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UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL
ORGANIZATION

INVESTMENTS IN SCIENCE AND TECHNOLOGY FOR INNOVATION

Introduction

Decades of studies indicate that education is critical to economic development. New investments in education and vocational skills are essential to building the foundation for strong economic growth. Investment in science education in particular, is critical because as technology changes so do the nature of the jobs surrounding it. To sustain economic growth, a nation must be able to attract higher wage jobs that will increase gross national income (GNI). These higher wage jobs require new skill sets and often higher education levels as well. A clear example of this comes from the economies of the Asian Tigers, consisting of Japan, the Republic of Korea, Hong Kong, the Republic of China, commonly known as Taiwan, Malaysia and Thailand. These countries were the first newly industrialized countries, noted for maintaining exceptionally high growth rates and rapid industrialization between the early 1960s and 1990s. In the 21st century, many of these countries have evolved into advanced economies and high-income economies¹. When these countries embarked on economic growth they largely relied on agriculture and trade. The textile industry boomed first because of cheap labor but the value of goods produced was relatively low. However, governments in these countries also invested heavily in education, especially in math and the sciences. The result was a relatively rapid change in industry from low profit margin products such as textiles to high profit margin goods such as cars and computer memory chips. The Republic of Korea today is the largest producer of computer memory while Taiwan is the largest producer of computer motherboards². These types of industries require several components before they can take hold including infrastructure, tax shields, and stable government, but the most critical factor is skilled workers. Investments in human capital and science education are the key to this type of growth.

Developing countries are not alone in requiring government support in nurturing industry. The United States is currently at a critical crossroads on how to best pave the way for continued economic prosperity. In a recent report from the Economic Office of the President titled *A Framework for Revitalizing America*, the Obama administration has outlined a government program to ensure the United States remains competitive and that new industries such as clean energy take hold here. The plan calls for large stimulus funding in basic research because it recognizes that the private sector cannot perform this function alone due to the large capital needed and the risks involved. A good example of this from the twentieth century is space travel. For decades, the only organization in the

¹ <http://gbr.pepperdine.edu/001/tigers.html>

² A motherboard is the central printed circuit board (PCB) in many modern computers and holds many of the crucial components of the system, while providing connectors for other peripherals.

United States that invested in space travel and research was NASA. There were many reasons for this including:

- a) The space race with the USSR was a source of intense national pride and the United States government felt that it could not afford to lose.
- b) Being a command economy, the Soviet Union had the freedom to invest almost unlimited resources for space. This could not possibly be matched by the American private sector alone.
- c) The amount of capital required was immense and furthermore there was no real return, at least initially, on investment to induce private investment.

The United States won the so-called space race and together with cold war defense spending helped fund hundreds of projects that led to a variety of civilian technologies including the microwave oven, GPS navigation, CAT scans and fuel efficient aircraft³. Proponents point to these achievements as proof that government policy can play a large role in accelerating technological innovation. Of course, government policy can sometime lead to adverse outcomes as well⁴. This is why the form of funding is important. The following paper will examine two areas in which governments can address science and technology, education and technology investment.

Education

Interest in Science

For the last decade, numerous studies have warned about the impending crisis concerning a lack of students interested in the sciences either as a possible future career, or as an intrinsic interest that will continue after school. The problem affects both developing and developed countries. The clearest indicator for this decline is the lack of interest in science among today's youth (especially in the United States). It should probably come as no surprise to the reader that most students in high school dislike science. An OECD report from 2003 reports, "*While absolute numbers of S&T [Science and Technology] students have been rising, the situation is exactly the opposite with regards to the relative share of S&T students among the overall student population during the same period. This is true not only in tertiary education, but also for upper secondary graduates in many countries.*"

In 2008, UNESCO published a report titled *Science Education Policy-Making: Eleven emerging issues*. One of the aims of the report was to study the main reasons high school students were not interested in the sciences. They therefore commissioned a study to interview 15 year olds throughout the world and classify their attitudes towards science. The classifications are presented as bullet points below.

³ <http://www.buzzle.com/articles/development-gps.html>

⁴ http://www.americanheritage.com/articles/magazine/it/1987/2/1987_2_24.shtml

- **Science teaching is predominantly transmissive.**

As a student, learning science is simply a matter of being like a sponge, and soaking up this knowledge as it comes from the teacher or from the textbook. Science knowledge is dogmatic and correct. There are no shades of grey about science.

