Education: a Crucial Role for COMSATS

Jean-Pierre Revol
CERN
and
COMSATS International Technical Advisory Committee

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Introduction

• Many thanks to:
  – Dr. Abdulai Baba Salifu, Director General of the Council for Scientific and Industrial Research (CSIR), for inviting me to Ghana, his hospitality, and for teaching me “akwaaba”
  – Dr. Imtinan Elahi Qureshi, Executive Director of COMSATS, for inviting me to the 16th COMSATS Coordinating Council meeting, and for giving me a challenging mandate:

  “What do I think COMSATS, as an international organization, should focus on in the future?”

• A rather delicate subject for someone who is new to COMSATS International Technical Advisory Committee!

• I will draw from my experience as a scientist at CERN, as a former advisor to the Director General of CERN, and as a former coordinator of relations between CERN and a number of Non-Member State countries
CERN: European laboratory dedicated to fundamental research in the field of particle physics, located near Geneva, across the border between France and Switzerland.

Today, the Large Hadron Collider (LHC) is the flagship of the laboratory.
Discovery of the Higgs boson
Event from the ATLAS detector, candidate for $H^0 \rightarrow \mu^+\mu^-\mu^+\mu^-$
Discovery of the Higgs boson
Event from the CMS detector, candidate for $H^0 \rightarrow \mu^+ \mu^- e^+ e^-$
A special particle, imagined in the 1960’s to answer the delicate question of mass in the Standard Model of particles and interactions.

50 years later, we found out that this mathematical construction of the human mind actually corresponds to the choice of Nature and is the answer to a question asked by humankind, in line with the many questions, which drove our evolution on Earth.

A major achievement for CERN, for the scientists from all over the world involved in the CERN programme, in a unique cooperation among countries.

This unique world-wide cooperation may in fact the biggest achievement of CERN, and could be an inspiration for other types of cooperation.
1952: the Conseil Européen pour la Recherche Nucléaire (CERN) created with “a mandate to establish a world class European research organization in fundamental physics”

1953: a convention is signed establishing the Organization

1954: birth of the laboratory – 12 European countries (rebuilding Europe after World War II)
CERN today: 20 Member States

~ 2300 staff; ~ 980 other paid personnel
> 10000 users
Budget (2012) ~1000 MCHF

Member States: Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, the Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland and the United Kingdom

Candidate for Accession: Romania

Observers to Council: India, Japan, the Russian Federation, the United States of America, Turkey, the European Commission and UNESCO

CERN is an observer to the United Nations General Assembly

Associate Member in the Pre-Stage to Membership: Israel, Serbia

Applicant States: Cyprus, Slovenia, Turkey, (Pakistan, Brazil, Russia preparing)
From a European laboratory to a World laboratory

A total community of ~ 13’000 members

Distribution of All CERN Users by Nation of Institute on 9 January 2012

A total community of ~ 13’000 members

(contacts with Kwame Nkrumah UST, in Kumasi)
The idea of a high-level Commission on Science and Technology for countries of the South was triggered by a physicist, Nobel laureate from Pakistan: Prof. Abdus Salam.

Both COMSATS and CERN are promoting science and technology as a means of strengthening South-South and North-South collaboration.

In doing so, both international organizations are promoting education, which is crucial to the harmonious development of human civilization.

Education is one area where COMSATS could play a more important role.
COMSATS and CERN

- COMSATS consists of **21 member countries** from Africa, Asia and America.

- CERN consists of **20 European countries** (soon 21 as Romania is in the process of becoming a member state) and cooperates with ≥ 45 countries from Africa, Asia, America, Australia and Europe.

- Six members of COMSATS are cooperating with CERN: People’s Republic of **China**, Republic of **Colombia**, Arab Republic of **Egypt**, Islamic Republic of **Iran**, Islamic Republic of **Pakistan**, Republic of **Tunisia**.
Human curiosity is at the basis of the evolution of Society. Human evolution is linked to the ability to ask questions. It is here in Africa that the very first questions were formulated.

Fundamental research is the expression of human curiosity in three main domains:
- **Structure of matter** (particle physics, nuclear physics, solid state physics, etc.)
- **Life** (botany, chemistry, molecular biology, etc.)
- **Structure of the Universe** (astronomy, astrophysics, cosmology, etc.).

Finding answers to questions led to innovations and development, as still happens today:

“I think there is hardly any example of twentieth century innovation which is not indebted in some way to basic scientific thought”

(Hendrik Casimir)
History shows clearly that it is **fundamental research** that **drives the development and progress of Society**:  
- Without fundamental research there is no innovation  
- Without innovation there is no development

Unfortunately, politicians seem to have difficulties understanding this. It is even more true in member-countries of COMSATS:  
“**COMSATS member-countries devote, on average, about 0.5 per cent of their national budgets to science, compared to 2.5 per cent by developed countries**”  
**Eduardo Posada Florez**  
(Chair of COMSATS Coordinating Council)
How does fundamental research feed innovation?

