Enhancement of Engineering Education to meet Global Development

M.G. Prasad†, S Rajaram++ and B. Rajavel†

†Noise and Vibration Control Lab
Dept. of Mechanical Engineering
Stevens Institute of Technology
Hoboken, New Jersey
mprasad@stevens.edu

++Alcatel - Lucent
Whippany, New Jersey
srajaram@alcatel-lucent.com

Abstract

It is estimated that the global population in 2020 will reach 8 billion compared to 6.6 billion today. The major share of this projected increase in population will come from developing countries in Asia, Africa and also from South America. Human population growth over time from 5 million BC to 2008 AD is represented by a J shaped curve. The rapid advances in engineering and the benefits to humanity over the ages, and especially since the start of the Industrial Era are also represented by a J-shaped curve. An observation based on the “J” shaped curve is that most of the population increase in recent years is correlated to advancement in science and engineering. From agricultural revolution to metal working to irrigation ploughing to industrialization, advances in engineering have kept pace with human population growth. To meet the demands of human population growth, advancement in engineering is vital. For example, though food production has kept pace with population growth, the so called green revolution relies heavily on petroleum-based fertilizers. Increased demand for oil has caused food prices to rise sharply on a global scale in the early part of the 21st century. Hence, it drives policies for alternative energy sources to meet population demand. It is well known that several developing countries are experiencing rapid economic growth. Future engineering education programs should address the global challenges these countries pose and also capitalize on the resulting opportunities. Some of the main challenges and opportunities include understanding cultural diversity, working under resource constraints, global competition, and constant learning and upgrading of skills. In addition, engineering education must also address critical human needs and challenges such as, eradicating poverty, addressing healthcare, man-made and natural calamities like earth quakes, global warming, renewable energy sources, etc. This paper focuses on how present engineering education programs can be enhanced to reflect global development needs. Various aspects of engineering education to prepare engineers to meet the global demands will be discussed.

Introduction:

The global population is now increasing very rapidly compared to growth in the last few centuries1. As seen from Fig. 1, the major portion of the population increase comes from developing countries. If we see the J shaped curve2 as shown in Fig 2 which is an indicator of how human population increased over time, we realize that most of the population growth occurred from the start of the last century.
Superimposed in Figure 2 are the major developments in human evolution through the ages, and simultaneous advances in engineering technology leading up to the Industrial Era and beyond, to the current Information Era which we live in today. The rapid advances in engineering and the benefits to humanity (quantified using reasonable metrics such as longevity, health, income, prosperity, etc.) over the ages, and especially since the start of the Industrial Era would also be expected to represent a J-shaped curve similar to rapid population growth.

If we analyze the “J” shape curve in detail, we can infer that the rapid population increase occurred in the very recent past, very similar to the rapid advances in science and engineering. It is well understood that advances in science and technology have led to increased life spans and reduced the risk of mortality. Therefore, it is reasonable to deduce that engineering has played a crucial role on human population growth over time. Beginning with the agricultural revolution over 7000 years ago, to the more recent exponential and explosive growth in electronics and information technologies, engineering advances have kept pace with human population growth.
To meet the increasing demands of human population, advancement in engineering is vital, and in the extreme, critical to its sustenance and very survival. For example, with increased demand for oil due to rapid economic growth in countries such as China and India, along with a rapidly depleting commodity, food prices have risen sharply globally in the early part of the 21st century. It is therefore imperative to define new alternative energy strategies and policies to meet this population demand. Not addressing this crisis, along with other urgent crises such as global warming, could have catastrophic consequences worldwide such as drought and starvation on an unprecedented scale, especially in developing and under-developed regions which are the most vulnerable. Engineering solutions have always addressed basic human needs, and advances in engineering are critical to avert such catastrophic human tragedies.

As mentioned earlier, several developing countries such as China and India are growing rapidly, and are among the fastest growing economies in the world. In addition to competition for raw material resources, such rapid economic growth in several important regions of the world also creates unique challenges and opportunities for engineering knowledge resources (talent). These new challenges and opportunities have implications for both developing and developed nations alike. Present engineering education programs should evolve and address global challenges and opportunities to enable future engineers to succeed and grow in an increasingly interdependent global economy.

