peers when it came to performance-based tasks, that is, students who learn by inquiry are able to design experiments, to apply their knowledge, to answer critical thinking skills questions, compared to their peers who were learning science in a traditional way.

The second finding was that teachers were much more confident in their skills of teaching using inquiry, than teachers of course, in a traditional classroom.

The third finding, through classroom observations, was that students who were in the classroom with inquiry, were engaging in working collaboratively in teams, communicating their findings to others, reasoning from evidence, arguing from that evidence and those were all skills that as my colleagues noted are important for future preparation of the STEM[33] workforce.

The other finding, which was very surprising to us, was that when we looked at the state assessments for reading and math, the scores were statistically significant higher in their reading scores and in their math scores. So, the question is why? Why do students who engage in scientific inquiry in their classroom end up with higher reading scores and higher math scores? And our hypothesis is that students who are engaging in inquiry are measuring the speed of a moving car, they are calculating the acceleration rate of that car, they are growing plants and graphing the growth of that plant over time to look at trends, so that they are applying there mathematical skills to scientific concepts and as a result we saw higher mathematical scores from their state tests, their state standardized tests.

In addition, students are not only in an inquiry-based science classroom, in the states in Mexico that are involved with INNOVEC, they are not only doing science, they are also reading about science, writing about science in their science note books, communicating about science to their peers and to their teachers and as a result in this five year rigorous randomized controlled trial, we also found that the students literacy skills, reading skills where statistically significantly higher on the state test than their peers who were in a traditional science classroom.

So now the five-year study is over. We are done randomly assigning schools to receive the LASER program, the inquiry-based program or to just teach science as usual. So, the question is what happens now? So, we also received a three-year grant from our Ministry of Education to test what happens in those schools once we are done working directly with the teachers in Schools. So, once we step away and we are no longer giving teachers professional development, we are no longer giving the schools the materials or the kits, to teach through inquiry, does the school system continue to provide professional development to teachers? Do the teachers continue to use the pedagogical methods that we worked with them over the five-years? Do the students who received LASER inquiry-based science, continue to have higher scores than the students who were in the comparison condition?

And what we are finding, we are very happy about this, is that in our students' sustainability study, our students' scores are continuously higher now than the comparison students. So even though they were elementary students and they are now in middle school, their scores are still out ranking their comparison scores students. The middle school students who have gone into high school are selecting courses on science in higher rates than their comparison students.

And finally, in the school sustainability study, the schools are continuing to use the program, without the support of an external partner and

[33] An integral approach on Science, Technology, Engineering and Mathematics.

the schools are continuing to see teachers using pedagogy when they didn't before.

So, I say all this because we do have strong evidence that this type of inquiry-based science education that's being used in INNOVEC in schools of different states in Mexico, what we are seeing in the United States is that those students are engaging in much more advanced scientific thinking compared to the students who are in the traditional way.

So, this important work that is being done in INNOVEC, we are pleased to be a partner with INNOVEC in its implementation in Mexico to bring inquiry-based science to classrooms all over the country and we are pleased that we now have strong, rigorous evidence all over the country from a randomized controlled trial study, that shows that in elementary school and middle school, inquiry based-science education actually does make a difference and hopefully translates in PISA scores as well.

Thank you so much.*

** Transcription*

Comments

REFLECTIONS

Answers & Questions

ANALYSIS

Panel IV. How to assess progress in the development of scientific skills and competences in students?

- What does PISA tell us about the development of scientific competences in students around the world?
- How to make the assessment of scientific competencies a common issue within the performance tests in schools?
- What is the available evidence about students' progress in learning science through inquiry and experimental activities?

Cimenna Chao Rebolledo
Science learning and science formation is today much more than a privilege and an additional subject in the curriculum. In the complex and ever-changing world we currently live in, science learning and science formation are fundamental parts of literacy, of our educational formation. The most complex decisions that humanity as a whole must take in the immediate future depend on literacy, on the scientific knowledge we manage to have. Therefore, to question ourselves regarding assessment is to evaluate how we have been developing in this field, in this path towards a scientific literacy which is so necessary in the complex times we are living in.

Felipe Martínez Rizo
It is a fact that those five pillars are fundamental. I suspect that in several cases in Mexico, when we try to implement innovative approaches as has been done by INNOVEC since a long time ago, we will often lack the support of the said five pillars. The curriculum currently used in Mexico presents an additional obstacle, since it covers too many topics, and teachers often feel compelled to treat them all, which prevents them from covering each with the appropriate depth. I believe that outside assessments are not helpful to Mexico. Maybe the worst of them all is what is known as "Olympiad of Knowledge". It becomes definitely harmful for the educational system, and it gives a lot of problems in several schools for some weeks at the end of the school-year, when they are trying to identify the students who know better topics which are not important but are difficult, without understanding properly the difference between cognitive level and difficulty level. If I ask regarding the capital city of Mexico or the capital city of the state of Jalisco, it is very easy because both cognitive level and difficulty level are low; but if I ask about the capital city of Uzbekistan, the difficulty level is very high but the cognitive level keeps on being low, since the student only needs to memorize a name. In a similar way, when this "Olympiad of Knowledge" asks students the meaning of "coprolite[34]", it is a completely irrelevant question with no importance whatsoever, and which tells us nothing regarding complex cognitive capabilities. In the context of several schools, this becomes difficult because they are subject to a lot of pressure and activities. Therefore, some very important and positive efforts, like those undertaken by INNOVEC, may not generate good results because the aforementioned pillars are not present. Teachers may not have had a good formation, or there may be no support from those context elements towards the innovation of results. Therefore, the lack of results may lead us to think that innovation is useless, but the truth is that it was not implemented properly.

Kristina Reiss:
I would like to add two ideas. The example that was mentioned is very important. Professional development of teachers is something we promote and obviously we have reached better results in language than we have in mathematics and science. Language teachers are able to understand what application means. However, in science it is much more complicated, obviously. But when we talk about cultural differences, there should be no cultural difference in understanding the nature of light.

In my view, we should really get much more engaged with professional development of teachers. We take for granted that teachers will understand any ideas given in the curriculum. But I think it is much more than just the subject within these curricula. It is about the way to teach the subject, about the progression in learning, about how to work with children and so on. And this is something we need to practice. Everybody in the world needs to practice. Conditions are changing and the way to do the work is changing. We should take much more into account that this is also valid for teachers.

In my view, sometimes we offer much better professional development for many other kinds of professions rather than to teachers, because we think "teachers have been educated, they know the subject, and this is enough for another 30 years". But think back 30 years and think about development that has taken place in those years, particularly in science. I do not mean what is taking place in some very specialized industries that are far away from our daily life. I mean progress, in medicine for example, that came from specific ideas in the 1970s, 80s or 90s and that is now being applied.

I think we should focus on supporting teachers on how to get involved with this innovation on a regular basis not just in terms of incorporating these subjects in a new curriculum. We need professional development on a regular basis. In five years or so, many of our teachers need to get in contact with new results, particularly in science.

Carol O'Donnell
The challenge that I think we are all facing is that we recognize now that inquiry-based science learning does make a difference. Especially in students' higher order critical thinking skills and their ability to perform tasks that are much higher level. The problem is we remained in terms of our assessments fact-based driven. We believe too many of our assessment are based on assessing our students' content-knowledge about hundreds of facts. And yet yesterday we heard that students have access to content today in the tip of their fingertips, through their phones, through their computers, through their laptops.

We have to move away from pushing content into students and move towards getting students to use that content to solve complex problems in much more advanced ways. That's the future that our students are facing. And so, the question is assessments have to change from being simply multiple-choice content driven. The reason we see the results we do in PISA is because they are much more, as you noted, applying knowledge to new situations. Our

[34] A coprolite (from Greek "kopros", excrement, and "lithos", stone) is a fossilized piece of excrement.

classrooms have to get to the point where we are also not just pushing content into students' heads but given students opportunities to understand that knowledge and to apply it. Our assessments have to evolve soon.