- **Direct ways:**
  - For instance, Faraday’s work
  - The **discovery of the spin of the proton** opened the way to medical imaging by **Nuclear Magnetic Resonance technique**
  - **Quantum Field Theory** led to using antimatter (e⁺e⁻ tomography), etc.

- **Indirect ways:** **Tools** developed for fundamental research find applications in other areas:
  - Application of **accelerator & detector technology** to medicine
    - Hadron therapy (cyclotrons) [Centre Lacassagne, TERA, ...]
    - Production of radioactive isotopes medicine & industry
    - Industrial processes using accelerators
  - Application of physics methods and instrumentation to biology (Maurice Wilkins – J.D. Watson & F. Crick 1962)
  - Accelerator driven power plants using thorium for energy production and destruction of nuclear waste

**EDUCATION**
First PET scanner developed in collaboration between CERN and Geneva Cantonal Hospital. (David W. Townsend, Alan Jeavons and Prof. Alfred Donath)

“... some essential and early work at CERN contributed significantly to the development of 3D PET, and then to a new scanner design, the Advanced Rotating Tomograph.”

David Townsend, 2008
“WWW ... changed forever the way information is shared”

WWW >>> Sharing information
Without the GRID we could not have discovered the Higgs boson

GRID >>> Sharing computing resources
The Energy Amplifier, an accelerator-driven system proposed by Nobel laureate Carlo Rubbia

- Concept validated by CERN FEAT and TARC experiments, which led to other applications:
  - Isotope production for medical diagnostics (CERN Patent)
  - Neutron facility n_TOF]
How could there be research and development without education?

Education is the most judicious investment a society can make:

- a benefit to society, as educated people understand society better and may contribute to its development
- a benefit to individuals, as education helps them understand better their place in society and allow them to contribute to its development

Research needs educated people, this is one of the reasons why Europe is investing in CERN

In return, CERN plays an important educational role, as most CERN staff go to industry after a few years of research at CERN and bring with them their experience from CERN
Educational programmes at CERN

- Apprentices
- Academic Training
- Exhibitions
- Visits
- Outreach
- Technical Training
- Conferences
- Accelerator School Fellows
- Doctoral Students
- Physics School Computing School
- Technical Students
- Microcosm
- Language Training
- Communications Training
- Management Training
- CERN-Latin America School
- Summer Students
- Science on Stage
- Teachers programmes
How does it work?

- Raise the interest of young people by introducing them to modern science topics they find interesting and challenging (similar approach by Prof. Adewale Solarin in Nigeria)

- Once they are interested, students are motivated, willing to learn basic concepts, and they start asking questions:
  - At this stage, we are back to the basic mechanisms of evolution and innovation

- **Importance of training physics teachers:**
  - Teachers are role models
  - There is a multiplication factor
  - Teachers constitute a unique link in bringing modern science to the classroom
CERN ‘themes’ are attractive for young people:

ANTIMATTER
BLACK HOLES
DARK MATTER
THEORY OF EVERYTHING
WWW
PET SCAN

THE Higgs PARTICLE
DARK ENERGY
BIG BANG
EXTRA DIMENSIONS
GRID
HADRON THERAPY
Education was clearly on the mind of Abdus Salam, when COMSATS was created, thus I think that COMSATS, as an international organization, should focus on education in the future.

This is the best way to have countries from the South help themselves – this educational effort should target children, students, teachers and perhaps also politicians ...

This could be done initially through cooperation with CERN, and perhaps other international organizations (UNESCO?)

COMSATS could start by taking and expanding some of the most successful CERN programmes (Physics teachers programmes, Physics schools, etc.)

Potentially interesting multiplication factor for COMSATS (X 21 countries)
A possible practical scheme

- Start by running, with the help of CERN, the teachers programme, in any of the COMSATS countries
- Train COMSATS personnel who could run the programme within the country, and who could export it to other COMSATS member countries
- This only requires modest resources. Follow the advice of Sherry Ayittey, Ghana's former minister for environment, science and technology, concerning fund raising

Is there any good reason not to try to do it?
World-wide scientific cooperation

Build on the universal character of Science

Africa should no longer be the “white” continent on this map.
Science:
“Coherent ensemble of knowledge concerning certain categories of facts, objects or phenomena obeying laws and verified by experimental methods”
(Larousse Dictionary)

Knowledge is the most precious asset of humankind
Science must be a bigger part of our culture
Developing science through education, research and development must be a priority of Society
COMSATS can play a crucial role in the development in the South, focusing on education – well in line with COMSATS’ mandate
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Faraday, famous 19th century English physicist (1791-1867) contributed brilliantly both to applied research and to fundamental research.

Why do we remember Faraday today? Not because he improved light house candles!
A the time of Galileo, **Observation** became the basis for advancing science, and **instruments** could be built to allow observations beyond the natural possibilities of human beings.
Tremendous domain of physics!