Some of the main challenges and opportunities from an operational perspective include understanding and operating in culturally diverse organizations and regions of the world, finding optimal engineering solutions constrained by resources and global competition, managerial and organizational skills to develop products and solutions across many physical global locations, and constant learning and upgrading of new skills to meet new needs and challenges of the economy.

In addition, engineering education must also address critical human needs and challenges such as, eradicating poverty, addressing basic and major healthcare needs, man-made and natural calamities like earthquakes, development of clean and sustainable energy, global warming etc. In this paper, various aspects of engineering education to prepare engineers to meet the global demands will be discussed. Thus it is evident that technical skills alone are not sufficient to succeed in the global society.

Enhancement of engineering education to meet global challenges:

Most of the innovation in science and engineering took place during the latter part of the 19th century and early part of the 20th century. If we look at the J curve, rapid increase in population also took place around the same time. It would be reasonable to empirically observe that science and engineering adapted or evolved to meet the growing global population needs. During the start of population increase in the beginning of the 19th century, the major global needs were food and energy which were achieved by the green revolution and innovation of petroleum related products.
At the start of 21\textsuperscript{st} century, it is well known that several developing countries are experiencing rapid economic growth. China and India have both achieved phenomenal economic growth but have followed different education approaches\textsuperscript{3}. India as a country has pursued a “deep” education approach compared to China which has opted for a “wide” education model. The deep education model refers for the most part to providing higher education for few. The wide education model refers for the most part to basic education for the masses. Based on empirical evidence from India and China recently, and from other developed countries before them, it is an irrefutable fact that education influences economic development and vice versa.

A larger labor pool with basic education has allowed China to attract large scale manufacturing plants. Technically savvy and English speaking labor has made India a choice destination for international software and services outsourcing\textsuperscript{4}. Analysis of the Indian education system shows a greater emphasis in the areas of Mathematics and Science in grade schools. This leads them to have more analytical and logical skills which are very essential for information technology (IT). Consequently they are now one of the leading IT outsourcing countries in the world. Such an emphasis in Science and Mathematics alone meets the current needs of IT today, but may not be sufficient to meet future economic growth in new high technology areas.

These new economic power houses and developing countries (like China and India) pose different global challenges to the world. In addition to competition for raw material resources, such rapid economic growth in several important regions of the world also creates unique challenges and opportunities for engineering knowledge resources (talent). These new challenges and opportunities have implications for both developing and developed nations alike. Engineering education programs should evolve and address current and future global challenges these countries pose to the world, and also capitalize on the resulting opportunities in a global economy. Some of the main challenges and opportunities from an operational perspective include

- Understanding cultural diversity and operating in organizations that may be spread over several regions of the world
- Finding optimal engineering solutions constrained by resources and global competition
- Managerial and organizational skills to develop products and solutions across many physical global locations
- Constant learning and upgrading of new skills to meet evolving needs and challenges of the economy.

In addition, engineering education must also address critical human needs and challenges such as,

- Eradicating poverty and addressing basic and major healthcare needs
- Man-made and natural calamities like earth quakes, global warming, etc.
- Development of clean and sustainable energy

To address the future global challenges, the traditional core engineering disciplines such as Mechanical, Civil, Chemical and Electrical should be enhanced. Some of the changes in engineering education that should be considered are,
Creating multi disciplinary engineering programs combining engineering, business management and administrative disciplines.

Possible multi disciplinary engineering programs that may be considered include combining different engineering disciplines such as Mechanical and Chemical engineering, Mechanical and Electronics etc.

Engineering education must expand its core curriculum to include courses in System Analysis and Design, Reliability & Quality engineering, Statistical Process and Quality Control and Six Sigma processes.

Evolve the engineering education programs to new growth areas. Some of the areas are Genetic engineering, Bio-technology/Bio-informatics, Nano technology etc.

The engineering curriculum should not only focus on providing technical knowledge to future engineers but also train them to adapt to working in different culturally diverse environments. The curriculum should include courses to teach soft skills and global professional skills in addition to traditional engineering hard skills which are now taught in the colleges. The three different but all interconnected skills which is essential to succeed in global markets are shown in Fig.3.

