EDUCATION IS OUR FUTURE

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by

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The world today is one of increasingly borderless exchange of goods, capital, and labor. More countries than ever—and from a broader spectrum of development—are active participants in the global economy. This has brought about rapid technological change and competition among nations.

Intense global competition has driven the more able producers and entrepreneurs to expand and grow rich[1] – and the less able to be swept away.

Today, knowledge is the most important factor in economic development. It is not low-wage, unskilled labor that drives a country's economic growth. The true key to prosperity in today's world is a well-educated, technically-skilled workforce producing high-value added, knowledge-intensive goods and services, employed in private enterprises that have the capacity to find, adapt, and adopt modern, up-to-date technology and sell sophisticated goods and services in global markets.[2]

But while a few of the world's richest countries produce the majority of scientific and technological innovation and therefore create wealth, most of the developing world struggle to establish science and technology (S&T) as the driving force towards growth.

For the Philippines to strategically engage in the global economy, the Philippines must develop and adapt technologies to respond to local needs. In the process, the country will develop new competitive economic activities to serve not only local but also regional and global markets. All these must increase productivity, wealth and standards of living that lead to economic growth and poverty reduction.

Producing wealth and high value goods and services will require an intensive effort to raise our Science, Technology and Innovation (STI) capacity.

This lecture argues that science, technology, and innovation have the potential to contribute substantially to economic growth and poverty reduction. Basic to the realization of this potential is education. This is fundamental for a knowledge economy based on information technology and a country's human capital.

This lecture is divided into four parts:

The first part describes the advances in STI around the globe.

The second part looks into other countries' experiences in applying STI to spur economic growth and ease poverty. It distills the lessons learned from these countries' experiences.

The third part discusses the state of STI as well as the direction, strategies and efforts currently undertaken in the country.

The fourth part identifies critical gaps in STI readiness and makes recommendations for government, policymakers, universities, research and development (R&D) institutes, and industries.

I.
SCIENCE, TECHNOLOGY AND INNOVATION: TRENDS

Scientific and technological innovations developed as early as the 1980s are expected to change, even accelerate, at least until the first two to three decades of the 21st century.[3] Such innovations will continue to fuel economic growth, especially in those countries that have given a high premium to science and technology. Robert Solow, one of the Nobel Prize winners in economics, estimated that more than 50 percent of the economic growth in the US since World War II has derived directly from technological innovation.

Countries that have catalyzed technological innovations have identified prospects in the horizon where they can accelerate and scale up processes that transform ideas to products.

Japan, for instance, identified rapid and intensive technological innovations in the areas of environment; electronics; life sciences; marine and earth science; production and machinery; communication; information; health, medical and welfare; agriculture, forestry and fisheries; and transportation.

South Korea forecasted materials; information, electronics and communication; medical care and health; production; life science; energy; environment and safety; transportation; agriculture, forestry and fisheries; and minerals, water resources, urbanization, construction and civil engineering as areas that will experience great leaps of progress.

In the coming decades, innovations in biotechnology, information, communication and technology (ICT), nanotechnology, and neurotechnology will continue to originate in other countries and fundamentally change the way we all live. Along with biotechnology and ICT, James Canton, a world-renowned futurist, foresees that nanotechnology[4] and neurotechnology[5] will be the four areas of radical innovation. Consequently, they will be the source of a huge chunk of the global wealth in the next five, ten, twenty years.[6] And for developing countries, biotechnology and ICT have the greatest potential for improving the quality of lives and well-being of people.

Biotechnology refers to the use of microorganisms such as bacteria or biological substances such as enzymes, to perform industrial or manufacturing processes.

Biotechnology research focuses on gene manipulation and transfer, DNA typing and cloning and the much-debated genetically modified organisms (GMOs).

Biotechnology in agriculture and food can increase production and productivity and improve the quality of products, and is especially critical now. The World Bank calls for a dynamic agricultural development agenda to lift the close to 1 billion people across the globe from poverty. The Bank support this year to agriculture and rural development will reach US$3.1 billion.

In medicine, biotechnology will enable us to better diagnose diseases, promote the use of gene therapy, stem cell therapy and xenotransplantation[7] to prolong human life.

ICT is an umbrella term that includes any communication device or application, encompassing radio, television, cellular phones, computer and network hardware and software, satellite systems and so on, as well as the various services and applications associated with them, such as videoconferencing and distance learning.

The importance of ICTs lies less in the technology itself than in its ability to create greater access to information and communication in underserved populations.

Leveraging and harnessing the tools of ICT for education and development can result in widened access to knowledge and increase in opportunities and incomes.

Since the 1990s, there has been a steady ICT diffusion. More economies invest in ICT as they move towards a knowledge society. ICT will continue to grow, that by 2020 it will be worth US$7 trillion.

Nanotechnology is the science and technology of devices and materials constructed on extremely small scales, as small as individual atoms and molecules.

Nanotechnology embraces many different fields and specialties, including engineering, chemistry, electronics, and medicine, among others, but all are concerned with ultimately bringing existing technologies down to a very small scale, measured in nanometers.

For a product to be counted as nanotechnology, it is enough for some of the materials to have particles that may be only a few nanometers big – a nanometer is a billionth of a meter or about 100,000th of the thickness of a sheet of paper.

These nanoparticles are incorporated into other materials that bestow on them useful properties. Silver nanoparticles, for instance, are found in food-preparation equipment. Titanium dioxide, ground into nanoparticles, are used in sunscreens and cosmetics. Carbon nanotubes have been embedded in materials like plastics for a long time now.

Nanotechnology has several important applications in agriculture, farming, public health, and the environment. For instance, with nanotechnology, precision farming through computers, global satellite positions systems, and remote sensing devices, determine if crops are growing at maximum efficiency.

Neurotechnology is a set of tools that can influence the human central nervous system, especially the brain. It will be used for therapeutic ends such as cures for Alzheimer's and will enable people to consciously improve emotional stability, enhance cognitive clarity, and extend sensory experiences.

Results of work in these areas are dramatically changing various dimensions of our lives, individually and collectively. Developed countries have made rapid advancements in the electronics and information field by creatively drawing from the physical sciences and engineering. They are now building on these innovations and working on the wide-ranging and life-changing possibilities of convergence between the life-sciences and engineering.

While these countries have boldly forged ahead in such new, exciting, and dynamic ventures, efforts in the Philippines seem to have stalled on the lower-end side of technology. This is not to belittle such efforts but rather to explore the reasons why the Philippines has not advanced as fast as Malaysia, Singapore, or Thailand and how this country can move ahead.

II.
COUNTRY EXPERIENCES IN DEVELOPMENT THROUGH STI

Robert Reich, author of *Super Capitalism,* argued that technological advances led to innovations that heightened competition and created new sources of wealth.

These technological advances skyrocketed during the US-Soviet arms race, which propelled the two countries to step up public financing of infrastructures, education and research, all in the name of national defense. In the 1970s, the US underwrites 70% of the country's research, many of which involve defense technology. *(Table 1)*

These technological discoveries have found their way to commercial markets through defense contractors, universities, and entrepreneurs, and have since then further propelled the US economy. Since the early 1970s, the US GDP tripled in size with productivity increasing by 80% in 2006.

Economic development of this sort, however, requires massive investments in infrastructure, human resources, as well as time. Poor countries do not have enough of these to start with. While they continue to work for economic growth through building their human capabilities and physical infrastructure, poor countries could leapfrog or adopt a new technology directly and skip over earlier, inferior versions of it that came before.

By far, the best-known example is that of mobile phones in the developing world. Fixed-line networks are poor or non-existent in many developing countries, so people have leapfrogged straight to mobile phones instead.[8]

Another known example is the way Grameen Telecom in Bangladesh integrated new technologies in micro-credit lending. It deployed cellular wireless networks so that small-scale entrepreneurs can widely share mobile phones.

Strategies such as these will help a growing number of countries enjoy significant gains in economic productivity associated with a freer flow of information. One recent study of Africa claims that "a one percent increase in mobile penetration rates is associated with 0.5-0.6 percent higher rates of FDI/GDP."[9]

Technological leapfrogging has become the basis for various countries' latecomer strategies for catching up with existing industrial leaders.

Harvard economics professor Alexander Gerschenkron, who fashioned the concept of latecomer development in the 1960s, suggested that a less developed economy can tap and use the technologies and practices of an advanced economy, and this in turn will let the developing countries skip several stages of development that the advanced economy had to go through.