- Today, scientists are studying the Universe over dimensions varying by 45 orders of magnitude!

As instruments become more powerful, we are expanding the scale and studying new features.
Challenges of heavy ion physics

Lorentz contraction | Matter creation | Thermalization? | Expansion

Lorentz factor: 1380 to 2750
\( R_p = 0.81 \text{ fm} \)
\( R_{Pb} = 5.75 \text{ fm} \)

- **Theoretical challenge**: Involves many concepts from elementary particle physics, nuclear physics, equilibrium and non-equilibrium thermodynamics and hydrodynamics
- **Experimental challenge**: fast (≈10^{-23}s) dynamical evolution, from extreme initial conditions to a dilute hadronic final state; extreme experimental conditions:
  - **extreme particle density** \( (dN_{ch}/d\eta \approx 2000) \)
    - \( \times 500 \) compared to pp@LHC
  - **requires large dynamic range** in \( p_T \):
    - from very soft (0.1 GeV/c) to fairly hard (100 GeV/c)
  - **requires particle identification (PID for hadrons and lepton), which limits** luminosity and interaction rates
    - 10 kHz (Pb-Pb), 200 kHz (pPb), 300 kHz (pp) \(< 1/1000 \) of pp@10^{34} cm^{-1} s^{-2})
PbPb collision in the ALICE detector
The ALICE detector at the LHC

Detector:
- Length: 26 meters
- Height: 16 meters
- Weight: 10,000 tons

Collaboration:
- > 1000 Members
- > 100 Institutes
- > 30 countries
pPb collisions in the ALICE detector

- Low luminosity ($8 \times 10^{25}$ cm$^{-2}$ s$^{-1}$) pilot run in September 2012
- 30 nb$^{-1}$ collected by ALICE in a run started mid-January 2013, which ended February 10, 2013
- At $\sqrt{s} = 5.02$ TeV, the c.m. reference frame moved by $\Delta \eta = 0.465$
Cosmic ray shower in the ALICE detector

- Observation of high multiplicity cosmic muon bundles (one event with > 100 muons every 5 days)
- Primary energy corresponding to ALICE events $10^{13} < E < 10^{18}$ eV
History shows that it is fundamental research that drives the development and progress of Society, that the success of a civilization is linked to its support to science:

- Greek civilisation (first to define the search for knowledge as a value);
- Pre-medieval Arabic civilization;
- 15th century Chinese civilization:
  - Debate between Eunuchs and Confucianists: “Why go look at what’s going on elsewhere?”

The size of Zheng He’s armada was not exceeded for five centuries. (28000 sailors, 300 ships (some 130 m long)
“Certainly, one might speculate idly whether **transistors** might have been discovered by people who had not been trained in and had not contributed to wave mechanics or the quantum theory of solids. It so happened that **William Shockley, John Bardeen and Walter Houser Brattain**, the inventors of transistors in 1947 were versed in and contributed to the quantum theory of solids.”

“One might ask whether **basic circuits in computers** might have been found by people who wanted to build computers. As it happens, they were discovered in the thirties by physicists dealing with the counting of nuclear particles because they were interested in nuclear physics.”

1943: J.-P. Eckert and J. Mauchly build the first electronic computer **Eniac** (Electronic Numerical Integrator and Calculator)

etc. … Electronic industry, radio waves, laser, … Web
Main role of science in our Society

- **Satisfying human curiosity**, finding our place in the Universe, changing our reference frame, from **village**, **region**, **country**, **Earth**, to **Solar System**, **Milky Way**, **Local Group** of galaxies, etc.:

**Where are we? How did we get here?**

**Only a few milestones**

- **Eratosthenes of Cyrene** (276-194 BC, Greek mathematician, poet, athlete, geographer, and astronomer);
- **Copernicus/Galileo Galilei** (16th century): new place of the Earth in the Universe (from geocentrism to heliocentrism) – a process that proved costly at that time (**G. Bruno**);
  Revolution in the method for answering questions! (400 years ago!)
- **Eratosthenes of Cyrene** (276-194 BC);
Milestones

**Copernicus/Galileo Galilei** (16th century): new place of the Earth in the Universe;

**Einstein** (1905): relativity implying a new relation between space and time (*i.e.* cosmic muons, GPS);

**Alexander Friedmann, Abbé Georges Lemaître, Edwin Hubble** (1929): the *expanding Universe*, as opposed to a static Universe, leading to the Big Bang model;

Recent discovery that the **matter we are made of is only 4% of the contents of the Universe** *(we are a minority)*;

Realization that **space & time were perhaps both created in the Big Bang** *(difficult even for physicists)*

Discovery of the **Higgs field**

Other milestones

**Charles Robert Darwin** (1859): “on the Origin of Species” *(idea of continuity of living species through evolution)*;

**Crick and Watson** (1953): double helix structure of DNA, the fundamental molecules of life *(Chemistry → Life)*