I also wanted to note that one of the other major findings that we found, and that I think it is important for this panel, and reflecting on yesterday's conversations about equity and inclusion from the last panel, was that when we disaggregated the data and looked at subgroups of students, the students who were most impacted by inquiry-based science education were students who were learning a second language, students who were the most economically disadvantaged, girls and students who have special needs. Those populations are typically underserved in science education. And yet we have strong evidence that when disaggregating the data those students consistently outperformed their peers in their comparison traditional teaching classrooms and I think that is important when we think about equity and inclusion.

Cimenna Chao Rebolledo

Thank you very much. We now close this first part dedicated to interventions, and I believe it is important to point out at least three aspects. The first one is that the assessment of scientific capabilities must be in accordance to the formation of such capabilities, which are not limited to specific facts or data, or to the fact of being able to apply a given formula to a concrete problem, but go much beyond, towards the development of scientific thinking.

The second point I consider very important is to understand that, although scientific knowledge is universal, the way in which science is taught is not universal at all. This would seem to be a problem of cultural appropriation or cultural differentiation. Assessment and teaching must not differ, since then we may obtain paradoxical results. Here I would also point out the specific case of Mexico mentioned by Dr. Martínez Rizo, regarding aims and actual learning of science by Mexican students, because they express a desire to approach science but the results in this area tend to be very poor. I believe that we should seriously think on the meaning of such a situation.

Finally, the fact that the development of scientific capabilities, as was shown by Carol based on the results of LASER program, is not only beneficial for teaching and learning in the specific field of science itself, but helps as well with fundamental capabilities for overall learning. Therefore, I believe we should consider the second question, regarding the way to assess scientific capabilities in an everyday basis, that is, the idea of inquiry, observation, reflection, and argumentation in our work in the classroom.

QUESTIONS FROM THE AUDIENCE

Member of the public

Some time ago, PISA undertook a test focused in reading comprehension, which is now a tool used by all supervisors and school principals. It is called SISAT, and is basically an early-alert system to assess reading comprehension, analytic capabilities, as well as logic and mathematical thinking. So my question is the following: If sciences are traversal and include reading, writing, and mathematics, then this is quite relevant because in most basic education schools we are using SISAT, which has a lot to do with key learnings, all of them relevant to science. Why then PISA does not include in its tests students of basic education? Thank you.

Member of the public

My question is directed to Dr. Carol, have you implemented the methodology you talked about in any environment of non-formal education, outside school, like at a museum?

Member of the public

Rather than a question, I would like to thank Dr. Martínez, because during his intervention he acted as the voice expressing the thoughts of several teachers. I work as a teacher since 22 years ago, and his ideas seemed to me extremely clear and precise. Regarding the formation of teachers, as he clearly stated, there is a lot of work to do at teaching colleges.

On the other hand, teachers formed a long time ago need to be updated, since we cannot give what we do not have. I believe that those programs are wonderful, but often only the most committed people participate; they need to have the initiative and they pay their own travel expenses in order to attend updating workshops. Unfortunately, this is not enhanced or provided by the educational system. Therefore, we cannot support students properly because we did not receive such formation at teaching colleges, and we are not able to attend updating workshops. I hope that Dr. Martínez Rizo may act as a voice expressing what so many teachers feel and believe, so that in time all this may be transmitted to students. Thank you very much. I heartily congratulate you.

Member of the public

When we talk about inclusion, we almost always focus in gender inclusion. I believe we are forgetting how to adapt spaces, materials, and even assessments to the population presenting some kind of disability, so they may also have the opportunity of a quality education. This population is not at risk, but we put it at risk.

As a different comment, I believe that education must not only focus in formation, but it must also aim for society to understand the needs of a whole country, of all humanity, paying special attention to what science has to offer. We are extremely behind regarding scientific capabilities, which are not even included in the general or professional capabilities, neither for basic education nor for middle-superior education.

Member of the public

Good morning, everyone. We have already seen the results by PISA. This allows several countries to understand their specific problems, so that their scientific community may support teachers with the aim of helping students to develop a scientific thinking, and this includes different areas of knowledge and subjects of the curriculum.

The question I ask to the Mexican educational community is the following: What is the work you have undertaken based on the results of the test, considering that the teacher is a key factor in the development of such kind of complex thinking by the students? How have you enhanced the professional development of teachers towards the generation of scientific thinking in students? Thank you very much.

Carol O'Donnell

Maria were you the one who asked the question? First of all, thank you for the question. It's interesting because the Smithsonian is a massive informal Institution Museums. The learning that takes place in museums is very different of course than the learning that takes place in schools. We call it "freeform learning". There's a researcher who references that. So, the question is the model that I talked about is very comprehensive: curricular materials, professional development for teachers, administrative support.

In informal settings we have engaged in inquiry-based learning after school, so we have a program for example that's called *ATHLAS* (Always Thinking Like a Scientist). So, we bring student to an afterschool program and we engaged them in inquiry-based learning where the scientists and the teachers work together to mentor high school students who actually are the teachers of middle school students in the afterschool program. So that's outside of the boundaries of the school day.

The second example is that we have been recently developing inquiry-based modules with the help of the Inter Academy Panel so there are 130 countries who are collaborating in this effort to address issues like mosquito borne diseases, climate change, obesity, things that we believe are important to all students that may not be a part of the school day standards for that State or country. So right now, we are working with this after school alliance and testing this kind of learning in out of school settings in Indonesia, Panama, Australia and in the United States. So, we definitely believed that bringing inquiry-based science learning to out of school settings is absolutely critical. According to this researcher, his name is Falk, who talks about free form learning, where learning takes place everywhere, his quote, his percentage is that 95% of our learning happens out of school and only 5% in schools. So, what is important, I think you raised a very good question, is that we make certain that we engage students in inquiry in out of school settings.

In our museums we have two examples. One is called *Curious* in our Natural History museum. Where kids get actually to interact with the specimens of the Natural History Museum. And another one is called *Spark-lab* in our American History museum when kids get to actually physically build and solve problems, engineer solutions so, an important issue to bring inquiry to out of school settings. Thank you for the question.

Felipe Martínez Rizo

To begin with, I would like to thank the comment by the person who talked about me. Secondly, I will focus on the intervention by the teacher from Zacatecas. He mentioned that PISA applied in the past an assessment of reading comprehension. Here I would like to state that all tests by PISA assess reading comprehension, mathematics, and science, but each time the emphasis is in one of these three areas. Later he talked about an early-alert system based on the results of certain tests. Regarding that aspect I would like to comment that it is simply impossible to know the level of each student, at each grade, in each aspect included in the curriculum, by merely applying tests. That is out of the question and, in fact, OECD has disregarded all proposals involving applying PISA tests at other educational levels. It makes much more sense to apply such tests at a national level, as we have done with ENLACE by SEP, and EXCALE by INEE, which now has become PLANEA. Those tests are applied at different grades and educational levels, following a method not unlike that of a census. However, I would like to insist in that it is impossible to evaluate all students from all grades, in all educational aspects, through large scale tests. Moreover, it is absolutely unnecessary. When too much weight was given to the test ENLACE, which was a big mistake, then both schools and state educational authorities were very worried regarding the results of the next ENLACE test, so in several states, like Nuevo León, they invented pre-ENLACE tests, which were applied in December, since it was considered that the results of ENLACE came too late, when the school-year was almost finishing. Then they applied this similar test, whose results were available in January, so that teachers could make use of them and improve their strategies on time. It is terrible that teachers have to wait for the results of an external test to know how their students are doing! The teacher must know the progress of his own students without the aid of any external test, and he can do it in a much more accurate way by his work in the classroom. Therefore, I believe that early-alert systems based on external tests are not a good idea. Teachers themselves must assess their own students since the beginning of the school-year, so that they can plan their teaching strategies accordingly.