Students learn about scientific theories which by definition need not be dogma or correct. School schedules rarely permit sufficient time to discuss the case for evolution or the big bang theory and most science at this stage must be accepted as fact. Nonetheless, science may be presented as the evolution of theories and the presentation of opposing ideas may make the subject more exciting.

- **The content of school science has an abstractness that makes it irrelevant.**

So much of what is taught in science is uninteresting because it is not related to our everyday lives. Science in films and in the media is often exciting, but that is not an aspect of the science we hear about do in school. There are science topics that would be interesting but these are not in our school curriculum.

Hollywood and the media industry may be doing more harm than good for science when they develop films such as Star Trek and Back to the Future. While such films do prompt children to dream about where science may take us, they are often quickly displeased when they realize teleportation and time travel are a long way off. The alternative is to have engineers and scientists interact with students and demonstrate the cutting edge technologies that science has enabled. Many middle schools and high schools have science oriented clubs such as robotics clubs and model rocket clubs that allow students to channel their creative minds towards practical scientific endeavors. Corporations are increasingly involved as well by offering science scholarships for higher education, and promoting science fairs (such as Intel's science fair). Public entities such as the National Institute of Health (NIH) and NASA have also established outreach programs to promote science education and allow students an opportunity to see what science can do for humanity.

- **Learning science is relatively difficult, for both successful and unsuccessful students.**

Science is more difficult than a number of the other subjects, and especially compared with ones I can choose in the later years of schooling.

- **Hence, it is not surprising that many students in considering the senior secondary years are saying:**

Why should I continue studying science subjects when there are more interactive, interesting and less difficult ones to study?

Science and engineering are complex subjects that demand much attention and care from students. Educators should be careful in revising standards for these subjects as

this may have adverse consequences down the road (i.e., high school students being ill-prepared for the rigors of college courses). However, technology has enabled these subjects to be taught in a far more effective manner. Today's high school physics and chemistry labs have equipment and computer simulations that make it easier to explain complex reactions and experiments. Though the math and critical thinking skills are still vital, modern tools like computer and calculators remove many of the mundane tasks in science and allow students to concentrate on mastering the core material.

Gender Issues

One does not need to look far to see that science and engineering subjects continue to be male-dominated fields. Beginning from the grade in which science becomes an elective all the way through college and graduate school, men outnumber women by more than three to one⁵. Many cultural stereotypes exist concerning this inequality including the notion that women simply are not “wired” the way men are for science.⁶ Though there is scant scientific evidence for this theory, many academics use it as an excuse for not doing more to increase female participation in the sciences. The problem of gender inequality in the sciences has existed for quite some time but it was given comparatively little attention until the 1980s. The publication of “The Missing Half” in the 1980s first brought attention to the lack of women in Science and Technology. Since then, UNESCO and numerous other organizations have conducted studies to determine how to increase female participation. One of the major foci has been on increasing the visibility of female role models in the science and technology fields. Numerous non-profits and government organizations have organized seminars to help promote the sciences among women and there is evidence that these movements are having an impact⁷.

In many developing countries, the lack of girls and women in the sciences parallel the more general disadvantage women face in access to education. Cultural stigmas concerning the role of women in society often preclude them from having access to formal education. Families that can afford to only send one child to school will overwhelmingly chose to send their son rather than their daughter. Solving this issue requires multiple approaches ranging from economic empowerment to new educational policies and is beyond the scope of this topic. However, even when these issues are accounted for, science and technology tend to be underrepresented, indicating these subjects require more attention. A survey conducted by the University of Oslo in 2004 on behalf of ROSE (The Relevance of Science in Education) indicates *that there are clear differences between boys and girls interests in science education in both developing and more developed countries. In both cases the curriculum content and the dominant pedagogy are still generally biased towards the boys' interests of boys, thus implicitly limiting access to girls*⁸.

⁵ <http://www.gao.gov/new.items/d04639.pdf>

⁶ *BBC News*, “Harvard row over sex and science” January 18, 2005.

