2006-2290: ENGINEERING EDUCATION, DEVELOPMENT, AND THE DIGITAL DIVIDE: BASIS FOR A COMPARISON OF INDIA AND LATIN AMERICA

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Abstract

Several Latin American countries have recently drafted policy (Engineering for the Americas, Organization of American States, Lima Declaration, 2004) to enhance and improve engineering education specifically with the development of that region in mind, thereby creating a cadre of engineers trained to consider their discipline within the context of regional economic growth. India has become a leading producer of engineers and technologists, dramatically enhancing the country's competitiveness in the global economy. On the other hand, India also continues to be a country plagued by socioeconomic disparities. Should India, as well, be creating engineers focused on development problems of India in addition to producing globally competitive engineers? Some of the socioeconomic disparity in India could be alleviated by adopting suitable policies that provide opportunities to more people to attain an affordable education, thereby reducing the poverty level or the gap between the rich and the poor; there is evidence that India is pursuing some of these policies. India provides an interesting example for Latin America, as it seeks to become globally competitive like India, but to also engender economic development and reduce poverty in the region. The objective of this paper is to discuss preliminary findings, and suggest a framework for understanding the relationship between engineering, technology and development.

Introduction

Societies should be preparing their engineers to compete in a flat world. This is the message gleaned from Thomas Friedman's new book, *The World is Flat*, which is being read and commented on widely by those interested in globalization and the global economy [1]. In fact recently the book was highlighted by several presenters at the Organization of American States (OAS)'s 'Engineering for the Americas' conference in Lima Peru (Nov. 29 – Dec. 3, 2005) [2]. Friedman, a New York Times journalist, asserts that the world is flat because of political changes and information technologies which have leveled the playing field and allow individuals from any country to compete equally in the global market. The message conveyed at the Lima conference was that in order to compete globally Latin America must produce more engineers, and those engineers must be well trained – like India, which, for Friedman, is the prime example of how the world is now flat.

Of course, the world is not flat for everyone, as evidenced by the digital divide. While the digital divide is a relatively new concept, it is based on the old divide between rich and poor, north and south, developed and developing. In general, new technologies are acquired by those that have the education, money and infrastructure to utilize them. There are sectors of society participating in the information revolution in most developing countries, but the socio-economic divides persist as well. It seems clear that engineers and engineering educators have a key role to play both in bridging the digital divide and promoting development, however it is less clear precisely how this role is carried out for maximum benefit to local development. The OAS in a recent report stated that it is impossible to "de-link the socioeconomic and cultural development of a country from its scientific and technological advances", and that all countries needed to "value science, technology, engineering and innovation as crucial components of their development strategies, to reduce poverty and to construct Knowledge Societies" [2]. One aspect of this link between science, technology and socioeconomic development is an appreciation of the possible distinction between engineering expertise for innovation and competitiveness in the global market, and engineering for local development, such as infrastructure-building and capacity for information communication technologies (ICTs) expansion (bridging the digital divide). Both are critical; however, the tendency to focus on global competitiveness for attracting foreign direction investment, while important, could have the negative effect of obscuring the latter. Foreign high technology companies are often seen as the method by which technology transfer will occur from developed to developing countries, however there are no guarantees that the transfer will take place, much less that it will help to bridge the digital divide within the developing country. Thus, engineering education should play an important role both for countries' competitive advantages in the 'flat world', as well as for the ongoing work of creating sustainable development in local communities.

That education is a key element to the successful development of a society is well discussed and accepted in the literature on socioeconomic development. For example, various approaches to development highlight education as critical, albeit in different ways [3]. The human capital approach views as instrumental the increase in people's skills and knowledge, and hence their ability to contribute to society and earn more money. The basic needs approach has always considered education as a basic need, along with health, water, nutrition and housing. The human development and human capabilities' perspectives point out that education enhances the capabilities of people, which can lead to development as long as there are corresponding opportunities [4]. The emphasis is on "what people are able to do and be" [5] with education obviously playing an important role. Tilak [3] points out that the type of education is important, and advocates for a strengthening of basic (usually the focus of development initiatives) as well as secondary and higher education, stating that higher education is perhaps a more sustainable means of socioeconomic development. The United Nations Development Programme (UNDP) has targeted education in its 2000 Millennium Goals, specifically primary education [6]. The World Federation of Engineering Organizations (WFEO) under the auspices of UNESCO has stated the goal of "capacity building and the application of engineering and technology for poverty reduction and sustainable social and economic development" [7]. The two strategies listed on their website focus on the improvement of engineering education quality.