Now regarding the last intervention, about the results of tests, the new model, and so on. I am well aware of the criticism towards the new Educational Model, stating that it had overemphasized the assessment of teachers at the beginning, without providing a pedagogical model, but I do not agree with such criticism; I believe what was done to be reasonable and necessary at the time, in order to suppress the inappropriate power that the Syndicate of Teachers had over educational decisions. It was needed, it could be done in a short span, and it was done. However, I believe that the most important changes are still to be implemented. The new curriculum is not perfect, but it is a great improvement in comparison with RIEB[35], which did not render good results. I think we are moving forward. There are still several steps to be taken. First we have to go from the curriculum to the textbooks, which is very difficult. The curriculum may be excellent, but sometimes it is not well adapted to textbooks. We still do not know the new textbooks, but we hope they will be adequate. And later comes the most important and most difficult step: From the textbook to the teaching practice in the classroom. As I already mentioned, that one is the most important one, the most complex one, and it will take a long time.

Kristina Reiss

I would like to answer to two questions concerning PISA. The first one is in respect to the 15 years old students. Why not elementary School children? PISA is testing systems it is important to see that students are not tested, children are not tested, but systems. And 15 years old because in many countries of the world schooling is finished after those 15 years, so children go to school for nine or 10 years in a compulsory full-time school. This is the reason why this age group was chosen.

Secondly, there are many, many evaluations in primary schools, there are many OECD endeavors which give information about the system in earlier stages, so states and countries are encouraged to participate in those evaluations.

I would like to add that it is very important to understand what Dr. Felipe Martínez said: it is teachers who evaluate children, teachers evaluate students. They are the ones that are able to do this, we don't have to forget this. And if they are not able to do it, then they´ll have to learn. Never a system evaluation will give me a specific information about students, and we need this information. It is just two different ideas.

To the teacher who asked about inclusion, PISA is a system evaluation and that is why children are excluded who are for example not able to read a question, who have lived in a country for less than one year and who are in a way disabled because they are not able to fill in the questionnaires, and the point is not to discriminate, the point is to get understanding about systems and not about children. Thank you very much.

Cimenna Chao Rebolledo

Here we close, and we take with us the task of keeping on further understanding this deep relation between assessment and the formation of scientific capabilities.

[35] Reforma Integral de Educación Básica (Integral Reform Of Basic Education).

PANEL V

The role of Enterprises and Foundations in the promotion and development of scientific competences in students

Keynote Speaker. Nathalie von Siemens
Panellists. Jana Nieto / Leopoldo Rodríguez / Cecilia Bilesio
Moderator. Carlos Mancera

Nathalie von Siemens

Managing Director / Spokesperson, Siemens Stiftung. Germany.

OPENING

What if I told you that all of us sitting in this room, we have all that we need to solve all the world's problems?

What if I told you that in every classroom in every corner of this world children have everything they need to solve all the world's problems? … Ladies and gentlemen,

I am not going to be formal; I just wanted to thank El Colegio Nacional and INNOVEC for inviting us to this wonderful place and to this incredibly inspiring conference. I also want to say hello to all who follow us online – I think it's from 5 or 6 countries.

So, ladies and gentlemen – *amigas y amigos*,

GLOBAL QUESTIONS

Technology is undeniably the most powerful driving force behind human development. Humans invent technology to live better lives. Some of these technologies provoked revolutions. We were cold, so we invented fire and more of us survived. We were hungry, so we invented agriculture and many, many more survived. We wanted to learn, so we invented letterpress printing and people understood. Then we arrived at the 19th century. We turned electricity into power. And that was the beginning of the industrial revolution.

That revolution introduced industrial production which is based on three simple principles: standardization, memorization, and repetition. Industrial production means creating or assembling large volumes of identical goods, with very little deviation from the norm, as quickly as possible. This is a complex and difficult task and results in a very broad offer of products. In industrialized societies the majority of people can participate and enjoy this offer. Because for the very same premises of standardization, memorization, and repetition the majority of people can also participate in the production process. Industrialization offers a large number and variety of goods, but also of jobs. And with jobs the majority of people enjoys personal development and financial security.

This is why in many so called developed countries, industrial value creation forms the basis of the society`s wealth. This is also why many so called developing countries aim to establish industrial value creation within their economies. Exporting commodities and natural resources usually does not allow the majority of people to participate in GDP wealth in the same way. This is also why we all believe that STEM education is of vital importance in a society. In industrialized and in industrializing societies STEM education is the door opener to wealth, rewarding jobs, and political maturity.

Industrialization was and is a blessing.

But, with the good, came the bad.

Industrialization caused a rapid paradigm shift in how people work. Those first generations caught up i the shift suffered from brutal working conditions and poverty. And of course, we still struggle to find a solution to problems we inherited from the industrial revolution: man-made environmental destruction and climate change. But the social questions of the 19th century have been solved. We introduced laws to protect workers and to secure social welfare. And we established compulsory schooling, as well as a new way of learning suited to the industrial age.

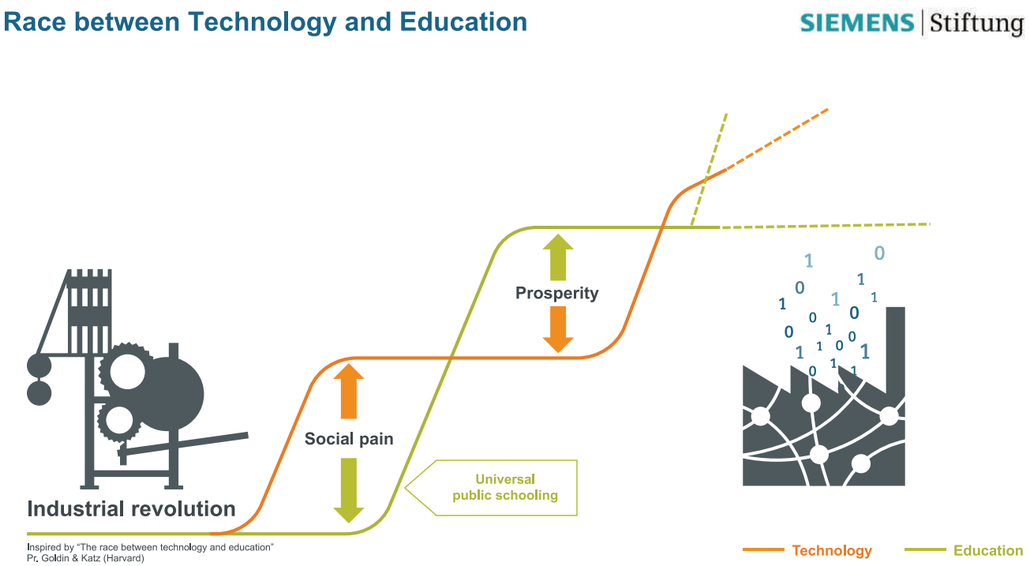
But now we face the next revolution: digitalization. The way we work and live is undergoing another paradigm shift. This will create new blessings for societies. But again, with the good, probably comes the bad.

RACE BETWEEN TECH AND EDUCATION

And there is a reason, that technological paradigm shifts always include a downside. As Andreas Schleicher from the OECD[36] tells us, it's the 'Race Between Technology and Education' that creates this downside.

Here you see two curves:

[36] Organisation for Economic Co-operation and Development, OECD.