⁷ http://dww.ed.gov/launcher.cfm?media/MathScience/Girls/RM/Learn/flashoverview/415_rm_overview.pdf

⁸ <http://www.ils.uio.no/english/rose/key-documents/key-docs/ad0404-sowing-rose.pdf>

Cultural Dilemmas

In countries with significant indigenous minorities such as the United States, Ecuador, Australia and Africa, science participation among the indigenous youth is particularly low. Socioeconomic issues are certainly in play but there is the added cultural dissonance that plagues indigenous youth. Most indigenous cultures are rich with scientific knowledge about the natural world that has been acquired through careful observation and experimentation over many generations. Unfortunately, this information is passed down through non-classroom activities and the values expressed by it cannot easily be standardized in a scientific text. When children in this context are presented with “modern science” in a classroom, the two sources of knowledge often do not mesh. If this difference is not acknowledged and addressed, it can create a serious barrier for educators. Incorporating salient aspects of indigenous science into formal science curricula can greatly benefit underrepresented indigenous minorities.

Other Problems

The issues highlighted here are just a few of the many problems that must be addressed in science education. Lack of adequate science teachers is another problem that continues to exist throughout the world. The disparity between educational pay and the salaries of scientists and engineers makes it difficult for schools to attract qualified teachers. Due to the natural complexity of the subject, areas like chemistry and physics require qualified teachers with professional scientific training. Please see the article titled *Eleven Emerging Issues* in the additional documents section for more examples.

Technology Investment

As was mentioned above, education is a major requirement for economic growth. It is not the only policy tool for growth, however. Many governments have invested in specific technology areas they wish to focus on. These are often published in long term policy plans. For example, the Obama administration has made a commitment to fostering a viable “clean energy” industry in the United States and has allocated billions of dollars through the *Recovery Act* towards this goal. The tricky part about government funding is the danger that it will not be used efficiently. In this case, the U.S government has employed multiple methods for fostering growth in clean energy. They include⁹:

Cash grants:

When the Recovery Act passed, many renewable energy projects had been halted as few developers had the ability to utilize the Production Tax Credit (PTC). Some forecasts expected the industry to shrink 25 to 50 percent. ARRA allows renewable energy generation projects to receive a 30 percent cash grant in lieu of the Production Tax Credit. The program has already supported over 1GW of renewable energy projects.

⁹ EMBARGOED UNTIL 1:30PM DECEMBER 16, 2009 EXECUTIVE OFFICE OF THE PRESIDENT
A FRAMEWORK FOR REVITALIZING AMERICAN MANUFACTURING

Loan guarantees:

Department of Energy (DOE) loan guarantees can back financing for factories that make wind turbines, solar panels, energy efficient windows, and other clean energy equipment. The program may also support wind farms, advanced biorefineries, nuclear power plants, and advanced coal plants – that will buy turbines, steel, and other equipment from American factories. Projects employing commercial technologies can re-ignite factories, while projects employing advanced technologies can help American factories bring promising but risky new technologies to the marketplace.

Manufacturing tax credit:

Section 48C Advanced Energy Manufacturing Tax Credit supports the building and equipping of new, expanded, or retooled factories that manufacture the products needed to power the green economy. The program covers a wide array of clean energy technologies, including renewable energy, energy efficiency, advanced transportation, and advanced transmission. The Recovery Act included \$2.3 billion in tax credits that will support over \$7.5 billion in total capital investment. This program has generated far more interest than anticipated. DOE and Treasury received significantly more technically acceptable applications than the program had resources to fund. Instead of turning down worthy applicants who are willing to invest private resources to build and equip factories that manufacture clean energy products in America, on December 16 2009, the Administration announced its support for expanding the program by up to \$5 billion. This funding will go to shovel ready projects that will create tens of thousands of new construction and manufacturing jobs and continue America's emerging leadership in manufacturing the clean energy products of the future.

Advanced Vehicle Manufacturing Loan Program:

Through the \$25 billion Advanced Technology Vehicles Manufacturing Loan Program, the Obama administration is supporting competition to produce the most cost-effective solutions to reduce oil dependence. To date, over \$8 billion has been awarded to Ford, Nissan, Tesla, Tenneco, and Fisker. Ford's loan will allow factories in 5 Midwestern states to produce over 2 million advanced combustion vehicles every year. Loans to Nissan, Tesla, and Fisker support locating three of the world's first electric vehicle factories in Tennessee, California, and Delaware. The factories are producing cars that raise the bar for fuel efficiency while simultaneously increasing the competitiveness of the domestic industry.