Since then, Gerschenkron's concept has been expanded to include poor and latecomer countries to specifically use ICT to accelerate development, promote growth, and reduce poverty.

One of the most notable catch-up stories is that of **South Korea**, now known as the "Miracle of Han River". Starting with virtually nothing after World War II and devastated in the 50s by a deadly war between the North and South, an impoverished South Korea managed to reach its current status as a developed country, with the third largest economy in Asia and the 11th largest in the world in terms of nominal GDP. If the recent Goldman Sachs report gets its predictions right, South Korea could be the 2nd richest country in the world by 2050, next only to the United States.

South Korea achieved its robust economic growth through investing heavily on infrastructure and education, ensuring stability especially in its financial system, and providing support—both through public financing and policy – to research and development.

In particular, South Korea has introduced, internalized and renovated foreign technologies, similar to Gerschenkron's late comer advantages. The World Bank describes this as stages[10] of imitation, internationalization, and generation.

At present, South Korea, like many other countries and noting that other late comers such as China are a threat to its economy's competitive advantage, has bolstered its R&D spending. *(Table 2)* The South Korean government's R&D spending has more than quadrupled over the last decade, from US$5billion in 1990 to US$24.2 billion in 2004. Currently, R&D public spending is 7% of Korea's budget.

Another spectacular catch-up story is **China.** Goldman Sachs in its BRIC[11] prediction foresees that China will emerge as one of the four new dominant economies by 2050. Already, China is ranked second in the world in terms of number of researchers, next only to the United States. Total R&D expenditure has dramatically increased, from $12.5 billion in 1991 to $94 billion in 2004. China's patent applications are also increasing twofold every two years. China is now the world's fourth largest economy, and if current trends continue, will soon become the world's biggest exporter. [12]

A crucial aspect to this growing productivity is the improvement of China's education system[13], which raised the skills level of its labor force. Like South

Korea, China first relied on importing foreign technology, adapted them to local needs and then later on developed its own indigenous innovation.

According to the Organization for Economic Cooperation and Development (OECD), China has mobilized resources for R&D at an unprecedented scale and speed, and has translated this to the socio-economic progress that China is experiencing for the last ten years.[14] At the crux of its R&D initiatives is China's National Innovation System (NIS), a conceptual framework for "analyzing technological advances, which consists of innovation actors and their relationships. There were NIS for (a) education[15] involved in linking universities that allowed them to set up their own enterprises *(Table 3)* with many enterprises involved in S&T. *(Table 4)*; (b) business[16]; and (c) government.[17] This structural reform led to massive state efforts at developing China's science and technology system[18], formally institutionalized by 1985.

Economic reforms and S&T prioritization have encouraged the entry of FDIs, which are now major contributors to China's R&D and innovation. Since then, more policy reforms designed to facilitate innovation have been implemented.[19]

China is continuously reviewing its innovation policies, and is building an "enterprise-based innovation system," aimed at developing more indigenous innovation for Chinese enterprises.

Like China, **India** rose from poverty and is also part of the BRIC prediction of Goldman Sachs. India is now the world's eleventh richest country, its GDP amounting to US$430 billion. However, India ranks fourth to US, China and Japan in terms of purchasing power parity.

For most of India's economic history, from the isolation and import-substitution phase of the 1960s to the economic liberalization of the 1980s, one thing remained almost constant: S&T has been a national priority.

Among its strategies[20] to promote S&T are investments in basic and heavy technologies, creation of R&D promotion policies, integration of S&T planning to the overall planning process of government, technology transfers and strengthened linkages between industry, R&D institutions and financial institutions.

In January 2008, India's Tata car company unveiled the Nano, the world's cheapest car. It sells for about US$2,500 or P100,000 thus opening a huge potential market for the developing world. This car breaks technological ground. It has a rear-mounted two-cylinder engine, which both saves fuel and creates interior space. Tata said the company was able to keep the cost of the car low by putting the plant in an area that receives tax concessions and having the suppliers set up plants nearby to cut transportation costs.

Similarly rising from Third World to First World status, **Singapore** boasts of having one of the highest per capita GDP in the world. It first nurtured its small and medium enterprises and actively promoted the transfer of engineering technology. In 1991, it undertook a major policy turn, implementing successive steps towards cultivating STI in the country.[21]

Singapore's STI policy centered on increasing its number of technically-trained human resource. Its education system is biased towards S&T, with 62% of its university students enrolled in science- and technology-related subjects.[22] Public spending in education has always been a priority, averaging at 22.4 percent of the national government budget.

Massive investments in education was complemented by Singapore's initiatives in (1) establishing and improving physical technological infrastructure; (2) issuing fiscal incentives for S&T and R&D; (3) promoting techno-entrepreneurship and venture capital; and (4) increasing transfer of engineering technologies from foreign companies to local companies.

In turn, these efforts helped encouraged the 6,000 transnational companies already investing in Singapore to engage in R&D, thereby producing high value-added products and services.[23]

Thailand, considered our closest competitor, has already moved ahead of the Philippines in pushing for a knowledge-based economy.[24] Thailand's standing has been advancing since it embarked on a National Science and Technology Strategic Plan in 2004.

According to this plan, Thailand aims to achieve economic development by building its capability on four core technologies, namely, information and communications technology, biotechnology, material technology and nanotechnology.

To achieve its objective, Thailand has pursued the following activities: (1) develop clusters to support and improve targeted technologies and industries; (2) promote public awareness and support for S&T (3) produce more S&T skilled human resources; and (4) build infrastructures and establish institutions that stimulate and promote STI.

Since then, Thailand's indicators have been rising steadily. Already, its R&D expenditure has risen significantly, from 0.12 of GDP in 1996, to 0.5 of GDP in 2006. Patent applications are growing by 276% from .02 per 100,000 population in 1996 to .07 per 100,000 population in 2004.

South Africa follows a similar development model but has a different strategic approach. Foreign aid and financial grants have been shifting from traditional relief and rehabilitation activities to projects at the core of which is building its scientific and technological capacity.

Again, investments are concentrated on public infrastructure and human capital. Adequate infrastructure facilitates a country's capability to harness science, technology and innovation for economic growth. Increasing a country's stock of infrastructure by one percent increases the GDP by one percent, or more in some cases.

Combining physical infrastructure and human capital on one hand, and linking with STI capabilities of other countries in the African region on the other hand, is its strategic approach. The South Africa and Mozambique Maputo Corridor,[25] a massive road, rail, ports and telecommunications project, illustrates how linkage with other countries in the region, and between industry and academe, can help build a country's infrastructure.

Apart from physical infrastructure, an equally important investment made by South Africa and its neighboring countries is education and improvement of its human capital.[26] An attempt to create its own Massachusetts Institute of Technology (MIT) in Africa through the African Institute for Science and Technology (AIST) is in the pipeline. AIST will serve as the Silicon Valley of South Africa and the whole African region.

Finally, another example of outstanding economic recovery through human capital development, Ireland rose from the 1973 and 1983 oil crises that devastated its economy to become the 2nd wealthiest country of the world, in terms of per capita income, next only to Japan.

Investment in higher education and R&D is a crucial factor to the economic boom of the "Celtic tiger". This allowed Ireland to use its work force's brainpower, productivity and flexibility to attract foreign investments.

Lessons learned from other countries' experiences

Given these sample development models, there are at least five common factors for development underlying their STI efforts, namely:

- Governments invested heavily in the provision of basic public goods and services, road and ports, energy and communications, clean water, health and education services which raise the productive potential of firms and people. These investments served as the foundation for technological learning.

- Governments nurtured the development of small and medium-sized enterprises. Building these enterprises requires developing local operational, repair and maintenance expertise, and a pool of local technicians;

- Governments supported, funded and nurtured higher education institutions, as well as academies of engineering and technological sciences, professional engineering and technological associations, and industrial and trade associations;

- Governments established inter-institutional linkages among universities, industries, government agencies, and not-for-profit organizations. Further, they fostered inter-disciplinary collaboration that includes not only the sciences and engineering but also business, law, and ethics; and

- Governments adopted good governance: transparency and accountability in the use of public resources, fairness and the rule of law in social and business transactions, a level playing field for investment and competition, and reward for risk takers and entrepreneurs.