One shows the development of technology. The other shows the development of education.

The development of education unfortunately lags behind technology.

This isn't necessarily anyone's fault – it is hard for a well-established system to adapt to disruptive developments.

Still, when the development of education lags behind technology, we feel it. We feel social pain. It was the pain people felt during the industrial revolution before we implemented regulations on work and introduced an effective way to learn. Only when the curve representing development of education is ahead of technology, do we enjoy social wealth.

That's because the education system provides knowledge, competencies, and attitudes that prepare us for our lives. And that includes helping us to become part of value creation – to enjoy the economic benefits of a new technology.

Today, there's another education gap to close. Otherwise, the same suffering that came during the great advances of the industrial age will be repeated for the first generations of the digital age.

The twist with digitalization is speed: the unprecedented acceleration of change. I think the legislative process moves too slowly to spare us from social pain, at least initially. We cannot even agree on regulations on the long-term consequences of the previous revolution in industry: namely man-made environmental destruction and climate change.

I am convinced: closing the gap between technology and education will be the key.

So what can we learn from the last time we closed that gap?

The educational gap of the industrial revolution was closed by introducing a new learning based on standardization, memorization, and repetition. The premises of industrialization itself. And this is the school we still have today.

Pupils mostly sit in the same direction, are given identical tasks, and expected to produce identical results. Look at standardized tests – it's right there in the name: 'standardized.' To us it represents educational justice – all learners are treated equally, and results are objectively comparable. And we can learn from OECD that in many countries – like in Germany – we still focus on memorizing and repeating.

This wasn't a bad system! It worked well for the age of industry, it helped people to learn what they needed in a life marked by industrialization.

Today, digitalization is already making its mark on the way we work. We don't want standardization and conformity; we want mass customization and batch sizes of one. The repetitive tasks are already being automated. And artificial intelligence is doing many tasks much better than humans can, such as pattern recognition for cancer screening.

The ability to do exactly as we're told is losing its relevance. In the digital age, divergent thinking, skills in creativity and innovation are in demand; the ability to work for the well-being of others is a social capacity that cannot be automated; the dexterity required for precious craftwork makes us superior over robots. But those competencies are not the ones our kids are focusing at school.

Our kids are being prepared for the past revolution while the next is already happening.

DIFFERENT ACTORS HAVE DIFFERENT ROLES

Obviously many of the lessons we learned from industrialization are still relevant to all societies that rely on the benefits of industrial value creation. Many so-called developing countries are working hard to help their people join the industrial age. But the next revolution is already happening, and we need to make sure we keep pace with digitalization. Both are possible, I believe, but it is a matter of deciding WHAT do we have to do, and HOW do we achieve it. Let me start with the HOW.

The digital revolution will impact us all in some way, so all parts of society need to be part of the solution. That means cross-sector collaboration among the private sector, the public sector, academia, schools and universities, civil society, and foundations.

Foundations do not replace talented teachers, passionate politicians, or resourceful entrepreneurs. But a foundation has the freedom and thus duty to experiment with new approaches. Charitable foundations are neutral and credible, free of lobbying on behalf of one company or industry, working instead for the good of society as a whole.

And foundations can build bridges. Bridges from one sector to the other. And help - as Leopoldo Rodríguez said[37]- to defy the prejudices against the private sector or also against the public sector and institutions. Foundations can help build trust. But they can also build bridges to the fringes of societies.

The distance between the fringes of society where social questions become first and most visible and the institutions that can implement systemic change often seems quite wide. And sometimes established systems do not realize the innovative power of these fringes of our societies. But this is where foundations come in. Our networks extend in both directions – from the far edges of society to the institutions and back.

[37] For more information consult the presentation as a panelist of Ing. Leopoldo Rodríguez, page 168.

Foundations can build bridges, but a bridge is no good unless people are using it. In both directions. Foundations have no impact without strong partners. These can be business leaders, with their access to networks and knowledge and financial resources. Or scientists and academics contributing new concepts. Operational partners on the ground. And we couldn't scale our best practices without collaboration with regulators and institutions.

At our foundation, Siemens Stiftung, we are lucky to have strong partners in all these sectors. That includes INNOVEC here in Mexico. We've been working with INNOVEC to implement one of our programs, *Experimento*, in Mexican schools since 2014. We collaborated on a new "Energy and Environment" Unit based on INNOVEC's Inquiry Based Science Education Program (SEVIC). Another new unit based on health is being developed as well.

We also count the company Siemens here as our partner, who is so kind to provide networks and communication and helps as in all ways they can. I just learned that the gas-lighting system in front of El Colegio Nacional has been built by Siemens 100 years ago – that's a nice learning for me today as well. We're also fortunate to count UNESCO as a partner. We worked with UNESCO on developing an education toolkit for teaching and promoting sciences to pre-school children in Mexico, with an emphasis on gender. The report on our findings is going to be released tomorrow, and we had lots of help from INNOVEC on that project, too.

Yesterday we heard from the Medellin subsecretary for education, Jorge Iván Rios, on STEM + H, where H stands for humanity. Our very close work with him and his colleagues at the education ministry has led to very promising results in reducing aggression in children in Medellin, which I will share in a bit.

Universities, foundations, public and private institutions in Mexico, Colombia, Chile, Peru, Bolivia, Brazil, Argentina, Ecuador… all our partners in Latin America and beyond play a role in addressing the HOW question I mentioned.

FROM SOLUTION TO CREATING

And that brings me to the WHAT. WHAT are we going to teach our children to help them play a role in the industrial age AND prepare them for the digital revolution at the same time? I believe that STEM education will play a decisive role in this, creating industrial AND digital value. We're already collecting exciting experiences with our partners that will help us define STEM's role in the digital transformation.

I mentioned our work with INNOVEC on *Experimento* before – it focuses on what I think is the first step in changing education: inquiry based-learning. Connecting STEM to real life, and teaching children how to think like scientists.

With *Experimento*, we tap into children's natural curiosity and unlock their enthusiasm for science and technology through age-adjusted experiments.

Experimento happens in the classroom. It's not additional to what the teacher has to do anyway. *Experimento* adapts to national curricula – so it is part of the formal education chain. *Experimento* includes teacher training and free online teaching materials. The role of teachers is not overestimated: they have one of the most important mandates in the society. But we need to support them better for this mandate. Because it's easy to teach science poorly – *Experimento* gives teachers the tools they need to teach science well. Because with *Experimento* the teachers not only teach science, but start thinking like scientists, too. Together with the pupils.

Experimento is being used on three continents, in 12 countries, and in four languages. So far, our age-adjusted experiments have reached nearly a million children worldwide. That includes about six hundred fifty thousand (650,000) in Latin America. And we are really proud of that. But this is not enough.

Despite efforts and so many initiatives around the globe in STEM education, our - and I say 'our' to all this initiatives – our impact is not as great as we had hoped. Many children still have no access to high-quality STEM education – apparently our advocacy work has not yet convinced all decision makers. STEM professions are not as appealing to young people as we had hoped. This is especially true for young women shying away from STEM jobs.

But these women can teach us something.

Research has shown that women gravitate toward professions if they understand them as relevant for society, if the jobs have social value. Perhaps it is not enough to explain to young people that STEM is economically vital, and that a skilled workforce creates wealth. Maybe STEM needs to resonate on a personal and emotional level, too. Maybe in spite of our efforts with inquiry-based learning we have given technical answers to emotional questions. And the question: "What will I do with my life? Who do I want to be as a person?" is a VERY emotional question.

So, I believe we have to re-energize the STEM discussion and make it relevant. Make it count for the lives of young people.