There is no apparent disagreement on the vital role of education in the socioeconomic development process, as well as the specific role of higher education (including engineering education) and technology in social and economic development of countries and regions, which implies the closing of the digital divide. Yet how to ensure that enhancing any particular aspect of education will lead to the presumed benefits to society is a more difficult question. There is a need to look more closely at how enhanced engineering capacity can lead to local development. The most obvious answer, as mentioned above, is to attract foreign direct investment (FDI). Foreign companies that require a highly skilled workforce are attracted to the countries with this resource, particularly if it costs less than in the home country. These workers then earn money that goes back into the local economy, as well as gain skills that they can carry into entrepreneurship or indigenous companies. A recent study of the impact of Intel's investment on the development of Costa Rica concluded that it has made a positive contribution to its "development of a technology and knowledge-driven economy" [8]. The investment by Intel has attracted FDI by many other hi-tech multinationals, and the development of a significant software industry in the country. This activity has involved local companies as suppliers, but even more significant according to the authors of the study, are investments Intel has made into universities in the area of technology and engineering, and an increase in student interest in these fields [8].

However, widespread poverty in many developing regions of the world suggests that FDI is not enough, even when it does produce optimal results with high skilled jobs and the transfer of technology and skills. Preparing engineers to compete globally in a 'flat world' does not appear to be enough to address the educational and engineering needs of developing countries. It was suggested at the recent OAS conference in Peru, cited above, that engineering education should address a 'double role', one goal being global competitiveness and the creation of high tech jobs and indigenous industries, hence promoting economic growth; the other goal should address the local problems facing development, such as infrastructure and clean water. A June 2006 conference sponsored by Engineers without Borders in Cameroon, Africa, for example, is focusing on *African Solutions for African Problems* with sessions focused on local development needs [9]. While this sort of initiative could prove very useful to Latin America, India - with its information technology industry - provides a compelling example of global competitiveness. India is the prime example, in fact, used by Friedman to illustrate his vision of a 'flat world'. Both regions are large geographically, and culturally diverse, with staggering socioeconomic inequities. India is considered a significant player in the world economy; Latin America aspires to be. What might Latin America learn from India as it embarks on a project to enhance its cadre of engineers for the benefit of the region?

Engineering Education in India

A. Structure of engineering and technology education

The current structure of engineering education in India includes both merit-based institutions as well as fee-based institutions, the latter being only for those with enough money to pay the tuition. The problem is that merit-based seats are very limited in number compared to the total population qualified to enter into them. This leads to many economically poor but meritorious students remaining without access to education. The colleges are structured into 3 categories - government colleges, aided colleges and private colleges. The government colleges are run and funded by the government (purely merit-based). The aided colleges are started and run by a private individual or group, but they are funded by the government (partly merit-based). The private colleges are solely run and funded by a private organization or individual, with no aid from the government. Most of the private colleges are self-sufficient and the fees are high; poor students cannot afford these private institutions. In India in 2004, the Supreme Court ruled that private colleges can select students based on their choice, thereby causing an even greater reduction in merit-based seats in 2006 in comparison to what existed in 2004. Thus the low cost seats available in 2004 were no longer available for the economically poor students. Placing more importance on merit would address this situation, but who would run the colleges and fund them? The private companies need to be encouraged to fund the merit seats and in turn benefit by recruiting these qualified meritorious students into their companies. Private companies can be encouraged to start their own colleges and fund the education of economically poor but meritorious students. As well, the government and aided colleges could increase their intake of need-based students by at least 10% with the existing resources, and perhaps more with additional resources of faculty, staff, lab facilities, class rooms, buildings, student residences, etc. However, this has to be done with the provision that all these graduates will be able to get jobs once they graduate.

There is the precedence of how higher education benefited the development of the United States. Thomas Jefferson founded the University of Virginia. In the 19th century, Congress created the land-grant colleges. States have long supported public universities and funded scholarships for the needy with the especially talented. All these and other similar acts stem from a common belief that higher education is for everybody's benefit, not just the individuals who received the education [10]. Jefferson believed that the U.S. could not become a democracy without an educated citizenry. The framers of the land-grant bill believed that there needed to be a focus on intellectual effort for the improvement of industry and agriculture. State universities, with modest tuitions and a mandate to educate all who could benefit from it, have produced one of the best citizenries in the world. The support of academic research has delivered prosperity, security, and health as well as a graduate education system that is one of the most highly regarded in the world. Higher education is the key to enhanced socioeconomic attainment, freedom and independence of individuals and hence countries.

