

Engineering Education in the Developing World: The case for Biological Engineering

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Abstract— Engineering education in the developing world is not only necessary for economic growth, intellectual development and innovation, but is also fundamental for national security and short and long-term sustainability. Successful engineering institutions and productive engineers are not only necessary to create knowledge based economies in developing nations, but they are also important players in maintaining economic viability that is tied to national security of immediate and distant neighbors. The necessity for innovation in engineering education and grounding of this training in local needs and markets is true for all forms of engineering, including biological and biomedical engineering that have been rather recent inductees to the engineering education portfolio. Developing countries are taking biological and biomedical engineering seriously to address issues in food and agriculture, processing and nutrition and various aspects of healthcare and medicine. In this paper we address the need, status, challenges and opportunities for the developing world in bioengineering and biomedical engineering education and discuss ways in which the fundamentals of engineering education can be strengthened for a sustainable society.

Keywords: *Biological Engineering, Biomedical Engineering, Developing World*

I. INTRODUCTION

Engineering education, both in the developed and the developing countries, is intimately connected to not only innovation but also national security and sustainability [1]. The need to address pressing national problems, challenges and threats has always affected the way engineering curriculum is designed, implemented and executed.

While the practice and education of the next generation of engineers has been streamlined to some extent in the developed world, in the developing world, political, social and economic turbulence has affected both the education and practice in multiple forms of engineering. The key problems faced by the developing world are no longer their own problems. Instead they affect mass populations in both the developing and the developed world. Thus higher education in

engineering that meets international standards and the local needs is critical to global security and sustainability [2-5].

In this paper, we look at the vision, challenges and future outlook of engineering education in the developing world, with an emphasis on biological engineering. The developing and the developed nations have seen a surge in research activity in biological and biomedical engineering over the last decades. The motivation for improved health-care, better pharmaceuticals, efficient technologies and higher quality of life is shared among the developed and the developing countries. In addition, the developing world faces issues associated with food shortage and public health crises that are less prevalent in the richer nations. Therefore biological and biomedical engineering education in the developing world is tied to national security, survival and sustainability in a way that is unique to these nations. This paper presents a mini-review of the current trends, challenges, opportunities and future outlook for biological engineering education in the developing world.

II. BIOLOGICAL AND BIOMEDICAL ENGINEERING IN THE DEVELOPING WORLD

Biological or biomedical engineering in the developing world can be broadly classified into two categories. The first one is engineering in agriculture and food sciences and includes areas such as genetic engineering and agricultural engineering. This area would also include food processing and food preservation, which are sometimes referred to food-process engineering in certain countries and contexts. The mechanical and electrical equipment associated with efficient food production are also topics of great interest but are outside the scope of this paper.

The second broad area that is of key importance to the developing nations is that of medicine, public health and pharmaceuticals. In general, there is little research on creating new drugs in the developing world, but recently there has been a surge of activity in the pharmaceutical industry in India, which is a notable exception. Other areas of biological engineering and healthcare include engineering approaches to

diagnose, detect and combat infectious diseases, infant mortality as well as prevailing epidemics. Additionally, there has been significant activity in the US, Chinese and European research labs in creating low-cost point of care diagnostics for applications in the developing world.

Engineering education in the agriculture dates back to 1960s and 1970s with the appearance of genetically modified crops in the developing nations [6]. As a result, there are a number of agricultural universities in these countries, although the real engineering component of that education varies tremendously. These engineering institutions are also predominantly located in countries where agriculture makes the backbone of their economies [6]. On the other hand, issues related to public health have primarily been dealt with in medical schools and technology development or innovation has been limited. Engineering and medicine have also been kept as two disparate areas of higher education.