We're seeing what happened in Medellin, as I mentioned before. Teachers using *Experimento* have reported lower aggression and higher self-confidence among pupils in their classes. And just to give you a bit of context – we are working in Medellin with schools that are poorly funded and in the difficult areas. With families that suffer. We don't have enough research yet, but it seems logical that inquiry-based learning done in groups – a core component of *Experimento* – contributes to these improvements in behavior. And STEM in itself adds fact orientation which seems plausible to help children learn to argue and exchange perspectives. That is the base of all social skills and of communication. This was always an implicit effect of Experimento – we've now made it explicit by adding values to the STEM education equation. We focus on values relevant to the learning process, such as initiative or ownership of one`s learning process. But also, on object related values.

Now, when it comes to values, a teacher cannot claim to have the right and wrong answers. Self-confidence, respect, tolerance, a sense of responsibility - also with regard to the environment- and solidarity cannot be evaluated on a standardized test. Instead, Experimento is using dilemmas – situations where learners are forced to decide themselves based on their own moral evaluation. And decision making is a skill best practiced using real-life scenarios – like the ones we examine in STEM subjects. First observations confirm that this kind of value education makes STEM interesting and attractive.

So, let us take the question of values and real life one step further. Climate change is real life. I think we all agree on that, and I think we all agree technology will be part of the solution. Our children need to know this – they need to know STEM is the key to saving the planet, to preventing human suffering caused by rising sea water levels, fatal droughts, and deadly hurricanes. With a growing global population and finite resources, we need to help children understand WHY it is important to live sustainably. And that can make STEM education attractive, because young learners see: it has a purpose. This is why Education for Sustainable Development – ESD – also has an important role to play, and not just for environmental issues – it is important to integrate economic, social, and cultural development, too.

And finally, there is another aspect that can make STEM more relevant in industrializing

and in digitalizing societies. It boils down to a single letter – the letter A.

If we add the letter A, which can stand for 'arts,' to STEM – we get STEAM. Something we know from the beginning of the industrial revolution: steam powers progress.

(This acronym works quite well in English – in German, we say MINT. With the "I" we address "Informatics", not irrelevant in times of digitalization. The word for art "Kunst", begins with K. Not sure how we're supposed to work a K into the word MINT. Maybe you'll have better luck in Spanish.)

For me A can stand for much more than the arts. A as in attitudes or asking, awareness or abilities. A as in action. STEAM is really about the creative process, which we know from the arts and humanities and which is precondition to all innovation. At our foundation, Siemens Stiftung, we have always believed in the social value of artistic creativity. We have a program called Changing Places. Artists come to urban spaces and abandoned buildings in cities, and through their inspiring and touching work, shape a different story about a neglected place. And it is this new narrative that can be the first step for people to create their own solutions to local problems. Artists help us change perspective and enter into a dialogue of all stakeholders.

(In fact, we're looking forward to shifting the urban narrative right here in Mexico with Changing Places in 2019.) We just received the encouraging news that the ministry of culture and the Goethe Institut México will be our partners for this wonderful project. But back to STEM.

Shifting the narrative through STEM education can be done if we include focus on the competencies and attitudes that are fundamental to divergent thinking, creativity and solution orientation. New methodologies like design-thinking are promising also for school education.

Inquiry based learning, STEM related value education, ESD, STEAM, all these approaches have one thing in common. They don't mean that we stop to teach Pythagoras in math or the law of the conservation of energy in physics. But in addition to teaching knowledge they help educating competencies and they help to acquire attitudes. They connect STEM to the narrative of children's lives, their personal and unique story. And to the narrative of our societies. The "old STEM" was about fixing, namely fixing a problem called the lack of skilled workforce. The "new STEM" is about creating, about creating a way of living. STEM is not anymore just something we have to master, it becomes part of a much bigger story.

The ideal of the industrial age was the perfect machine. Don't get me wrong on the following thought, my whole family background has a lot to do with perfect machines, I love perfect machines. But over time humans have not only loved and used their perfect machines, they have tried to BECOME like them. Standardized and repetitive and thus efficient. Now the ideal of the digital age is probably the perfect algorithm. And we worry that these perfect algorithms might outsmart us. That makes us again competitive against our ideal, we try and beat the algorithms, and we play check or go against them. But to beat a perfect algorithm, I must BECOME a perfect algorithm – do we really want our children to become algorithms? I would prefer giving all children the chance to develop what they are good at as humans.

GLOBAL QUESTIONS, LOCAL ANSWERS

And this starts locally. All education is local. Children from Baja California grow up in a much different environment than children who grow up here in Mexico City, or in the Andes, or in Germany. Part of making STEM relevant in children's lives is helping them learn about what they see around them every day. But that doesn't mean local knowledge doesn't transfer, there is plenty we can learn from each other.

The digital revolution is changing the way we work. In fact, how we work TOGETHER is changed by the digital revolution, too. It starts with the possibilities to interact through social media – and again hello to everybody who is following online. And if digitalization will require us to focus on divergent thinking and creativity, we will have to go from functional interaction – like well-oiled machines – to co-creation. Across sectors and across borders. This is more than establishing interfaces to roll out existing concepts. We all have to learn from each other and co-create something, which is more than the sum of the different perspectives we initially brought to the collaboration.

Siemens Stiftung is grateful and honored to be invited to be part of this exchange and contribute to this fascinating transformation. And the more we learn about the context and circumstances of each of our partners, the more impact we can create.

Here in Mexico, we are honored to work with INNOVEC and UNESCO and have so much more to learn about how new STEM approaches can perhaps be part of the solutions in this country specifically. Just look at the learning curve of Mexico in PISA.

We want to learn much more about the emphasis on the development of "territorio" in Latin America, small ecosystems with focus on how to translate education into (entrepreneurial) impact in communities.

Escalation fueled by strong men is on the rise in the world, while de-escalation and a collaborative approach on global issues is in decline. The Colombian peace process is a welcome contrast, and its impact on Latin America can teach us so much. And a lot have to be done to make the step from a peace treaty to actually living peacefully together.

And we have so much to learn about the Pacific Alliance. As you know, education is an important part of the treaty. And we see from all our work that not only cooperation across sectors is necessary to develop our educational systems further, but also international cooperation. But while we are used to international dialogue in politics, in business, and in education at the university level, there is very little international cooperation at the school education level.

So, why not bring all our networks together and view the Pacific Alliance and its associates as a platform? A platform of co-creation on inquiry-based learning, STEM and values, ESD, and STEAM?

CLOSING

So, coming back to my initial questions: I think, we can see that all of us sitting in this room do have all it takes to solve all the world's problems. Because we have all the insight and all the necessary networks to help understand our children that they have all it takes to solve all the world's problems.

And that is our job. Thank you.*

** Document for the Presentation*

Jana Nieto

Government Affairs & Social Responsability. 3M Mexico.

This morning I will talk a little more about 3M. In order to show the importance of social responsibility for 3M, I have to start from the beginning. 3M is now a global company, but we started in the United States of America more than 115 years ago. In 1908, when 3M was still a private company, we started with community support because our CEO at the time, William L. McKnight, since we were a mining company at Twin Cities, wondered how to build a better relation with the community. Ultimately, the people from the community worked at the company, we were neighbors. Then he wondered how to become a good neighbor. And so starts the history of 3M with social responsibility.

Many people connect 3M with innovation. From our point of view, our DNA has innovation, but social responsibility as well. In 1949 we started to apply volunteering programs, focused in education. How to support and help children? Because both father and mother were at work, and what happened then with the children? This has been an evolution, because at the beginning, when we started this program along with United Way, we noticed that both parents had jobs, so we wondered, what happens with their children? Therefore, the most urgent measure was to provide safe spaces for the children. As time went by, and since science is our passion, we started to acknowledge that the first years of childhood, between ages 0 and 6, is a very important period, so 3M should support the children of our employees and, more generally, all children from the communities where we work in the United States of America. Then programs like *Nacer Aprendiendo* (To Be Born While Learning) arose. In such a way, this passion for education was born, but it was only applied in the United States of America.