A similar trend is being seen in India lately. While the Indian Institute's of Technology (IITs) and Indian Institutes of Management (IIMs) benefit only the top percentile of the population, a number of other government and private engineering colleges have benefited thousands by producing educated and talented individuals who have helped to attract Microsoft and Intel to invest billions in India over the next few years. While this can be attributed to the success of the country's engineering education, the benefits reach others as well, as these establishments need cleaning people, hotels, restaurants, banking and other service industries which create employment, thus enhancing local development. They are also instrumental for local economic development through related and supply industries or ancillaries. For instance, the Ford Motor plant at Chennai is instrumental for a number of local small-scale industries that support the manufacturing and operations of that plant. Clearly, in addition to engineering job openings, the benefits proliferate to other industries and economic sectors. Thus, FDI, which the cadre of trained engineers helps to attract, does, in certain locations, produce positive effects for local development.

B. India's global competitiveness versus internal development

Outsourcing is the buzzword for economic growth in India at the beginning of the 21st century. India is one of the leading producers of well qualified and talented engineers and technologists at competitive rates, as evidenced by the Intel, GE, and Microsoft initiatives. This is proof of India's capacity, it continues to be a source of attraction for U.S. and European countries to move operations to India, taking advantage of the wealth of knowledge and skills available, which comes as a relatively cheap price. As noted above, outsourcing of projects from developed countries into India not only provides job opportunities to the engineers but to the entire economic strata starting from construction company workers to drivers to hotel servers to gardeners and cleaning people. However, the Indian economy cannot rely solely on outsourcing. The country needs, as well, to have its own, indigenous industries that can compete globally, in order to sustain its economic growth and not become dependent on foreign sources of capital. The foreign outsourcing works well for cities like Bangalore, Hydrabad, Chennai, New Delhi and Bombay, but these areas only represent a fraction of the total population. A more equitably distributed development that helps the majority of the population is what is needed, especially for those in rural India and smaller urban areas. It is proposed that engineering education must be geared towards that as well – innovation for local use, small business development, the use of native materials and talents, and engineering for urgent, local infrastructure needs. For this purpose, engineering students must be trained in hands-on practical skills, with problem-based learning relevant to local issues. Support must come from government agencies, educational institutions, and the private sector, in order to increase the engineering capacity of the population suited to India's needs.

C. Policy changes to address India's educational needs

India provides examples of this level of support addressing the digital divide from the primary school level through higher education. The current Indian education system has a wealth of knowledge and content associated with it, but it lacks a proper media of transmitting the knowledge to develop learning. Classes need to take advantage of the digital world and focus the class time on learning and not finding material or writing lengthy notes that the students need to copy. Modern education needs to combine the wealth of knowledge available in the Indian curriculum with the method of transmitting knowledge in the western curriculum to maximize the results at all levels of education. This is where Indian institutes of higher education, including elite schools such as the IITs are working together on a Ministry of Human Resource Development (MHRD) initiated National Project for Technology Enhanced Learning (NPTEL), which develops courseware both in video format and web formats. This is an effort to bring all of the engineering colleges to the same level and support them in teaching material. In addition, national television in India in collaboration with IITs and Indira Gandhi National Open University (IGNOU) transmits educational videos through the "Eklavya" channel all over the country. Major companies across the world are also investing considerable energy into this area. Intel has developed an *Intel Teach to the Future* program, which is a professional development program designed to help teachers effectively integrate technology with learning. This initiative has reached a major milestone in its world wide effort to help students and teachers develop 21st century learning skills, with three million teachers world wide having now completed training. A wide section of teachers in India were trained in this process. These teachers armed with strategies to develop digital literacy, higher order thinking, communication and collaboration, are reaching tens of millions of students across the globe.