Despite a substantial need and dependence of national security, to date, there are no system wide studies of the status of biological engineering education in the developing world. This is probably due to two main reasons. The first one is the lack of appreciation of biological engineering in the general public. Biological or Biomedical Engineering still remains one of the lowest ranked engineering in the developing world. This is due to higher demand and higher paying jobs for engineers in electrical, computer, civil or mechanical engineering. The second reason is the issues of food and to a certain extent public health are not considered engineering problems and have been dealt primarily by economists, policy makers, politicians and bureaucrats. Since these critical problems are not dealt by engineering institutions, the perception among the general public remains the same where medicine and health are considered to be non-engineering disciplines.

III. CHALLENGES IN BIOLOGICAL ENGINEERING EDUCATION

The current challenges facing biomedical and biological engineering education in the developing world can be divided into three categories. They can be summarized as input and output challenges and curriculum and teaching issues including teacher quality, training and retention and research related problems.

A. *Input and Output Challenges:*

The first major challenge for biological and biomedical engineering education in the developing world can be classified as input and output challenges. These challenges are associated with the quality of students coming into the program, their abilities, aspirations and overall quality. The output of these institutions into the marketplace and the society in general is also linked to the overall perception of the programs and their quality. While the overall level of education in the developing world is highly variable [7], the

number of students reaching university is fairly low [7]. In addition, due to economic pressures, students often choose certain areas, including certain engineering degrees, for their majors. Top quality students rarely opt for biological engineering or biomedical engineering as the majors of their choice. There are several reasons for this decision. The salaries associated with biological, agricultural or biomedical engineering are modest in comparison to other engineering fields, particularly computer and electrical engineering [2]. The general perception of the field and the associated parental pressure also plays a role in students opting for areas other than biological engineering. Since historically biological engineering has been associated with agriculture, there are fewer jobs available in the urban areas.

There is also active feedback between the output and the input. Since the input is often of mediocre quality, the output is not particularly impressive either. Due to other factors listed above, including lack of opportunities in the urban areas, the salaries are relatively low and the accessibility to top schools, hospitals and recreational facilities is limited. As a result the system as a whole is unable to perform coherently and the overall quality of the system continues to decline.

B. *Curriculum and Teaching Issues:*

The problems and challenges are not limited to inputs and outputs. There are numerous fundamental and perhaps fatal problems in the crucible that converts these inputs into outputs. Among these, curriculum presents one of the most fundamental problems. The curriculum is often dated and obsolete. There are few, if any, mechanisms for updating or reviewing it in regular intervals. In many instances, it is not even clear where the curriculum came from and how it was designed. More recent versions of the curriculum are often carbon copies of what is offered in the top institutions of the world with little regard to local needs or problems.

This lack of adaptation has two major consequences. The first is the output of the curriculum is an engineer with little appreciation or knowledge of the local challenges. The second is the inability of proper execution of the curriculum due to incompatibility of resources between the institutions where it was designed and the institution where it was offered.

The teaching staff at most biological and bioengineering institutions in the developing world is graduate of the same system. This cycle, due to low input and output quality, and massive inbreeding, results in continuous deterioration.

C. *Research Activity and Research Incentives*

The institutions engaged in providing biological engineering education have historically not been particularly research active. One of the main reasons for this lack of activity is limited number of graduate students enrolled in these institutions [8]. Lack of funds and weak industry has also led to disincentive for original research. Publications in peer review journals are also rare. Most of the research is

carried out in government labs and in some cases in private industry. This situation contributes to the poor quality outputs from these institutions, and in turn affect the overall performance of the engineering education sector.

IV. SUSTAINING BIOLOGICAL AND BIOMEDICAL ENGINEERING EDUCATION

The current status of biological and biomedical engineering education in the developing world is far from satisfactory. The success and sustainability of biological and biomedical engineering education would fuel economic growth and substantial improvement in the quality of life. There are three major ways in which quality biological and biomedical engineering education can be improved and sustained in the developing world.