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Fig.3. A 3-D Global engineering criteria for the development of the global engineering profession.
Application to Global issues:

Global experience:

For future engineers to succeed in the global market, they should know how to work in an environment with several constraints. The constraints may not only be technological, but also social, cultural and political, especially when dealing with developing countries. They also should know how to adapt to the different culturally diverse environments. In developing countries, economic constraints govern engineering projects and developments. This calls for innovative and less expensive engineering methods. Future engineers/technologists must also learn to be good team players while at the same time preserving their individuality.

The importance of encouraging students to participate in international exchanges and acquire new language skills should be emphasized to improve their global experience. Educators should integrate global perspectives into the existing curriculum. For example, the College of Engineering at Purdue University in partnership with three universities namely Universität Karlsruhe (Karlsruhe, Germany), Shanghai Jiao Tong University (Shanghai, China) and the Indian Institute of Technology Bombay (Mumbai, India) offer a unique program called Global Engineering Alliance for Research and Education (GEARE). GEARE is designed to supplement the education of engineers so they are prepared to function immediately in the global workplace. Students who are enrolled in the GEARE program participate in the following program:

- An orientation program, including language and culture
- One domestic internship
- One subsequent international internship
- One semester of study abroad with fully transferable engineering course credits
- A two-semester design team project (one semester at the home university, and one abroad) with design teams that include students from international partner universities working on an industry sponsored project

Similar initiatives are also undertaken by the National Science Foundation. They have introduced a program called “Developing Global Scientists and Engineers (International Research Experiences for Students (IRES) and Doctoral Dissertation Enhancement Projects (DDEP))”

Curriculum aspects:

Future engineering curriculum should also teach students to develop the ability to define solutions in an ill-defined and unstructured environment- ”what to do when one doesn't know what to do?”. Different countries having different types of teaching models and they have succeeded in advancing economically. For example, the higher education system in India (which is identified as one of the fastest growing economies), is based on more theoretical aspects that they need to translate into practice when they start working in industry. The Indian education system puts greater emphasis on math and science at the high school level than the US education system. But US universities are more creative and innovative. The US education system uses...
Free Thinking, Creativity, Risk Taking and Self Learning techniques. The US education system also puts greater emphasis on applications and practical hands on knowledge. This gives them the advantage of better prepared engineers to succeed in the global environment. To address future global needs, multi-disciplinary engineering education is necessary. The meet this requirement, the engineering curriculum must emphasize strong theoretical background in core science and engineering areas, combined with globally relevant hands on application. A strong theoretical foundation is needed to understand engineering from a multi-disciplinary perspective. This gives them the advantage of being better prepared to succeed in the global environment, with the ability to learn new areas of engineering as needed to support evolving technological needs.

Cultural constraints:

It is extremely important for future engineers to understand and adapt to different cultures because they will most likely be working in a very culturally diverse environment both domestically and internationally. For example, all the countries may not share a common language. Engineering curricula should consider training related to different languages and cultural aspects. This gives an opportunity for the students to learn about different cultures before they actually experience it in the real world. That makes them more confident to meet the culturally diverse global challenges.

Economic and Environmental constraints:

Engineering in general has been defined as "applying creativity, mathematics and science to solve problems within economic constraints". In a global sense, the engineers are required to execute the engineering project with an even greater understanding and appreciation of economic constraints which could be very different depending upon the country and society they are dealing with. Some of the present global environmental problems are global warming and the green house effect, air, water and noise pollution, sustainable energy needs etc. The future engineering student should be aware of various environmental Standards and regulations such as ISO 14000, etc. that their designs must conform to. Designing the engineering solution/design with environmental constraints will help eliminate or reduce global environmental problems mentioned above.

Role of Professional societies:

Engineering students should be encouraged to become members of various professional societies and to actively participate in their programs. Some of the professional societies are the American Society of Mechanical Engineers (ASME), Engineers without Borders (EWB), Institute of Electrical and Electronics Engineers (IEEE), etc. Since these professional societies have global participation, they provide opportunities for greater interaction and sharing of information which can lead to more awareness of technical and cultural issues in other societies and how to address them.