Private schools, which affluent students can afford, have already transformed their classrooms by incorporating technology into daily lessons, making learning exciting and helping students reach their potential. This needs to be extended to the government and poor schools that don't have enough funds to purchase the computers and infrastructure required for this transformation. Private companies need to contribute towards these efforts. Working together, governments, education and industry can advance the learning process and transform the education in India as well as around the globe. One such example of this is the IIT Kharagpur's initiative to 'adopt' villages in its vicinity and bring information technologies to these villages to create awareness and interest amongst the villagers. Another example is IIT Kharagpur's agricultural and food engineering departments which are setting up a laboratory on food processing technology to assist rural people.

Educators need to work on the development of more tools, workshops and online offerings shaped by ongoing feedback from program participants. The Indian curriculum is to be modified to help students develop the required thinking skills they need to participate and succeed in the knowledge based economy. Private companies and educational institutions need to collaborate on developing integrated courses where in the final six months to one year of a course a student participates in an internship in the company, so that they get trained for the job on hand. In order to retain quality graduates efforts are on to collaborate with top notch US universities like Georgia Tech and multinationals like National Semiconductors in setting up facilities for VLSI training at IIT Kharagpur. This not only retains high quality graduates in the country but also aids in developing indigenous technology. Distance learning programs can be set up, so that people in remote villages connected through internet gain education by listening to lectures given remotely by specialized teachers around the world. These efforts need to be multiplied, resulting in knowledge transfer and knowledge sharing possible without physically having to travel long miles.

In order to further reduce the socioeconomic and digital gap, and enhance regional development, it is proposed that more talented engineers need to be created that have incentives to stay in India and improve the status of rural villages rather than go abroad for greener pastures. Develop the talent, offer the training, and facilitate resources and opportunities (like scholarship, bank-loans, affordable education) for them to excel and stay in India and contribute in their local villages and towns. This could include adding courses to the engineering curriculum that deal with local infrastructure issues and pressing problems, such as the access to clean drinking water. Multidisciplinary courses and programs can integrate the social sciences such as economics and sociology with engineering courses for development so that students can work on solving engineering problems in realistic contexts. Engineering education at the four year, as well as at the two year level can help make these required changes in India. Better-educated and trained engineers can make the difference in India as they do in the developed nations.

Gender issues are significant in India, as in any other country, with a need to enhance educational and professional opportunities for girls and women. The Indian government has adopted policies to improve education for women. The policies of several state governments such as that of the state of Gujarat are to provide free high-school education and a subsidized college education for all its female students. This is because women are more intimately involved in the education and development of a child than any other member of an Indian family, and integral to the socioeconomic development process. Just recently in the federal budget announced for 2006-2007 the national government has proposed depositing Rs. 3000 (Rupes) for any female child passing the Standard VIII exam and enrolling in secondary(high) school education under the *Kasturba Gandhi Balika Vidyalaya* Scheme[11]. The level of education among women has improved drastically but there is room for improvement. In order to spur development in India, the government must encourage the female student population to be trained in professional fields such as engineering. This indicates that the government needs more schemes like the *Kasturba Gandhi Balika Vidyalaya Scheme* to promote college level education and also more emphasis should be given to programs and schemes that promote college education and employment in corporate India.

D. Other Initiatives to Reduce the Digital Divide

Finally, in addition to the above mentioned educational initiatives that link engineering with development and bridging the digital divide, there are projects implemented by engineers and other professionals trained in technology that India has initiated. For example, the Indian Tobacco Company (ITC) is training a person from every village in how to use a computer terminal, through which farmers can get the latest market information, as well as sell their goods directly to the retailer, thus eliminating the middle man [12]. The Indian government and private corporations can team up to promote more programs like this to provide education and technology access for rural parts of the country, the areas most marginalized in the development process. Another talent that can be exploited is to have a trained web designer in each village and have links that gives details about that place, its local picnic and tourism spots, the local restaurants and hotels that offer good clean food and rooms at affordable prices, and information about the ancient temples and monuments which will enhance the tourism of that place. India is rich in natural beauty as well, and this has not been exploited to its fullest extent. Web pages can help here tremendously to attract foreign and local tourists. It should also be mentioned that there are extensive initiatives to have e-governance throughout the country. In fact, the state of Andhra Pradesh is the one, which has been able to do this with near 100% availability of an internet based information system, possible under able guidance of then chief minister Chandra Babu Naidu. Other states are working in this direction as well, and efforts are on to provide information kiosks at each village through collaboration between government and academia. For example, IIT Kharagpur is supporting the state of Orissa in this endeavor.