1) *Partnerships*: A large number of international organizations, ranging from WHO to Gates foundation are providing funds to address problems of biological and biomedical engineering in the developing world [9]. These grants are largely focused on pressing problems in food shortage and security and public health. A number of universities and researchers associated with biological and biomedical engineering from across the globe apply for these grants and provide tangible and high impact solutions to the pressing problems. However, very few of these grant and partnerships include active biological and biomedical educational components. The educational components included in some of these grants are also limited to vocational training but exclude areas of higher education and long-term educational sustainability. As a result the experience of the researchers from top institutions in biological engineering, who are also often engaged in educational leadership are never fully utilized.

By encouraging governmental and non-governmental organizations to involve local researchers and universities in their programs would enhance cooperation and give opportunities to local researchers that are otherwise isolated from the biological education and training. Similarly, memorandums of understanding and economic aid packages targeted towards the healthcare problems in developing nations should include teacher training and quality assurance at the higher education level. This can be achieved through engaging researchers, in the developed countries, in the areas of biological and biomedical engineering, who are interested in addressing problems in the developing world. Encouraging educational partnerships, in parallel to research partnerships, would provide a unique and

comprehensive understanding of both education and practice of biological engineering to the developing nations.

2) *Teaching grants*: A number of federal and local governments in the developing world offer financial incentives, including grants to address problems in biological and biomedical engineering. However, the incentives to modernize curriculum, train teachers or develop educational components at the higher education level are often ignored. Such mechanisms exist at primary and even secondary education through incentives from international agencies (such as UNESCO and the world-bank) but modernizing curriculum and encouraging debate on curriculum and teacher training at higher education level are overlooked. Since biological and biomedical engineering appears fairly low on the priority list, the issues related to curriculum and teacher training are in worse state than other engineering disciplines. A top-down encouragement, in the form of grants, would allow university professors to take a serious look at the curriculum and encourage discussions. Alternatively, as a number of countries have encouraged research activity through federal grants, incorporating mandatory educational components in those grants would require researchers to think seriously about curriculum and efficient teaching.

3) *Industry Linkage grants*: Private industry in the developing countries or their developed neighbors are often interested in untapped markets. With agriculture and healthcare as key investment opportunities for countries with low-income neighbors, developing local expertise is a cheaper option than importing talent. In this regard, both private industry and local governments have a role to play. These key players should play a more vital role on reviewing the curriculum of local engineering institutions to ensure that the output is cognizant of the local needs and challenges. Industrial teaching internships for professors aimed at making professors aware of the challenges would lead to noticeable changes in the curriculum. With these linkage projects it is likely that the curriculum would adapt to both the fundamentals of biological and biomedical engineering as well as the local needs and challenges. In the long-term this would benefit the private sector by providing it with a work-force that is innovative, fundamentally sound and aware of the challenges faced by the local industries.

V. CONCLUSION

Biological and biomedical engineering will play a pivotal role in the development, survival and sustainability of the developing nations in the upcoming years. Issues related to food production, safety and security, public health, epidemiology and overall life quality and expectancy are areas where biological and biomedical engineering will play a central role. Increased globalization and rapid growth in these sectors in the developed nations will also have an impact on the practice and education of engineering in the developing countries.

As the government and non-government sectors realize the importance of these areas, more schools, colleges and departments will incorporate biological and biomedical engineering into their mainstream curricula and degrees. In a rapidly changing world, where the issues of food and healthcare are affecting nations across continents and influencing policy debates ranging from national security to immigration, biological engineering will have a central role to play in the developing countries. A shift in perception of biological engineering from a second class engineering to the cornerstone of national security and sustainability will lead to newer challenges in educating the next generation. As we approach that stage, it is more important than it has ever been to focus on quality control in curriculum and teaching and connect the curriculum with national and local needs and challenges. Quality assurance, well organized and up-to-date curricula and partnerships between public and private sector are necessary to shape

the landscape of engineering in a way that makes a substantial impact on national security and long-term sustainability of the developed nations.

ACKNOWLEDGMENT

The author would like to acknowledge Mr. Pawan Agarwal, Dr. Khurram Afridi, Dr. Adil Najam, Dr. Afreen Siddiqi and Dr. Teshome Yizengaw for many helpful discussions.

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