Conclusions:

The advances in science and technology have not only made countries of the world to come closer together, they have also resulted in the rapid progress of developing countries. We live in
a completely inter-dependent global economy with technology at its core, creating new challenges and opportunities. This new global environment requires evolution of engineering education to prepare engineers to meet these new challenges and opportunities. This important work to enhance future engineering education programs requires integrated involvement and partnership between universities, industries and government. Several aspects that should be considered to enhance engineering education for the global environment have been presented.

References:


Biography:

**M. G. Prasad:**

Dr. Marehalli G. (M.G.) Prasad is a professor of Mechanical Engineering and the director of the Noise and Vibration Control Laboratory at Stevens Institute of Technology. He has more than 100 publications and presentations in journals and conference proceedings in the areas of acoustics, noise and vibration. Dr. Prasad has been a consultant in noise control to AT&T, IBM and United Nations Industrial Development organization. He was the general chairman of the National Conference on Noise Control Engineering in 1991. He has chaired several sessions in several national and international conferences of societies such as ASME, INCE, ASA, and IIAV. In professional society activities, Dr. Prasad has been the vice-president of external affairs of the Institute of Noise Control Engineering, USA from 1987-1994. He has been the Metropolitan chapter of ASA during 1987-2004. Also, he has been the chairperson of the technical committees in ASME, INCE and ASEE. Dr. Prasad is a fellow of the American Society of Mechanical Engineers, a fellow of the Acoustical Society of America, a fellow of the Acoustical Society of India, and a board-certified member of the Institute of Noise Control Engineering.

**S. Rajaram**

S Rajaram is a Senior Manager in Alcatel-Lucent (formerly AT&T Bell Labs and Lucent Technologies) and a Solutions Architect for wireless and wireline communications products and services. He joined AT&T Bell Labs in 1981 to work in thermal-chemical processes for semiconductor electronics device manufacturing. He has extensive experience both as a Technical Expert and as Manager in the field of telecommunications R&D, product design, manufacturing and testing, reliability/quality engineering, strategic planning, business development, technical marketing & sales, and direct customer interactions covering all of Lucent/AT&T products such as wireless base stations, switching, transmission, optical networking, data communications, wireless and cordless phones, and power supplies.

He has a Ph.D. in Engineering Science from the State University of New York at Buffalo with a major in Thermal – Fluid science and a minor in Electromagnetics. With this dual background in Thermal Sciences and Electromagnetics, he has developed expertise in both mechanical and electrical aspects of electronics equipment packaging and design.

Expertise in the following areas:

1. Reliability/Quality Engineering and testing in design and manufacturing, including vendor/component and subsystem qualification and control.
2. Thermal Design and physical design of telecom and datacom electronic equipment.
3. Electrical design of connectors, boards, backplanes and packages.
4. Systems engineering and Architectural design for telecom and Internet services.
5. Leading solutions and product teams for electrical, mechanical, manufacturing, testing, component and reliability engineering.
(6) Strategic Business Planning and product roadmapping to integrate business and technical needs for products and systems
(7) Technical Marketing and Sales interactions with customers covering the spectrum of technical and business issues including Services and Applications.

He has given many seminars for the electronics industry in the fields of Thermal Design, Reliability Engineering, and Electrical Design of Interconnections and Packaging. He also spent one year as a United Nations expert training engineers in India working in the electronics industry across several industries.

B Rajavel

Mr. B Rajavel is a graduate research student in Noise and Vibration Control Lab, Mechanical Engineering Department at Stevens Institute of Technology, Hoboken, NJ. He received his B.Tech (Automobile Engineering) from Madras Institute of Technology, Anna University, Chennai, India and M.Tech (Mechanical Engineering) from Indian Institute of Technology Madras, India. Prior to joining as a research student he worked as Scientist/Engineer for four years at Aeronautical Development Agency, Ministry of Defense, Govt. of India, where he was involved in design and development of mechanical systems for Light Combat Aircraft (TEJAS).