III.
FILIPINNOVATION: SCIENCE, TECHNOLOGY AND INNOVATION IN THE PHILIPPINES

To assess the Filipinnovation potential, this section examines the state of STI and the present direction, strategies, and efforts in STI in the country.

I The state of STI in the Philippines

For the Philippines to ride the wave of technological breakthroughs and integrate itself into the global trend of innovation, three key issues must be addressed: a) the science and technology system, particularly science and technology education and research and development, is poor; b) the dearth of innovative ideas; and c) the slow or non-commercialization of inventions.

First, the science and technology system remains poor. Two extremely critical and related elements of this system are human resources and research and development.

A. On human resources skilled in science and technology:

Crucial to developing a talented and skilled pool of human resources in science and technology is the quality of basic and higher education that the country provides. It has been said much too often that our educational system has fundamental resource gaps. *(Table 5)* And such gaps have led to the lower-than-desirable levels of science and technology graduates that the country has.

Of the 430,102 college graduates last year, engineers and technology-related graduates constituted only about 13 % and IT 9.5% while business was about 21.5% and medicine and nursing had 19%.

The graduate level is even worse. Each time the country produces one graduate with a master's degree, Vietnam produces six, Thailand produces 25 and Singapore produces 200.

This is not the entire picture.

College graduates are a product of the country's primary and secondary educational systems. A good gauge of how our elementary and high school students are performing can be seen in the National Achievement Test (NAT) scores.

The latest NAT conducted among 1.6 million grade six students in March 2007 shows a mean percentage score (MPS) of 59.9 percent – 5.28 percentage points increase over the MPS of the NAT 2006. The MPS means that for every ten items, a grade six student can correctly answer five items. A breakdown of the MPS, however, shows that the science score of these grade six students is about 51.58 percent.

The MPS for the 2006 NAT of fourth year high school students is 44.33 percent, 2.6 percentage points lower than the 2005 MPS. The science score is 37.98 percent which means that a fourth year high school student can answer only about 4 out of ten items correctly.

In the 2004 High School Readiness Test conducted among our grade six students, only 0.06 percent got a score within the range of 75 to 100, with 75 as the desired cut-off mark for passing. This means that of the 1.2 million grade six pupils who took the test in 2004, only about 8,043 pupils have mastered the basic competencies in Science, English, and Math and are ready to move on to high school.

This is hardly surprising. While other factors explain these poor performances, one critical factor – the quality and number of teachers – egregiously stands out.

There are more non-majors teaching science subjects than teachers with science degrees. For instance, 90 percent of physics teachers are not physics majors and 80 percent of chemistry teachers are not chemistry majors. *(Table 6)* And of the prospective teachers enrolled in BS Education degrees, only 1.5 percent chose mathematics and science majors.

The Department of Education (DepEd), however, is responding to these gaps by allocating a total of P24.3 billion from 2006 to 2008. The DepEd has increased the budget for the purchase of textbooks, hiring of teachers and construction of classrooms to address resource gaps in public schools.

The lack of classrooms is also managed by holding double shifts where there is excess student population especially in the urban areas, primarily due to in-migration.

Meanwhile, DepEd is in the process of upgrading the quality and increasing the quantity of textbooks per subject each year. Allocation was increased to P2.1 billion for 2007 to replace all English textbooks and the same amount for 2008 to replace all Science textbooks.

These resource gaps have resulted in larger class sizes. The officially approved size of 54 students in a class in 2001 has gone up to 60. High classroom-pupil ratio affects the students' capacity to learn, as teachers have a harder time teaching a larger class size.

Other countries have smaller class sizes. The latest study of the United Nations Educational, Scientific and Cultural Organization (UNESCO) Institute for Statistics in 2003 cited that the Philippines has a public elementary school average class size of 43.9 students as compared to Malaysia's 31.7, Thailand's 22.9, and South Korea's 34.7. In secondary school, the Philippines has an even higher average with 56.1, while Malaysia's is 34, Thailand's is 41.5, and South Korea's is 35.4.

These are just the basics. Data on ICT tools are worrisome.

As of 2006, there are only 464 personal computers catering to more than 13 million public elementary school students, or a ratio of 1:25,995. In high schools, five million students share among themselves 45,221 computers, or a ratio of 1:111.

Access to basic ICT tools is limited. Only 46 per 1,000 people own a computer. A study on Internet penetration in Asia[27] showed that the Philippines ranked 12th among 14 Asian countries, with a 5.3% penetration rate. Compare these to South Korea with an Internet penetration level of 65.7%, Australia with 65.3%, Japan 58.7%, and Singapore with 55.8%.

The booming economies in Asia invest heavily in S&T education. China, which outnumbers much of the world in producing engineers, turns out 600,000 engineers annually and India has 401,000. When combined, this surpasses tenfold the number of engineering graduates produced by the US. Japanese and Korean engineering graduates increased by 42 percent and 140 percent, respectively, compared to twenty years ago.

B. On research and development in STI:

The budgetary support to R&D in STI has been erratic. In the past, it represented only 0.11% of the Gross Domestic Product (GDP), quite meager compared to Japan with 3.12% and Singapore with 2.15%.

Fortunately, this year, the country's R&D allocation has been increased to 0.43% of the national budget, or from P2.7 billion to P3.6 billion. This is a paltry sum. Taiwan's expenditure in R&D increased from US$388 million in 1978 to US$2.4 billion in 1990 to US$14.9 billion in 2004.

In any case, this extra allocation will fund more R&D and scholarships for scientists, engineers, and students. It has trickled down to the Department of Agriculture (DA), better-performing State Universities and Colleges (SUCs), the Commission on Higher Education (CHED) and the University of the Philippines (UP), having received increased budget allocations for R&D. Which is just as well. As it is, the number of scientists and engineers in R&D in the country[28] is only 152 per million population, less than half the ratio recommended by the UN for sustainable development. *(Figure 1)* It pales in comparison to Singapore, Korea and Malaysia.[29]

This is truly unfortunate.

The Philippines is a major producer of IT-enabled services such as interaction services, animation, finance and accounting, shared services, medical transcription and architectural and engineering services. Further, the Philippines has a large pool of English-speaking and highly trainable graduates. Yet, support for R&D is very weak.

Private firms in the country have minimal R&D expenditures. This shows that foreign firms in the country do not improve on nor use the full capabilities of Science and Technology personnel they employ. In a real sense, technology transfer, as we know it, does not happen in this country.

Second, related to the above is the country's lack of a culture that nurtures innovation and change. This has kept us in the backside of development.

This lack is reflected not only in the erratic budgetary allocations to STI in education and to R&D, as discussed earlier, but also in the absence of an overall coherent policy framework that would foster and underpin a culture supportive of STI.

In terms of enabling policies, there are laws that have not included inter-institutional linkages or laws that have been made irrelevant because of the current trends in globalization.

RA 8439[30] or the Magna Carta for Scientists, Engineers, Researchers and other S&T personnel in government, for instance, provides a program of human resources development in science and technology. Yet, the country lacks guidelines, plans, and programs linking the Department of Science and Technology (DOST)'s promotion of innovation with the Department of Trade and Industry (DTI)'s fiscal incentive policies. DTI's incentive policies, on the other hand, have yet to include tangible support such as tax breaks for local or foreign investors who will bring in new and applicable technologies. And DTI has yet to balance such breaks with the requirement that foreign firms in the country must introduce new technologies.

With the entry of foreign investors and the globalization of the workplace, the labor market has drastically changed and our Labor Code is unable to adapt to these changes. The old standard of working eight hours a day for 40 hours a week has become obsolete. We now have a 24-hour, seven days-a-week schedule mostly employing IT personnel, while others work from home with flexible schedules. More women are also working at night in call centers and

BPO companies, hence the prohibition against night work for women no longer makes sense. The Labor Code should be overhauled with a new set of flexible work arrangements and better security of tenure to further encourage new industries and income productivity.

The support for STI and R&D in other countries is almost palpable. Singapore, for instance, offers salaries competitive with the best US schools and Malaysia recently announced its goal to be an education hub with 100,000 foreign students by 2010.

In the US, the government allocated an additional US$5.9 billion in FY 2007 to increase investments in R&D, strengthen education and encourage entrepreneurship. The increase will go to biomedical research, studying the convergence of life sciences and engineering, advanced security technologies and research geared at producing marketable technologies.

The US is also opening up its doors to foreign students specializing in science and math with more lenient visa and immigration policies to attract experts to study, work and stay in the US.