Some years ago the situation changed significantly for 3M Mexico. Previously, 3M had been focusing on manufacture from Mexico to the whole world. But three years ago 3M Mexico experienced an important transformation, since it started investing in research and technological development in Mexico. In San Luis Potosí we have an industrial complex where we work on patents, developed by Mexican scientists. We have almost 400 Mexican patents up to now. On the other hand, in Mexico City we have the *Centro de Innovación* (Innovation Center), which is unique, with 15 laboratories. Then, acknowledging the strength of firms like *Ciencia Aplicada a la Vida* (Science Applied to Life), with over 100,000 patents around the world, and considering the social problems of Mexico, as well as the issues in educational matters, we started helping schools. There we have experienced an evolution too. We started with infrastructure for schools, donating materials like *post-its*, *masking-tape*, and other products of the sort. But we suddenly realized that in the Bajío region more boys than girls attended school, so we wondered what was happening there. Then we identified the problem: Several parents did not want to send their girls to school for hygienic reasons. Therefore, we made a donation of our fiber *Scotch-Brite* to 600 public schools in San Luis Potosí, to give support regarding hygiene, so that more girls could attend school.

As we were growing, we started to think on what we could do regarding sciences, which is a fundamental topic. Then we established an alliance with INNOVEC and, from the school year 2016-2017, we adopted ten schools in Mexico City and four in Estado de México (State of Mexico). During the whole year we supported children of primary school by preparing teachers and giving educational kits based on the methodology developed by the Smithsonian Foundation. We synchronized the curriculum by SEP[38] with the areas of expertise of 3M in advanced manufacture, nanotechnology, and biotechnology, to unite efforts. We identified the key educational modules[39] with which we could make a difference regarding science education. Last session we were talking about motivation. An important part of what we have done with these more than 2000 children during this school year, which is the second one with the project, is to go to those same ten schools, which have in total more than 5000 children from 1st to 6th grades, and in order to have an integral model we open motivational spaces. In 3M, all employees are Mexican, the scientists developing patents are Mexican, both from public and private schools. Then these Mexican scientists attend personally at their labs the visiting children, who have worked with one of the key educational modules. They have a chat with the children, tell the story of their lives, how they managed to work at a major firm like 3M, and all that is highly motivating. In some way, we humanize science by talking directly with these children, whose parents and relatives in most cases did not even finish high-school. Summarizing, this is a scope of the evolution and history of our commitment with science and education in Mexico.*

** Transcription*

[38] Secretaría de Educación Pública (Ministry of Education).
[39] From the program Sistemas de Enseñanza Vivencial e Indagatoria de la Ciencia (Systems of Life- and Inquiry-Based Science Education; SEVIC, from its acronym in Spanish), launched by Innovación en la Enseñanza de la Ciencia, A.C.

Leopoldo Rodríguez

Member of the Board of Innovation for Science Education (INNOVEC). Mexico.

A fundamental challenge in Mexican education is to understand how to achieve that students at all levels, from kindergarten to superior education, acquire the ability to learn. Learning to learn is a very important topic which, in the organization I work in, we learned a long time ago and are trying to spread. We are happy that in the current context of the Educational Reform, the idea of learning to learn is taking a central role. When we understand this, we acknowledge the importance of incorporating into such process elements which allow the student to learn and, to move forward on such aspect, the best way is to join practice with concept.

Since 15 years ago, I have been involved in the learning and teaching of one of the applied branches of chemical engineering: everything related with plastics. It has been necessary to awake the companies' interest in topics related with learning and, as a consequence, with research. When we manage to have this interaction of private enterprise with academics to reach both results simultaneously, the outcome is extremely advantageous.

It has not been easy, especially in Mexico, where there has been strong resistance at universities against the interaction of private enterprise with academics. When we manage to overcome such resistance, even if only partially, we get very important results. Paradoxically, the ones getting the greater benefit are the academicians. During a study tour around 15 years ago, I learned this from some of the most recognized universities worldwide regarding academics-industry cooperation, or "entailment", as it is usually called nowadays. Among these universities we have Cambridge University, Massachusetts Institute of Technology (MIT), and Stanford University; I am not saying that the prejudice has been completely overcome in those places, but they have certainly moved forward quite a bit in such regard. This correlates very well with something our friends from Germany have been insisting upon, which is the idea of a dual education, combining theory and practice; especially when we refer to science, there is nothing better than the possibility of a dual education. Curiously, just as practice is fundamental to improve in the practical aspect, which is obvious but not redundant, even if it may seem so at first sight, dual education turns out to be very helpful for the educational task. At Facultad de Química (Faculty of Chemistry) from UNAM (Universidad Nacional Autónoma de México; National Autonomous University of Mexico) we have been working on this since a long time ago. For more than 10 years we have been engaged in a project focused in the collaboration between academics and industry, a continuous cooperation with as much emphasis in theoretical learning as in actual practice, or even a little more in the latter. We still have so much to do, but I mention this to show you in which aspects we have been moving forward.

One of the topics scheduled for this session is to talk about our achievements, and that is all right, but I would also like to mention one of the most difficult obstacles, which is the economic aspect. This can be solved by establishing the principle of cooperation through the assembling of a foundation, but it is not an easy task. We have managed to establish such a foundation in Facultad de Química, UNAM. There are only two of its kind in the whole University: the Fundación General de la UNAM (General Foundation For UNAM), which of course addresses topics related with education, but is not directly involved in educational activities, and ours, the only faculty or school in the whole university with its own foundation, which supports education directly, including the economic aspect. Last year we finished our campaign on fund recollection, where we received donations for almost 80 million Mexican pesos. The main topic was education, with a focus on strengthening the collaborative effort having as its core the Centro de Transferencia Tecnológica (Center For Technological Transfer) established at Facultad de Química. There is so much we have to do, and the fact that an institution focused on the topic takes 15 years to render results is just a proof of it. We have much more to say about the work we still have to do, than about our current achievements, although we are happy with our results.

As several others have stated, the possibility of collaboration and continuous enrichment is fundamental. Collaboration is an absolutely mandatory topic; without it, we simply cannot move forward, so it is definitely essential. As time goes by, it becomes clearer that several disciplines cannot advance without cooperation. Another important matter is that such collaboration must take place at a global level. In several branches of knowledge it is simply impossible to move forward without such international cooperative effort. It is a very interesting process because it is redundant in a positive way, since people improve thanks to cooperation, and cooperation is clearly the path towards further improvement and self-confidence. The more contact we have in our everyday life with industries, universities, and international leaders, the better. If we are isolated, the lack of information becomes an unsurmountable obstacle. On the contrary, collaboration facilitates the whole process, and that is why it is essential.

One of the problems we face is the resistance and skepticism we experience in the academic medium. We must talk in a positive way, we must walk always forward, so that every step will be worth as two. I believe that, in this aspect, leaders of industrial and academic institutions, as well as public policies, must play a central role.*

** Transcription*

Cecilia Bilesio

Vice president of TAMSA, A.C. Mexico.

Thank you very much. I believe this is a fundamental topic: The participation of the private sector, and how to synchronize it with the public sector to educate with quality and propriety as best as possible. Group TECHINT Mexico (Tubos de Acero de México; Steel Pipes of Mexico) belongs to Group TECHINT International. Since the 1950s we are an industrial company, and we firmly believe that education is the source of equity, development, and progress. Being an industrial company, we are basically rooted at the communities hosting our industrial complexes, and that is why, since its very beginning, our foundation has been focused in education and health.