Lessons for Latin America

Latin America as a region shares many elements with India. It too has a highly unequal distribution of income, based on centuries of rigid socioeconomic structures with little social mobility, exacerbated by a legacy of colonialism. Its systems of higher education have commonalities as well, with the private schools accessible only to the wealthy, and many students with merit being left out either due to lack of funds, or due to lack of educational opportunities at an early age. As in India, education in the rural areas lacks, and the digital divide means that these areas fall further behind. While regions of India, such as Bangalore and New Delhi have become vibrant parts of the global information economy at the beginning of the 21st century, vast areas of the country, both rural and urban, remain mired in poverty and without basic needs, let alone access to the Internet. So too in Latin America, while individuals and firms in Buenos Aires, Quito, and Lima compete in the global arena, large percentages of the populations are living on less than a dollar a day. The education and creation of engineers is intertwined with the problem of the digital divide. Children without access to adequate educational opportunities, including access to technology, will not reach higher education. A region lacking in qualified engineers will not be able to adopt, utilize and adapt new technologies. The overriding suggestions for India emphasize the re-structuring of higher education to provide access wider socioeconomic sectors of society, participation of the private sector in engineering and technology education, and the inclusion of engineering curriculum focused on local problems and context. The projects in India focused on bringing internet technology to rural areas can also be found in Latin America, however since India is a single country they are perhaps more pervasive and consistently carried out. Further research comparing the country of India and the region of Latin America could be fruitful in this area, with policies and best practices potentially having relevance in both parts of the world. Both areas, for example, could re-examine tradition engineering courses in light of local development needs. Engineering curriculum which focuses solely on globally competitive engineers and innovation runs the risk of being overly outward-looking and lacking the resources to addresses the problems within.

Possible Solutions for India and Latin America

- *Integration* - A framework for linking engineering education to local development should consist of an integrated approach that begins with an analysis of how accessible the engineering programs are to the society as a whole; conduct a monitoring of investments from the private sector seeking to enhance engineering education and access; and include an examination of the engineering curriculum itself, including goals and outcomes.
- *Collaboration* - This integrative approach suggests a close collaboration between government, industry and institutions of higher education (Fig. 1). The OAS conference in Peru stressed such collaboration, and suggestions from India support this approach. Without this collaboration and instrumental approach to engineering education and development, the flat world will remain accessible to only a relatively small percentage of the developing world.
- *Funding* - Special scholarships, attractive salaries and benefits to attract engineers and others trained in technology to villages and rural areas to reduce the digital divide and work on other infrastructure projects. In addition to local government and corporate support for such funding, philanthropic foundations, non-governmental organizations, and higher educational institutions in the developed world can contribute to this effort to reduce the digital divide in developing regions.

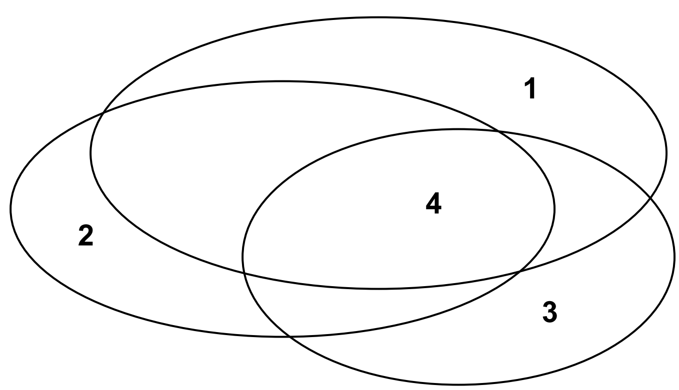

Fig. 1 Integrated Approach to Engineering Education and Development: 1-Government, 2-Industry, 3-Educational Institutions, 4-Regional Development

Summary

Engineering education, technology education and the transfer of technology are inextricably linked to regional development in a complexity that goes beyond investment by foreign companies. Education, training, availability of facilities, access to facilities for the rural students and others will certainly reduce the digital divide. The entire world might become more flat, but only with the cooperation and unified efforts of governmental organizations, NGOs, industry, and universities. Preliminary findings in the comparison of India and Latin America suggest that as regions they share many features, and provide a useful platform for comparing and better understanding the relationship between engineering education, the digital divide and socioeconomic development. It is suggested that further research be conducted to more closely compare government policies and initiatives, engineering educational development, and social and economic outcomes.

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