INSEAD business school in France, for instance, allows its students to move between France and Singapore campuses, encouraging continuous exchange of ideas. In June last year, they launched an MBA Program in partnership with China's Tsinghua University.

Leading universities have also increased math, science, and engineering degree offerings and have opened its doors to the influx of scientists and technologists from around the world.

Third, the commercialization of new products and inventions is almost non-existent. Transforming innovative ideas to products and services is extremely challenging. Universities and research institutions have a central role to play in these processes.

At its simplest, these processes include undertaking basic research. This has been challenged by the lack of skilled human resources as well as funds. Then there are the series of trials and tests, modifications and adaptations, that have to be undertaken, once again supported by unwavering commitments and funds. Further down the line, there needs to be these crucial linkages with industries and businesses. And all these ideally ought to be done in an atmosphere where networking, exchanges, and sharing are the norms.

As it is now in our country, our scientists have little or no incentive to innovate. Networking and exchanges are not easy; funds are always low, if they are available; transaction costs of doing business are exceedingly high; and there might not be a sizeable market for their inventions. Thus, others opt to showcase their innovation in foreign countries. The Philippines has one of the lowest patent applications in the region, explaining our low technological capacity.

Other than the basic scientific research, commercialization requires market research such as feasibility studies as to what invention fills a demand and what people will pay for.

For a largely agricultural country like the Philippines, there's no question that science and technology in agriculture and fisheries must become priority. Support, especially to small and medium enterprise (SMEs), must be delivered because SMEs create around 90% of jobs and operate in mostly rural areas.

This points up the need to promote techno-entrepreneurs. Technology is not helpful unless we establish a critical mass of people who will put it to use. That way, they will gain meaningful employment and raise incomes.

II Direction, Strategies, and Efforts in STI

Current efforts at promoting STI in the country include government-initiated STI programs, budgetary allocations for agriculture R&D and higher education, and academic networking.

Government programs in STI

The Philippines envisions the country to become a significant S&T player in the region by 2010, and in the world by 2020. The DOST has outlined a development map through the NSTP 2002-2020, which includes a program on R&D, technology transfer, human resource development, S&T promotion, information dissemination, advocacy and linkages.

To improve our human resource capacity, the DOST gives scholarship and training grants in the fields related to the functional activities of the department and its attached agencies. It has also launched the *Balik* Scientist Program to encourage overseas Filipino scientists and technicians to return to the Philippines and share their expertise.

Another program, the DOST-Japan Society for the Promotion of Science (JSPS) Joint Scientific Cooperation Program[31], promotes scientific researches and exchanges through exchange of scientists, holding of scientific seminars and conduct of dissertation and degree researches under the joint guidance of Filipino and Japanese advisers.

The DOST's support to SMEs is channeled through the Small Enterprise Technology Upgrading Program (SET-UP), a nationwide strategy to encourage and assist SMEs to adopt technological innovations to improve their operations and boost productivity. The program encourages technology transfer and technological interventions through better product and HR development, cost minimization, waste management and other operations activities.

The Philippine Research, Education, and Government Information Network (PREGINET)[32] was created in 2007 with the objective of learning from best practices in developed countries. PREGINET is a research and education network for collaborative R&D among government, academe and research institutions. It allows the country to participate and engage in joint projects with research institutions globally

Recently, the government released 200 million pesos for post-baccalaureate engineering and science scholarships, 100 million pesos to be administered by CHED and the other 100 million pesos by DOST.

Other scholarships and infrastructure development programs in engineering have already been approved and appropriated for.

Academic Networking

Special support to upland agriculture is given through the creation of a research consortium among six SUCs in the Cordillera Administrative Region (CAR). This research consortium will focus on conserving national agricultural heritage such as the rice terraces, the native textile industry and wood-based arts and crafts; improving the variety of rice and vegetables in the uplands; introducing organic farming; and creating a joint program on fish breeding.

The six CAR institutions include Abra State Institute of Science and Technology, Apayao State College, Benguet State University, Ifugao State College of Agriculture and Forestry, Kalinga-Apayao State College, and Mountain Province State Polytechnic College.

A far more ranging program entitled Engineering Research and Development for Technology Consortium (ERDT) is in place and will become operational. It aims to upgrade the quality of S&T graduates and colleges, increase the number of MS and PhD graduates in S&T and improve R&D infrastructure. *(Table 7)*

The ERDT Consortium consists of seven universities with the capacity to absorb and produce MS and PhD graduates in engineering and computer science. Apart from UP, other participating universities are De la Salle University, Mapua Insitute of Technology, Ateneo de Manila University, Mindanao State University-Iligan Institute of Technology, University of San Carlos, and Central Luzon State University.

Budgetary allocations

In the 2008 national budget, a bigger amount for R&D has been allocated to key government research agencies such as DOST, DA, CHED and SUCs.

For DOST and DA, the money will be used in the implementation of various agricultural research project[33] and government-academe partnerships.[34]

Additional funds are channeled towards more undergraduate scholarships and student financial assistance. The CHED scholarship programs[35] and the Higher Education Development Fund (HEDF)[36] are restructured for a clearer focus on development and research and a more efficient use of funds.

Some outstanding SUCs were given additional allocation. These include the Mariano Marcos State University, Central Luzon State University, Leyte State University, Aklan State University, University of Southern Philippines, which are notable for their R&D, international linkages and the commercialization of their inventions. *(Table 8)*

The University of the Philippines 2008 budget contains an allotment of P161 million for scholarships, P200 million for research and development projects through DOST, and P838 million for infrastructure through the UP budget. The UP engineering complex will serve as the national hub for generation and application of new scientific knowledge.

CONCLUSION:
WHAT NEEDS TO BE DONE?

In a global economy where knowledge and innovation determine a country's economic future, the Philippines' path to development must be based on a strong foundation of new science and technology.

Our country's development depends on the importance we place on innovation. Developing a culture of innovation requires enabling conditions brought about by the concerted effort of government, policymakers, educational institutions, R&D institutes, the media and industry.

These conditions are continued increases in investments in education, research and development; improvements in science and mathematics education at all levels; and inter-institutional collaboration among universities and research institutes, government, and business.

Upgrade science and mathematics education

Undertaking serious reforms in science and mathematics education is the first step. And it should take place at all levels, starting from basic and secondary up to higher levels of education. Our grade school children should be able to posses much more scientific and mathematical literacy than what they have now. They should be enthusiastic and excited about science and mathematics. And they can be if their teachers are competent and qualified.

The quality of undergraduate science education directly affects both the number of scientists and the capabilities of students who eventually become engineers, researchers and teachers. Improving this level of education is important. But once again – and this lecture emphasizes this strongly -- there is an urgent need to strengthen the preparatory science and mathematics that start in primary and secondary education.

Invest in education, research and development

Basic research, generation of new knowledge, and the creation of an educated workforce are essential to innovation and economic growth. Without sufficient investment in education and research and development, innovation is not possible.

There must be advocacy that consistently calls for increases in public and private investments in R&D. This is possible only when government prioritizes innovations in science and technology and ensures that such innovations move from the laboratories to the marketplace. The R&D agenda should focus on helping entrepreneurs utilize and apply technological changes so that even socalled “low tech” activities – like fishing and farming, for example – become more innovative and generate more domestic value added.

Such investments in R&D should support the development needs of the country whose population is estimated to be 100 million in a period of three years. There is a great future in this. There is a compelling need to address issues that have enduring impact on the Filipinos. These include innovative technologies in pharmaceuticals, agriculture, food, forestry, fishing, medicine and public health.

There are exciting prospects in R&D that are happening and that need to be continuously supported. Incubation parks have been established.

The 22-hectare Diliman Science Complex and Technology Incubation Park at the UP Diliman campus hopes to be the Philippines’ version of Stanford University-Silicon Valley and Hsinchu Science Park in Taiwan – a high-technology hub close to a research university.

The Park currently hosts the National Institutes of Natural Science, Geological Sciences, Marine Science, Physics, Molecular Biology and Biotechnology, Biology, Chemistry, Environmental Science and Meteorology, and the Mathematics department.

It will serve as the national center for the generation (R&D) and application (innovation) of new knowledge in the natural and applied sciences, and mathematics. It will enable our PhDs to pursue R&D, and make it possible for us to reinforce the training of our next generation of MS and PhD students in the sciences and engineering. It will also establish linkages with other state and private institutions of higher learning as well as other techno-incubation parks.