Regarding education, we participate throughout the whole age spectrum, since primary school, all the way through secondary and high school, and in superior education as well. We maintain focus in science and social-emotional capabilities. Our approach is very special. Instead of trying to develop our own programs, we look for associations with experts in the topic, with proven experience, who have already assessed the result of several programs; this allows us to make a proper investment of our resources. In the case of Mexico, we started supporting INNOVEC and its program in primary schools in the states of Veracruz and Nuevo León, where are our main complexes in Mexican territory. Later we evolved into an after-school program, implemented after regular lessons finish, but based on the experience of the joint work of the Smithsonian Foundation and INNOVEC. We took the decision to establish an agreement allowing us to apply their science modules and experiences in our after-school program. We have been implementing this for more than four years, and it has been very successful. We work with more than 300 children, whose participation approaches 100% during four hours after regular school. This program applies inquiry-based science education, for the children to develop the capability of solving problems, reasoning information, drawing conclusions, and working in groups. It has truly been very pleasant, since it has been spreading, and the benefit children get from a contact with science, through specialized programs since an early age, has been evident. We must acknowledge to have had full support from state governments in order to apply this program, and that we implement periodical evaluations with parents and schools, which have resulted in a very enriching experience for us.

We have another program in high school related with technical education, which has helped us realize the necessity for programs and science learning to take place in a structured way at schools, incorporating the corresponding curriculum, at all educational levels. Because when we started focusing in technical education we found that several students do not have the ability to detect the tools they need to get a scientific way of thinking. Therefore, we believe there is a lot of fertile ground for collaboration between the private and public sectors, and that we need a whole connection mechanism, both virtuous and sustainable, extending from basic to superior education. Thank you very much.*

** Transcription*

Comments REFLECTIONS Answers & Questions ANALYSIS

Panel V. El papel de las empresas y fundaciones en la promoción y desarrollo de competencias científicas en los estudiantes

- How do civil society and private foundations participate in science education of children and youth worldwide?
- What successful experiences are there for Mexico and Latin America in public - private collaboration for science education?
- What are the results of these efforts?

Carlos Mancera

The efforts of these two companies are extremely valuable. It is clear that their association with INNOVEC has widened the scope of the work they are performing. However, we are talking about only two companies acting in an enormous educational world. What do you should be be done regarding the educational system and the different sectors involved in education, so that your task can have a deeper effect in a world full of needs? What would you like to happen in the educational ecosystem for the valuable efforts you are undertaking to render better results and to spread out, so that many other organizations may participate in the task you are performing?

Cecilia Bilesio

Today, the challenge of the new industrial revolution is focused in value chains. Especially regarding big companies, but also at the level of middle and small ones, Mexico has recently developed very successful "clusters[40]", like the automotive one and the aerospace one, both of which require advanced manufacturing techniques. The creation of such clusters has proven that the capacity and potential for innovation and development are present in Mexico. In a similar way, 3M[41] has in this country, in the state of Veracruz[42], its main center at an international level for innovation, research, and development of specialized products for the energy industry. What we have detected is that these virtuous efforts performed by companies are generally well received by local governments and by the Ministry of Education (SEP). At least, that has been our experience. Based on what we have observed through 25 years of work in the development of several programs, we believe that we need a mechanism allowing the public sector, in collaboration with the private sector, to develop a sustainable ecosystem, where the public sector can adopt best practices, benefiting from the capacity of

[40] In this context, a cluster is a group of related companies which work in the same industrial sector, and collaborate strategically in order to obtain common benefits.
[41] www.3m.com.mx
[42] Centro Industrial de Tenaris en México (Tenaris Industrial Center in Mexico) is one of the largest in the whole world regarding the manufacture of steel pipes for the energy industry. It is placed in the state of Veracruz: www.tenaristamsa.com

companies to design and apply pilot programs in an efficient and systematic way. For example, with our program "After School" we are in coordination with SEP and with the schools involved to offer infrastructure, which may not be sophisticated but nevertheless provides a basis allowing the development of the curriculum to be effective, so that we can later work on values and best practices in education. When such best practices are detected, they must be encouraged, in order to improve and develop the process. It is also important to integrate materials and other basic aspects, like education for health, so that the children have a better disposition to be receptive to the programs. In short, they are integral programs focused on the child, where the school, supported by us, acquires the capacity to detect systematically the mistakes needing correction and the best practices which must be encouraged. In such a way, the program has a permanent assessment and improvement.

The Ministry of Education supports all the efforts performed at these schools, and we generally have the goodwill of teachers and management personnel as well. However, there is no system for the best practices to extend to all schools in an organized way, or at least for them to grow gradually till they are integrated to the institutions in the public sector. We believe that one of the most important aspects that should be developed is the capability of integrating best practices to the system in a sustainable and organized way, for them to function in a long-term basis.

Jana Nieto

At 3M we believe in collective impact, we believe that it is very important to coordinate our work. Therefore, when we received the invitation to participate in this event we took it very seriously, since it is an opportunity to bring together the key pieces, which conform the "golden triangle", that is, government, private sector, and social sector (foundations and IAP). It is an opportunity to get to know the different approaches towards a common goal, which is science education. How can we help children to get in love with science, that is, to keep their curiosity towards science but also develop the appropriate capabilities? After a broad survey of the methodologies proposed by several associations, 3M Mexico identified that the one by INNOVEC is the most appropriate, since it enhances the capabilities that both teachers and students need to develop. It offers the opportunity to live science, to experiment, to inquire, and to create capabilities. Moreover, we wanted the experience to be very fun and to be taken by students as part of their everyday lives. Therefore, with such an important ally as INNOVEC, I invite all private companies present here today to join this program, since we can accomplish much more if we articulate our efforts.

Last week I had the opportunity to participate in a forum, in the framework of a conference about infancy, organized by several national and international private companies which are collectively working in the support of nursery houses of DIF. We are accomplishing our task through games, so that the infants may develop social abilities since a very early age, with the aim of building a strong basis which allows them to understand science concepts when they start attending primary school.

One of the results of this kind of events is that we make agreements. I would suggest that all key parts in this process should meet often, not once a year but once every three months, and that we should register our successes, so that we can work in a more articulate way.

Carlos Mancera

I will take a couple of minutes to point out some important aspects that have been treated in the previous presentations.

The first one is that we are experiencing a process of high involvement by private companies and social organizations to participate in science education at school and, more generally, in the whole educational task.

As a comment, I will tell that till 1992 it was strictly forbidden for parents to express their opinion regarding anything happening at school. If parents were prevented from getting their opinion, just imagine the possibility of external actors participating in school matters! Therefore, this process of opening the school to others in order to improve education in general, and particularly science education, has begun from scratch.

It has already been highlighted the very important role of an organization like INNOVEC as a connecting bridge between the initiatives of the private sector, who are willing to contribute in education, and what is actually happening at schools. When we have a proven methodology, when the best practices at an international level have been selected, when those practices have been adapted to the reality of our country, when educational authorities, teachers, and other key parts have already been convinced of the urgency of this process and the advantages of a contribution like that by INNOVEC, then we have a full working engine allowing private companies to impact with an efficient contribution towards the improvement of science education.

Another aspect that must be pointed out is the following: Although philanthropy is very valuable and must be appreciated as an important element supporting science education, it has a natural limit, it simply cannot be enough to cover the needs of a whole population regarding science education. Therefore, the process must also satisfy the interests of private companies regarding their own future, the growth of their productivity, their possibilities of innovation, and the capability to better insert themselves in global markets. Then it is necessary to link education and productivity, in order to work in an articulate way at schools. To enhance the elements which link the private sector with the process of educational formation gives schools the opportunity to emphasize science education as something that is useful, something that helps individual development. All this requires will, action, and specially a great deal of patience and tenacity.