The United States is by no means the only country to use government funding to foster clean energy. Germany, Japan, and China are just few of the other countries that have also established ambitious policies to foster new renewable and clean energy technologies. By providing low interest loans and grants, governments can lower the barriers to entry in new technologies and encourage the private sector to invest in a particular area. A good example of this comes from Singapore. Singapore had long been a hub for electronics manufacturing. In the late 1990s, however, labor costs had increased

to the point where it was no longer attractive for electronics manufacturing companies to operate there. As a result, many manufacturers relocated to places such as Malaysia and China. The Singaporean government therefore embarked on ambitious plans to recast itself in a new light. The government spent approximately \$2.3 billion on investments, grants and other incentives -- behind an effort to become an integrated biotechnology hub¹⁰. The plan included new industrial parks for biological research, joint partnerships between universities and pharmaceutical companies, and a number of subsidies and tax credits to encourage multinational drug companies to establish R&D centers in Singapore. The plan also contained millions for education training in biologics and PhD grants in biopharmaceutical research¹¹. It is an example of how a carefully targeted government policy with clear coordination between various stakeholders can lead to growth in a new sector.

Conclusion

Investments in Science and Technology through education as well as grants and partnerships is useful and in most cases vital for long term economic growth. Unfortunately, it requires long term sustained funding because the returns often take many years to materialize. This is why policy makers must be careful to allocate funding wisely and ensure that efforts in both education and other investments are coordinated. It must be noted that there is criticism in some circles to this type of government involvement. Some believe that market forces alone are more efficient in fostering growth and all the government needs to do is stay out of policy planning and lower taxes. The proponents of this idea argue that government policy makers are not good at picking what technology or even scientific field is most well suited for the country. Indeed there are examples where heavy handed government policies have led to poor technology project selections.

This is why education and investment in *human capital development* is so attractive. It arms the population with the knowledge and scientific literacy required for higher waged jobs but does not necessarily limit the areas from which those jobs will come. Many developing countries are finally beginning to realize this. For example, India has long suffered from both historical neglect of infrastructure and education. With policy makers currently facing a budget deficit, the government must choose how to invest its funds. Many in the government point to the phenomenal success of China and believe that the answer must be to invest in new highways, skyscrapers and airports. While infrastructure investment is clearly lacking, evidence suggests that the foundation for China's growth lays not in infrastructure, but in education¹². During the 1980s, China's infrastructure lagged India's in terms of highways and miles of rail. The Communist emphasis on universal education and a culture that held the teaching

¹⁰ <http://www.nytimes.com/2003/08/26/business/singapore-goes-for-biotech.html>

¹¹ http://www.edc.ca/english/publications_14226.htm

¹² <http://economictimes.indiatimes.com/Features/The-Sunday-ET/Special-Report/Human-capital-development-The-reason-behind-Chinas-growth/articleshow/5357558.cms?curpg=3>

profession in high esteem set the stage for growth decades down the road. An educated workforce fostered new industries as well as a large influx of foreign direct investment which fueled economic growth and paid for much of the infrastructure investments seen today. A critical dimension that governments and corporations need to bear in mind is that investments in science and technology education are not zero-sum games; *The Economist* provides a clear example of how these investments may in fact be positive-sum games: “America does not become less competitive because China invests more in science; indeed, outside highly proprietary areas, Chinese investment in science will help to advance scientific knowledge in general.”¹³ As governments and bureaucrats around the world wrestle with budget constraints, it is important to ensure that the long term and often invisible impact of science and technology investment are not ignored.

Guiding Questions:

What policies does your government have in place for investing in science and technology, particularly science and technology education?

How might your government encourage private sector businesses and investors to increase their investments in science and technology during the contemporary global economic slowdown?

What programs does your country use to promote science and technology education? What have been the results to date in terms of improving science and technology education?

Is your country experiencing a serious shortage of qualified science and technology teachers and professors?

How might UNESCO and other UN agencies and bodies better coordinate local and international efforts to promote increased investment in science and technology education and initiatives?

How might the different relevant stakeholders, governments, international organizations, educators, businesses, parents, and students, persuade more girls and women to pursue advanced science and technology (S&T) education and careers?

¹³ *The Economist*, “Nightmare scenarios” October 5, 2006.