Following this lead, we must set up and maintain more regional S&T parks that can provide institutional facilities, including advanced laboratories, and a nurturing environment that will sustain R&D.

Promote Industry-Academe-Government linkages

There is a need to strategically engage foreign and local business enterprises and draw in their capacity to finance R&D investments. Companies like Intel, Nokia and Microsoft are capable of supporting R&D centers, equipping laboratories and must therefore become active components in the overall national S&T effort. And so are local business firms like United Laboratories, JG Summit and San Miguel Corporation.

Likewise, local SMEs, which represent 90 percent of all businesses registered in the country, play a crucial role in the pursuit of R&D. SMEs, accounting for a third of the country's GDP, should pursue R&D thru active government intervention especially in the areas of agriculture and fisheries production, manufacturing and food processing, and trading and other retail services.

We should improve our capability to transfer technology. Government should help enhance the private sector's ability to acquire existing technology, improve and adapt it for the particular needs of local enterprises, and incorporate it into local production processes. In other words, government should focus on helping the private sector absorb and utilize technology that is already in use elsewhere in the world.

A yet untapped resource for technology transfer is the overseas Filipinos. Filipino workers overseas – especially those involved in science, technology and engineering – are an excellent conduit for harnessing networks for development and competitiveness.

Apart from the billions of dollars-worth of remittances they bring in to the country, we should focus on the knowledge and expertise they have learned, and try to apply it to our local industries. They can help bridge the technology gap in the country if we provide them enough incentives to practice their profession in the Philippines.

Transform innovative ideas to high-value products and services

One of the most dynamic repercussions of effective inter-institutional linkages is the translation of innovative ideas to high-value products and services. Such linkages drive technological research and development.

With technological R&D, the country will not only be end-users of ICT tools and work as contract assemblers of electronic and semiconductor products but also be creators of systems and chips that run cellular phones or computers, for instance.

Right now, the country's 30-billion dollar electronics industry consists mostly of assembly, packaging and testing. These activities account for only 5 percent of value added in the global semiconductor industry.[37]

Thus, if we are able to dive deep into the technology and develop systems and chips, for instance, that Nokia, Sony Ericsson, and other technological giants would license from us, we would see our products in every mobile phone and base station that these giants sell and deploy worldwide.

Then, we will be able to secure a larger slice of the global ICT revenue pie. Apart from this, the country will be seen as a significant player in the ICT field.

It is worth noting that while revenues of our ICT companies such as Globe, PLDT and Smart are at record highs, they are still top importers of foreign technology in the form of boxed solutions. On the part of these service providers, there seems to be little impetus to study technology and undertake research in depth with the objective of creating innovation through local development of high value blocks. The bottom line, for them, is already high and the need for R&D is not felt.

This must definitely change or we will continue to be end-users of technology, not its developers. We would all benefit from a Bell Labs -- where fundamental advances and breakthroughs in communications and information theory have been discovered, formulated, and translated into useful products that have made – and continue to make -- life easier for all of us.

But this is possible only if research and development into fundamental ICT theory and tools is carried out as part of the R&D agenda of inter-institutional linkages. Such an agenda would contribute to the development of cutting-edge hardware and software for the ICT industry and their applications. And these would translate into export winners for the country.

Create an enabling environment through public policy

Public policy must foster an ecosystem that would make our S&T system thrive. STI must be integrated in policies on education, agriculture, health, environment, public works, and trade and industry.

For this reason, the 13th Congress had to establish the Congressional Commission on Science, Technology and Engineering (COMSTE). The Commission is mandated to look into the country's science, engineering and technology development. Among its tasks is to undertake a thorough review of science education in public and private schools, particularly at the graduate level.

COMSTE has six priority areas – sectors that provide opportunities to improve competitiveness through identification of S&T input, human resources and infrastructure. These six areas are energy and environment; electronics and semiconductors; IT and IT-enable industries; agriculture and food; health sciences; and science education and R&D.

COMSTE intends to respond to our waning competitiveness and build public support for making the wealth-generating fields of science, technology, engineering a national priority.

In the process, COMSTE hopes to revitalize an S&T ecosystem that will generate knowledge and innovation.

Conclusion: creating the future

Our goals are to pour massive investments in upgrading science, mathematics, and engineering education at all levels and to unceasingly foster a culture that vigorously supports research and development in science, technology and innovation. The ultimate aim of all these is to uplift the living standards of Filipinos.

National and local governments, policymakers, educational and research institutions, media, industries, and the private sector have to forge strong and functional partnerships to bolster our competitiveness. No one individual or institution can do this job. Collaboration cannot be dispensed with and all must do their share.

Creating the future through science and technology is exciting but difficult work. It will take vision, leadership, and sustained commitment to achieve our strategic mandate - to create a future where our people can enjoy a better life. That objective is within our reach.

TABLES

Table 1
US Legislation and Public Spending for National Defense

- Project sputnik invested on US researchers, educators, scientists and inventors, through the **National Defense Education Act**
- Building of 40,000 miles of straight four-way free lanes through the **National Defense and Interstate Highways Act.** The roads will ease the transport of the US military.
- 1950s to 1960s: **100** US corporations received **2/3s** of the value of US defense contracts
- 1959: **50%** of California's non-agricultural workforce was employed by defense contractors
- In the 1970s, the US government underwrites 70% of the country's research

Table 2
R&D Public and Private Spending (In billion dollars)

	1950s	1975	1990s	Present
US	5 n	71.6	137.3[b]	338
Western Europe		55.1	103.4[b]	
EU		52.1	98.9[b]	
South Korea		0.378	5	24.2 [c]
China			21.4	136
India		1.7	6	24[d]
Singapore		0.28	0.292	2.6[d]
Taiwan		0.388[a]	2.4	14.9[d]
Japan		18	56	129

a - 1978 data
b - 1995 data
c – 2003 data
d – 2004 data
Source: http://www.nsf.gov/statistics/s1893/rd.pdf

Table 3
The comparison of university-owned enterprises in China, 2000-2004

Year	Number of enterprises	Turnover (100 million RMB)	Total profit (100 million RMB)	Net profit (100 million RMB)

2000	5451	484.55	45.64	36.04
2001	5039	602.98	48.17	35.32
2002	5047	720.08	45.93	35.33
2003	4839	826.67	42.98	27.95
2004	4563	969.3	49.93	29.53

Table 4
The comparison of university-owned hi-tech enterprises in China 2000-2004

Year	Number of S&T enterprises	Turnover (100 million RMB)	Total profit (100 million RMB)	Net profit (100 million RMB)
2000	2097	368.12	35.43	28.03
2001	1993	447.75	31.54	23.98
2002	2216	539.08	25.37	18.63
2003	2447	668.07	27.61	14.73
2004	2355	806.78	40.98	23.86

Table 5
RP Basic Education Resource Gaps, 2008

Particulars	Estimated Shortage, Start of SY	Programmed FY 2008	Estimated Shortage, End of SY
Classrooms @ 1:45 double shift across all regions	12,418	10,472 + 556[a]	1,390
School Seats	1,774,237	1,250,000	524,237
Teachers @ 1 teacher per 45 students	12,733	10,000	2,733
Principals	24,709	1,600	23,109
Textbooks and Other Instructional Materials	74,485,235	32,358,755	44,234,813
Additional requirements for Other Instructional Materials	2,108,333		

Source: DepEd Briefing Materials, 2008 Budget Hearing
a - GASTPE equivalent classrooms

Table 6

Proportion of Teachers who are Non-Science/Math Majors

Subject	Majors	Non-Majors
General Science	42%	58%
Biology	44%	56%
Chemistry	34%	66%
Physics	27%	73%
Math	80%	20%

Table 7
ERDT Consortium Objectives for the Next 10 Years

- Implement research agenda aligned to the National Service Training Program (NSTP) and Medium Term Philippine Development Plan (MTPDP)
- Attain a critical mass of MS and PhD graduates to reach at least the UNESCO benchmark of 3.4 researchers, scientists and engineers (RSEs) per 10 thousand population.
- Upgrade the qualifications of practicing engineers.
- Come up with accessible graduate programs for engineers.
- Improve and develop engineering colleges.
- Develop a culture of R&D.