QUESTIONS FROM THE AUDIENCE

Member of the public

The application of these programs requires investment. Although the responsibility lies in the government, it can be shared by the private sector. I suggest the investment assigned to these programs, like SEVIC, to be made every six years instead of every year. As part of my job I constantly visit schools. Therefore, I can witness that when SEVIC is being applied, all children are very happy. However, this does not happen with subjects like language and mathematics. Then it is clear that the work being accomplished is important. We are systematically bringing children to the development of science, but for that we need resources and we need them at the appropriate moment. I also believe that the commitment of educational authorities must increase.

The concrete question I ask is, how important do you think it is a constant and permanent investment in this area?

Member of the public

Which are the criteria regarding public-private investment in terms of regions, since there are places where the number of students is not large enough for them to have a teacher?

Which is the appropriate formation for teachers in the context of public-private collaboration?

Member of the public

This is a thought about the comment on the necessity to coordinate the actions of the private sector regarding education. I believe that the

private sector lacks inner communication. There is no organized register of what is being done by each of the parts involved, like communities and public institutions. I suggest that we build such organized register and encourage real communication with public educational institutions. We should not let these ideas to simply remain at the level of a forum intervention. There is no call at a national level for private companies to join and participate in science education. The panelist from the Smithsonian Institute stated that 95% of what we know is learned outside school, why then are we not enhancing such kind of learning? Why are we focusing all our efforts in the school as a formal institution?

Member of the public
This is a comment specially directed to Dr. Von Siemens.

I work for Siemens. I currently represent 7000 workers and I constantly listen to their needs. I am Mexican, so I belong to a country with a lot of needs. I represent several Latin American countries, in Central America and the Caribbean, which also have a lot of needs. The situation is very different from that of European countries and other countries which have managed to develop properly. I would like to say that I am extremely proud to belong to this project, that I know it is real and effective, investment is substantial, we can witness the results when we visit schools and observe the children. This mission is appreciated and valued in our country, by Mexican citizens and by the company we represent here. Thank you very much.

Member of the public
First of all, I would like to thank the private companies who shared with us today the actions they are undertaking in the benefit of the learning of our students. There are several positive points, but many questions as well. What must we do so that all private companies are willing to invest in education? What can we do so that all schools have the appropriate materials to work in science? How can we manage that all our students have the opportunity to work through life-engaging activities? This is an enormous task, and it presents the difficulty that it becomes an administrative burden for schools. My experience was that children participating in SEVIC performed incredible tasks. They had a lot of fun, expressed themselves quite freely, and developed incredibly! However, school principals had a problem, first with the recovery of materials, and later regarding the administrative task of filling the records comprising a huge amount of data. We must find a solution to that.

Jana Nieto
About the first question, it is true that the government assigns a budget to the various institutions following an annual basis. However, regarding science and education there is a dialogue led by CONACYT[43] with the argument that a budget assigned for a longer period of time allows for better planning and usually leads to greater accomplishments. So, this would be very positive for long-term programs.

I am very happy that Peñoles is here with us today, since it is a private company conducting very good programs focused in infancy. This is a great opportunity to get to know each other, as well as to invite other private companies present, so that we can organize, share experiences, compare areas we work in, and form a common front to show the government our success and give continuity to our programs. In such a way, we will manage to have a collective impact and keep on growing.

[43] Consejo de Ciencia y Tecnología (Council For Science and Technology).

Regarding the last question, when we develop a program it is important to have feedback, so that we can know which schools participated, how many children were involved, etc. However, it is fundamental to prevent such feedback and reports from becoming a burden, since it would be a huge mistake if some children are left without the opportunity to participate due to administrative issues. So we will work on the possibility of making that easier, and any proposal from the part of educational authorities is most welcome. We must work together to overcome this obstacle.

Nathalie von Siemens.
Thank you for the comments and for the questions.

The big question is how can we help people and all children participate? I think there are some ideas that could help. One is the idea of the STEM regions. Something that we do in Germany but that we also initiated together with partners of several of the Latin American countries we are active in. A STEM region sounds very simple. It is something like a round table where you bring together the key stakeholders of STEM, not on the national level but first on the regional, or the community level. If this is done regularly then it becomes a platform where people can exchange and learn what others do and also learn about how we can fund together. Sometimes it is a matter of how we co-finance and if everybody takes their share then it is possible, and I think that STEM regions are very, very valuable because if you have a sort of coverage of STEM regions you get a lot of insight and you get to know what initiatives are there.

In Germany, for example, we have something like 10,000 or 15,000 of STEM initiatives. So, we´ll never be able to know if they are good or bad, if they are impactful or not, if we don´t sort of connected them to a network, and STEM regions can help a lot.

The second question, how do we bring quality from the few to the many? And this is also obviously something that is our duty as actors in this field. We have started ta lot of research on evaluation, and we are working together with with TUM School of Education in Munich on evaluating *Experimento*[44]. I think we need to much more share our results of impact. The more data we get the more we need to share this data because this is the only way to convince people and it does make a difference. If we think back 10 to 15 years ago no one talked about early childhood education. So today…is a given. We are totally convinced that we need early childhood education. It wasn´t a given that was a lot of work. We heard a lot about patience, so thank you for the long-term perspective that you are also taking. We need a long-term perspective, but it does work if we combine this network approach, for example in STEM regions, if we combine the sharing of our impact and also where we have not that good impact. If we fail, we need to share this as well because no one should repeat something that didn't make sense, and so it is also a little bit about honesty in that context.

And something that I just wanted to mention is how do we bring ideas to the many. One channel that helps enormously is the open education resource movement. So, we are very active in developing free online material. So, material that doesn't need to be purchased, it is there, you can down load and if it concerns *Experimento* it is not sophisticated, it is not expensive, the material that we use for our experiments usually you can buy it in the supermarkets or pharmacies. We think that's important because we feel there is a very big

[44] https://www.siemens-stiftung.org/es/proyectos/experimento/

barrier in science. “Science is big and difficult. Math is big and difficult”. No, it´s not. We need just to bring down barriers. And having free material, easily accessible material, that is also one of the roots we really need to work more and work together so, in our open education platform resource you´ll find about 5500 materials already that you can download and that can be distributed.

Cecilia Bilesio

I am very happy to see that we all have a common goal, and that the private sector is convinced of the importance of science for the development of the country and the children, so they are willing to participate in this process. I believe that a collective conversation regarding the importance of science education would be very helpful, specially with the participation of teachers, who are the people in direct contact with children. There are several initiatives from private companies, but most of them are isolated. We must organize ourselves in order to apply the programs which have been proven to be effective, so that both public and private sectors may provide the will and resources to make them efficient. I believe this is extremely important. INNOVEC has taken the initiative, but I think that we should develop it in more depth.

Leopoldo Rodríguez

I believe it is clear the need of all of us to share our experiences more often and more accurately. We seldom communicate what has been done, what has not been done, the reasons therein, and the results obtained. We must share the information, between ourselves and with society, the government, and academic organizations, so that we generate a pressure for those experiences to move the process forward.

Carlos Mancera

I believe that we all should be very happy to witness the enthusiasm regarding the possibilities for participation and contribution by foundations and private companies. We should congratulate INNOVEC for its linking role, which has managed all these efforts to be coordinated and become more effective. I think this will greatly benefit teachers, the materials they receive, and the support they get in the hard task of education; they should also be as free as possible from administrative hindrances and obstacles. In short, I feel that we all have a very positive attitude, and that is what will allow us to keep on building and moving forward. Here we close our forum, and I thoroughly thank all panelists, as well as all the audience, for having been here with us today.

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