Source: Philippine Competitiveness through Engineering Research and Development for Technology by Dr. Rowena Cristina Guevarra, UP College of Engineering

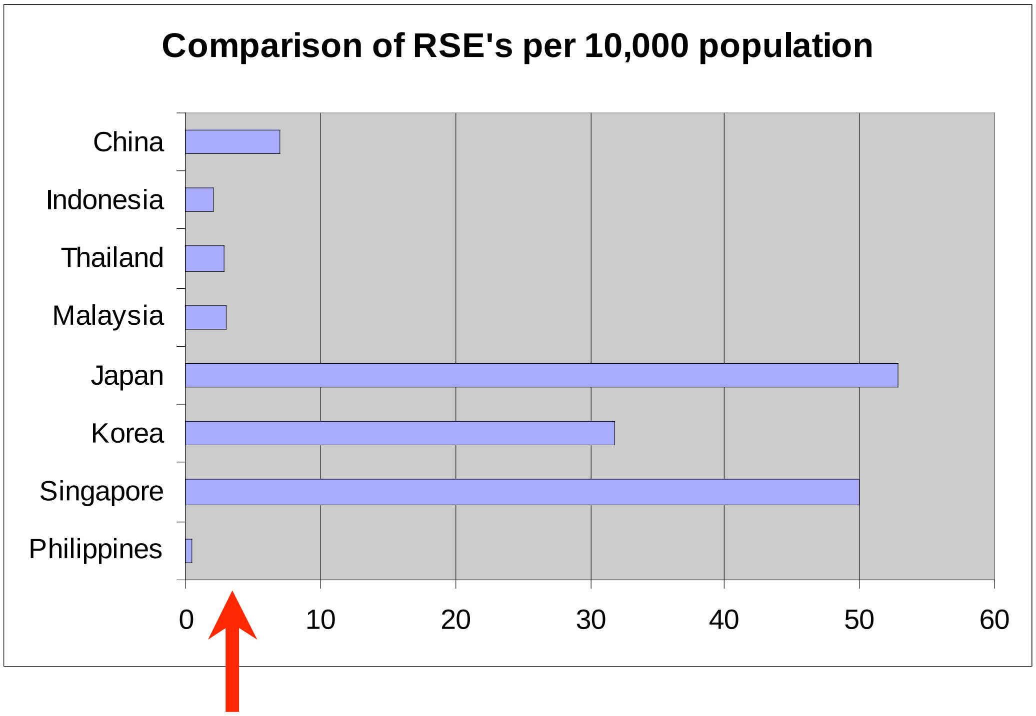
Table 8
Aklan State University and Visayas State University R&D Efforts

Aklan State University	**Visayas State University**
R&D Projects: • seedless rambutan and pomelo • high quality pina fiber • tissue culture of Aklan Pina • Mayon Turbo Stove and Dryer or the Poor Man's Gas Stove which uses rice hull • Breeding and commercialization of Native Darag chicken • Biodiesel additive from waste fats and oils • Mangrove reforestation and Aquaculture	R&D Projects • utilization of abaca fiber in the automotive industry • biofuel R&D on Jetropha oil • promotion of a plant oil stove • jackfruit products as an alternative to junk food • probiotic white cheese from carabao
Other Projects: • extension and community service through Farmer-Teachers • community radio for Agri-Development integrated rice crop management	R&D Institutes: • Philippine Root Crop Research and Training Center • National Abaca Research Center • National Coconut Research Center-Visayas • Institute of Tropical Ecology • Philippine Carabao Center • Agricultural Training Institute
ICT Initiatives • internet library • library automation system • Korean Internet Volunteer Computer Literacy • digitization of commercial viable research output • digitization of the English Proficiency module.	International Linkages: • Taiwan: National Taiwan University • Thailand: King Mongkot's University of Technology, Thonburi • Vietnam: University of Natural Sciences, Vietnam National University-Ho Chi Minh City • Japan: Tokyo University of Agriculture and Technology, Saitama Medical School Research Center got Genomic Medicine, Chiba University, Mie University • China: Zhejiang Gongshang University

	• USA: Cornell University • Australia: Australian Centre for International Agricultural Research, University of Queensland, Center for Agriculture in the Tropics • Germany: Federal Republic of Germany, University of Hohenheim, Akademie Fur Natur-und Umweltschutz, Deutcher Akademischer Austausch Dienst, DaimlerChryslerm Euronatur, Bosch and Siemens, Hausgerate, Goerg-August University of Goettingen, University of Halle, DED-German Devt. Service, InWent

FIGURE

Figure 1
Developing Countries RSEs



Developing Countries: 3.4

Source: UNESCO Institute for Statistics, 2004

ACRONYMS

AIST	African Institute for Science and Technology
BPO	Business process outsourcing
BRIC	Brazil, Russia, India, China
CAR	Cordillera Administrative Region
CHED	Commission on Higher Education
COMSTE	Congressional Commission on Science, Technology and Engineering
DA	Department of Agriculture
DepEd	Department of Education
DOST	Department of Science and Technology
DTI	Department of Trade and Industry
ERDT	Engineering Research and Development for Technology Consortium
FDI	Foreign direct investment
GDP	Gross domestic product
GMOs	Genetically modified organisms
HEDF	Higher Education Development Fund
ICT	Information, communication and technology
JSPS	Japan Society for the Promotion of Science
MIT	Massachusetts Institute of Technology
MPS	Mean percentage score
NAT	National Achievement Test
NIS	National Innovation System
NSTP	National Science and Technology Plan
OECD	Organization for Economic Cooperation and Development
PREGINET	Philippine Research, Education, and Government Information Network
R&D	Research and development
S&T	Science and Technology
SET-UP	Small Enterprise Technology Upgrading Program
SME	Small and medium enterprise
STI	Science, Technology and Innovation
SUCs	State Universities and Colleges
UNESCO	United Nations Educational, Scientific and Cultural Organization
UP	University of the Philippines

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NOTES

[1] Provided, of course, that there is an enabling environment within a country; i.e, the right macroeconomic policies and strong institutions

[2] Source: http://go.worldbank.org/6EWO0SHKA0

[3] According to DOST's National Science and Technology Plan (NSTP) 2002-2020, the Philippines' roadmap to S&T development

[4] Nanotechnology, or the applied science of manipulating matter at the atomic level, produces new machines, materials, fuels and drugs.

[5] Neurotechnology, uses relevant technology to analyze and influence the human nervous system, especially the brain, to heal, manage and enhance mental performance and functioning.

[6] Nanotechnology industries today generate US$10 billion. By 2015, this will multiply tenfold to US$1 trillion. Neurotechnology will generate US$180 billion by 2015, from its current worth of US$100 billion. Information technology industries will have a similar growth, that by 2020, it will be worth US$7 trillion. Biotechnology, on the other hand, will amount to US$25 trillion by 2030.

[7] Xenotransplantation is a process which improves the chances of acceptance of an animal organ to human transplant

[8] Accessed on January 14, 2008 from this website: http://www.economist.com/opinion/displaystory.cfm?story_id=7944359

[9] Accessed on January 14, 2008 from this website: http://humanitieslab.stanford.edu/2/189

[10] Stages of South Korea's Development:

Step 1 - Imitation (1960-1980)

At the onset, Korea set up its industries by copying foreign technologies. To this end, several government institutions were established from 1966 to 1971. These include (1) the Korea Institute of Science and Technology (KIST), the first modern, integrated technical center; (2) the Ministry of Science and Technology (MOST), the agency mandated to "integrate plans for S&T development, coordinate governmental R&D, as well as international S&T and research on nuclear energy; (3) and the Korea Advanced Institute, an institution assigned to "carry out high caliber masters and doctorate programs;" and (4) the Korea Science and Engineering Foundation (KOSEF) an organization aimed at enhancing R&D capabilities of Korean universities by offering research grants in basic and applied research and long-term fellowships.

Legislation such as the Technology Development Law and the Engineering Services Promotion Law were enacted in 1972.

During this time, Korea invested a larger portion of its budget in S&T compared with other developing countries. From 0.18% of GNP in 1964, S&T spending rose to 0.30% of GNP in 1970, and 0.37% by 1980.

Step 2 - Internalization (1980s)

By the 1980s, Korea's innovation activities involve modifying or adjusting existing technologies to fit the Korean context – or the internalization of foreign innovation. This internalization effort came with industry realization that it cannot compete with advanced foreign products unless it suited it to Korean market idiosyncrasies.

By this time, private sector expenditure in R&D overrode that of the government's – in 1990 it reached a ratio of 8:2.

To further encourage private sector initiatives in R&D, government implemented more effective and precise R&D policies, and extended tax incentives for R&D. It also established a national R&D program that heightened the competitive environment among researchers in universities, national research institutes and the private sector.

Step 3 - Generation (1990s onwards)
In the 1990s, 80% of Korea's research capabilities were in universities. This led government and industry to forge a policy for cooperative research between university and industry. Science research centers (SRC) and engineering research centers (ERC) were created in universities to establish cutting edge research capability in the latter. The ERCs eventually got incorporated to industry, thus the whole project not only resulted in cutting edge researches but the flow of high quality manpower to industry as well.

[11] Brazil Russia India China (BRIC)

[12] China is now a major destination for foreign direct investment (FDI), which amounted to US $60 billion in 2005. Its FDI stock relative to GDP is significantly larger than Korea and Japan, and is now comparable to that of United Kingdom and Canada. For the past 15 years, China's economy has expanded dramatically, with an average of around 10% a year GDP growth and strong macroeconomic performance.

[13] Total enrollment in China in 2003 numbered at 29.43 million students in 83,726 schools, up 30% from the enrollment in 1984. http://english.sina.com/china/1/2005/0228/22640.html

[14] R&D investment has steadily climbed since 1996. The number of high tech imports, on the other hand, is on the decline. During this rise of R&D spending and decline of high tech imports, it must be noted that value added to industry outputs are still on a steady rise.

[15] China's NIS: Education - The Chinese NIS roots back to the 1979 government decision to make the country's universities both education centers and research centers. By 1995, China embarked on "Vitalizing the Nation through Science Education," an education strategy that required universities to contribute in economic development. This involves linking universities, research institutions and enterprises together.

[16] China's NIS: Business - Aside from universities, another major source of innovation is the business sector. It has become the dominant R&D actor, now performing over 66% of R&D in China, up from its 40% share during the 1990s.

Twenty-five to thirty percent of total business R&D comes from R&D operations of inward foreign direct investment. Aside from the transfer of technology, knowledge and know-how to China, FDIs are also major investors to the country's R&D.

[17] China's NIS: Government
In 1978, China embarked on the "Open Door Policy," which opened its economy to foreign trade and investment, culminating with China's entry to the World Trade Organization in 2001.

[18] China's S&T system reforms, 1985: (a) allocation mechanisms for public R&D funding; (b) transformation of R&D institutions in applied research into business entities and/or technical service organisations, and the incorporation of large R&D institutions into large enterprises; (c) creation of markets for technology; and (d) reform of the management of human resources in public research institutions.

[19] China Innovation Policy from 2000 (a) Relaxing regulations - Since 2000, the government has taken a series of initiatives to make returning more attractive by loosening restrictions, such as granting special permits for entering and leaving the country so that returnees can continue to work abroad and also work in China. They may also be allowed to remit their after-tax earnings, a right otherwise reserved to foreigners working in China. (b) Development parks and incubators - For example, in 2003, 45 incubators dedicated to returned overseas scholars hosted about 3 000 enterprises employing more than 40 000 persons. (c) Tax incentives and project funding - There is some interregional competition, especially between Beijing, Shanghai, Shenzhen and Guangzhou, to attract returnees through tax reductions or exemptions, favourable import regulations and/or financial support to start-ups. (d) National programmes to attract high-level scientists such as the "100 Talents" programme of the Chinese Academy of Sciences and the recent similar initiative by the National Natural Science Foundation of China.

[20] India S&T promotion strategy throughout the years.
- Industrial Policy Resolution of 1948 - India invested heavily on basic and heavy technologies. It placed emphasis on FDI, technology licensing and financial and technical collaborations, while the level of R&D was negligible.
- 1950s - R&D promotion policies. Substantial investments were allotted to establishing science-based education and R&D infrastructure. Engineering colleges and students rose from 38 and 2940 in 1947, to 138 and 25000 in 1970. Institutions such as the Indian Institute of Technology, modeled after the Massachusetts Institute of Technology, were set up, and agencies such as the Council for Scientific and Industrial Research (CSIR), the Department of Atomic Energy, and the Defense Research and Development Organization were expanded. R&D activities these establishments perform centered on:
(a) scaling down of plants based on foreign technology to suit Indian markets
(b) adapting foreign processes to Indian conditions and local materials and,
(c) tackling on-the-spot production problems and quality control.
- 1960s - Despite India's restrictive economy characterized by regulation and monopolies in the 1960s, Science & Technology remained a priority agenda for India. S&T planning was integrated to the overall planning process of government, through agencies such as the Department of Science and Technology (DST).
- 1970 to 1980 - While technology transfers and FDI flows declined drastically, a positive outcome surfaced from India's restrictive phase. Local R&D activities increased, both from public and private funding. Private companies increased its R&D expenditures more than eight-fold from 1970 to 1980, reaching Rs1207 million by 1981. R&D expenditures in the CSIR also increased from Rs215 million in 1971 to Rs690 million in 1981. India, however, remained dependent on highly complicated technologies while mastering standard tech.
- 1980 - India's closed economy, however, offered little incentive for its large firms to conduct R&D while its small firms had little capacity to do so. This led to a stark decrease in R&D by the 1980s, making industries resort back to technology importation with little effort to learn from, or assimilate said imports.
- mid 1980s - Process of deregulation and liberalization was initiated. Coinciding with these major economic reforms is India's greater focus on promoting technology and R&D. Government conducted the following initiatives:
(a) Restrictions on technology imports and foreign equity participation were relaxed.

- Up to 51% foreign equity was permitted in many sectors, except in those reserved for the public sector.
- In areas of sophisticated technology and/or export-oriented ventures, up to 100 percent equity was allowed.

(b) The Technology Policy statement of 1983, for the first time, recognized the need for establishing linkages between scientific, technological and financial institutions to promote effective transfer of technology from institutions to industry.

(c) A fully-fledged Ministry of Science and Technology was created in 1985, with the earlier Department of Science and Technology (DST) and a new Department of Scientific and Industrial Research (DSIR) as constituents. A high level post of scientific adviser and a science advisory council to the Prime Minister were set up in 1986 to advise the Prime Minister on major issues relating to S&T development.

(d) Also, a quality system management (SM) scheme to strengthen in-house R&D and provide quality assurance of same was set up as well as a DSIR scheme to grant recognition to scientific and industrial research organizations (SIROs) in the private sector.

- 1990s - A progressive environment for promoting R&D was already in place. India was already opened to foreign investment and most of its industries were deregulated. In 1993, a new draft of technology policy emphasized the need for strengthened linkages between industry, R&D institutions, and financial institutions. A consortium approach emerged from this policy, whereby commercial exploitation of technologies developed in laboratories and the academe shall be encouraged.

Also, the CSIR took a more commercial orientation – previously a government funded agency, it was required to generate at least 30% of its budget from consultancy and technology sale to private sector. Since then, CSIR has participated with the United Nations Conference on Trade and Development (UNCTAD), World Intellectual Property Organization (WIPO), United Nations Industrial Development Organization (UNIDO), UN Economic and Social Commission for Asia and the Pacific (ESCAP), and Asian and Pacific Center for Transfer of Technology (APCTT) in activities related to science, technology development and transfer.

This liberalized environment has encouraged foreign direct investments, with India's foreign investment flows rising from 103 in 1990 to 5099 in 2000. Of the 5099, 2399 are FDIs, many of which are multinational enterprises.

- 1990s – R&D centers increased sharply when the Intellectual Property Law was passed in 1994. Prior to its passage, India had only 2 R&D centers, but the number ballooned to over 60 by 1994.

These centers are now restructuring to become global in nature, shifting focus from developing products for Indian markets towards the world.

And because of India's high quality labor force and numerous scientists and technologists, more companies such as Astra, Unilever, GE and Microsoft are establishing R&D centers and ventures in the country.

To illustrate, India's domestic IT industry developed rapidly through collaboration with industry in developed countries. Collaboration efforts include establishment of IT centers and contractual arrangements for outsourcing with Indian companies. Consequently, India's software and IT-enabled services sector grew rapidly. In 1998, these sectors account only for 2% of India's exports. But by 2002, exports in these sectors account for 14% of the country's total exports, amounting to 2% of Indian GDP.

- 1990s – Industrial Clusters - The liberalization period also facilitated a conscious encouragement of industrial clusters. Most notable of these clusters is high tech Bangalore, dubbed as India's Silicon Valley of India. This is where thirteen of the twenty-three companies in the world rated as level 5 on the Software Engineering Institute's Capability Maturity Model (CMM) are located, and about 35% of the risk capital invested in India between 1998 and 2001 is estimated to have been invested. In view of Bangalore's success, other states such as Masharastra and Andra Pradesh are encouraging other high technology and biotechnology clusters.

[21] Timeline of key STI policy initiatives of Singapore
1980 Ministry of Trade and Industry formulated the Second Economic Plan to deal with labor shortages and improve the low productivity performance of the economy
1982 The Small Industry Technical Assistance Scheme (SITAS) was introduced to help supporting industries upgrade. It was renamed Local Enterprise Technical Assistance Scheme (LETAS) in 1986; The National Computer Board was established to spearhead computerization
1984 The initiatives in New Technology (INTECH)Scheme was introduced to give incentive in upgrading in technical skills
1985 The Economic Committee was set up to revive the economy from recession and to identify new directions for economic growth. Strategies were proposed to develop manufacturing and services as twin growth engines
1986 The National Information Technology Plan was formulated; Economic Development Boards Local Industry Upgrading Programme (LIUP) was introduced
1987 The National Productivity Board's Report on Initiatives for Reskilling the Workforce, a national training blueprint was released.
1989 The SME Master plan Report, a blue for the upgrading of local small and medium sized enterprises was released
1991 The National Science and Technology Board (NSTB) was formed to develop the country into a center of excellence in Science and Technology. The National Technology Plan was formulated, setting out the directions for the promotion of R&D in Singapore. A number of Research Institutes and Centres were established
1993 The Cluster Development Fund (CDF) was launched to initiate the development of indigenous industries in high-growth clusters
1995 The Innovation Development Scheme was launched
1996 The Singapore Productivity and Standards Board (PSB) was formed through the merger of NPB and SISIR. The new Board took over the role of SME development from EDB. The National Science and Technology Plan (NSTP) 2000 and a $ 4 billion R&D fund was launched to facilitate the development of S&T in Singapore from FY 1996-2000. The Promising Local Enterprises (PLE) was launched
1997 The Committee on Singapore's Competitiveness was launched
1998 Singapore One, the nationwide broadband multimedia infrastructure network was launched
1999 Industry 21, development blue prints for each manufacturing and exportable service clusters under EDB, was launched. The Techno-entrepreneurship 21 Committee was established to develop and harness the growth potential of technological entrepreneurship. The Technoentrepreneurship Investment Fund was launched to spur the development of the venture capital industry in Singapore

[22] These include engineering sciences, information technology, architecture and building, health sciences and science and related technologies.

[23] More than 100 multinational companies, including Rolls Royce, Motorola, Philips, GE, Delphi, Eli Lilly, Hewlett-Packard, Matsushita, Sony, 3M and Daimler-Chrysler have established R&D facilities in Singapore, and the country has recently attracted pharmaceutical heavies such as Aventis, Merck, GlaxoSmithKline and Wyeth to set up regional hubs.

[24] According to the World Bank's Knowledge Economy Index, in the period of 1995 and 2002, Thailand scored 4.26 and 4.78 respectively. The Philippines scored 2.99 and 3.70 respectively.

[25] South Africa and Mozambique's Maputo Corridor is another example. This transportation project, which involves a variety of technology-based activities, present excellent opportunities for industry-academe team up. Existing projects under the Maputo Corridor include the following: (a) upgrading and constructing road links from Witbank to Maputo; (b) improving rail facilities from Maputo to Johannesburg, together with lines connecting Maputo to Zimbabwe and Swaziland; (c) updating Maputo's port and harbor operations; and setting up a new, integrated border post to facilitate movement between Mozambique and South Africa and (d) improving telecommunications facilities, as well as related non-transportation investment such as the Maputo iron and steel plant, which will use natural gas from Mozambique's Pande fields

[26] South Africa's Human Capital improvement scheme –
Currently, the focus of donations given to Africa for education revolves in primary education, but the secondary and tertiary levels are now also gaining attention. The World Bank is currently considering large loans for post secondary education in Africa, aside from the loans it has granted to strengthen the STI capacities in some African countries.
The African Institute for Science and Technology (AIST) is also in the pipeline. An attempt to create its own Massachusetts Institute of Technology in Africa, the AIST initiative aims at developing S&T institutions in Africa that will have strong developmental impact. In particular, the AIST shall develop Africa's knowledge-base workforce by offering undergraduate and masters degree programs in science and technology within the African context.
In Nigeria, an AIST-Abuja is already being built. Its president, President Obasanjo has allotted 550 acres of land for the AIST in Abuja. The school will initially target 3300 of Nigeria's brightest students, who will be taught by reputable African professors from around the world coming from the Diaspora.
Interdisciplinary research and education centers will be organized in: (1) Petrochemical engineering; (2) Materials; (3) Water resources and environmental engineering; (4) Mathematics and computer science.
The AIST is also tasked to develop strong links with industries and businesses in Africa. These links will include:

- setting up industrial advisory boards to guide the activities of departments and interdisciplinary institutes;
- sponsoring research and development;
- sponsoring innovation and technology transfer to industry.

With these linkages, it is hoped that AIST and African industries will develop a push-pull relationship, "with industry pulling the AIST into new fields, while the AIST pushes the frontiers of industry through innovation and the supply of students," both of which have the end goal of tapping African countries' potential to develop and prosper in a globally competitive environment.

[27] Sun Star Cebu, 18 November 2006

[28] Of the 69,375 graduates in Science and Engineering, only 9,896 were employed in R&D related work. Government agencies employ only 37% of them. DOST researchers are about 7% of the total R&D personnel, while the private sector employs 11%.

As of 2005, there was a 20% average annual increase of graduation in Computer engineering and other IT related programs. But IT professionals eventually end up in the service sector and not as research scientists and engineers.

[29] Singapore has 4,613, Korea's 2,193 and Malaysia's 726 per million population scientists and engineers engaged in R&D.

[30] RA 8439 provides for a program of human resources development in science and technology to achieve and maintain the necessary reservoir of talent and manpower that will sustain its drive for total science and technology mastery.

Under this law, the State shall establish, promote and support programs leading to the development of S&T manpower, such as science and engineering scholarship programs, improvement of the quality of science and engineering education, popularization of science, and provision of incentives for pursuing careers in science and technology.

[31] The DOST - JSPS Joint Scientific Cooperation Program is an inter-institutional cooperative arrangement initiated on 15 March 1979 through the signing of a Memorandum of Understanding (MOU) for Scientific Cooperation between the then National Science Development Board (now the Department of Science and Technology) and the Japan Society for the Promotion of Science (JSPS).

This bilateral program aims to establish sustainable collaborative relations for the advancement of the mutual benefits of the Philippines and Japan under the principle of reciprocity. The Program is designed to create high potential research nuclei in the fields of natural sciences, social sciences and humanities. The Program fosters and looks after the next generation of leading researcher in the country.

[32] The PREGINET, launched in September 2007, is a project funded by the Department of Science and Technology (DOST), and is implemented by the DOST's Advanced Science and Technology Institute (DOST-ASTI). At present, there are 76 partners connected to the network coming from research (29); academe (14); and government (33).

[33] Agricultural research projects in biotechnology, promotion and development of organic farming, integrated R&D program for organic vegetables, legumes and root crops in the Cordillera Administrative Region.

[34] Research partnership between Philrice and Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA), University of the Philippines-Los Banos (UPLB) and the Bureau of Postharvest Research and Extension (BPRE).

[35] The CHED scholarship programs have been rationalized– from over 20 different programs to just 3 major headings namely: State Scholarship; Special Study Grant; and Study Loans.

[36] The Higher Education Development Fund (HEDF) will also be rationalized – the bulk of its money will go to scholarship programs and the remaining funds will be for research and graduate scholarship; for quality assurance and upgrading; and for management and information systems development.

[37] Paper presented during the conference entitled "Policies to Strengthen Productivity in the Philippines", sponsored by the Asia-Europe Meeting (ASEM) Trust Fund, Asian Institute of Management Policy Center, Foreign Investment Advisory Service, Philippines Institute of Development Studies and the World Bank, June 27, 2005