33rd Annual International Conference of the IEEE EMBS
Boston, Massachusetts USA, August 30 - September 3, 2011

Biomedical engineering education in developing countries: research synthesis

Tania S. Douglas, *Senior Member, IEEE*

Abstract— **Biomedical engineering (BME) contributes to development through improving human health. This paper examines BME education to address the needs of developing countries. Components of different BME programs described in the literature are synthesized to represent what has been proposed or implemented for the production of graduates able to address health problems in a manner suited to the local environment in which they occur. Published research on BME education is reviewed with reference to problem context, interventions and their mechanisms, and intended outcomes.**

I. Introduction

Developing sustainable solutions to improve health and address global health disparities can only be done with reference to the cultural and socio-economic context in which they are to be applied. An "implementation gap" exists between health innovations and their deployment in the developing world, because their implementation is often untested, unsuitable, or incomplete [1]. In an effort to bridge the gap, a number of universities in developed countries have embarked on global health programs to train students in and develop solutions for the health problems of the developing world.

Biomedical engineering (BME) provides a framework within which to educate future leaders to design and implement health technologies that are appropriate for and useful in their social context, particularly because of its multidisciplinary and design-oriented nature [2]. Perhaps for this reason, universities in the United States have included a BME component in their global health programs [2-4], or included global health and development components in their BME curricula [5].

What the developed world refers to as global health is often local public health in developing countries. Developing countries are not homogeneous societies and often display large socioeconomic disparities. Many developing countries have capabilities in BME education approaching those of developed countries. They may benefit from the lessons learnt by the latter in designing and implementing education programs in BME.

BME educators from both developed and developing countries have described the challenges and successes as well as the content of their BME programs in the Proceedings of this and other conferences and in other forums. However, the majority of the literature discusses BME programs in developed countries. This paper synthesizes research on this topic, and considers it with regard to the needs of developing countries.

A research synthesis rather than a traditional narrative review is presented, with the aim of deriving prescriptive knowledge for BME programs. The approach entails reviewing the literature with reference to a combination of a problem context, for which interventions are suggested, to produce, through particular mechanisms, intended outcomes [6]. Components of different BME programs are synthesized to represent what has been proposed or implemented to produce graduates able to address health problems in a manner suited to their context. Literature on programs in both developed and developing countries is included. General attributes of BME programs rather than specific curriculum topics are covered. Finally, such educational programs are discussed with reference to the developing country context.

II. Context

Advances in health care and improved population health are driven by scientific and technological progress, the influence of which is mediated by BME. Health in turn drives employment, innovation, sustainable development and growth [7]. Multidisciplinary education programs are meeting the need to prepare students for careers developing and disseminating interventions that advance global public health, and produce researchers able to interact with governments, non-governmental organizations (NGOs) and communities to devise and implement sustainable health care solutions [2].

BME education and research rely on collaboration with health care providers. Engineers and clinical professionals tend to focus on different aspects of technology: clinicians are concerned with ease of use, while engineers are excited by innovation; this dichotomy results in a communication gap which may be bridged by acquainting BME graduates with medicine and with the way in which clinicians think; they should understand the language of medicine [8]. The same may be said for the gap between engineers and other professionals that deal with the social and political aspects of medicine and health care. Successfully addressing complex problems through BME requires collaborative efforts among individuals with diverse training and experience, and shared

The author is with the Biomedical Engineering Program and the Medical Imaging Research Unit at the University of Cape Town, South Africa (e-mail: tania@ieee.org).

meaning among members of collaborative teams.

Biomedical engineers have certain professional and ethical responsibilities; graduates are expected to be able to address the problems associated with the interaction between living and non-living materials and systems [9]; they should consider the social and ethical implications of the solutions they develop and appreciate how living systems will interact with these solutions. Public policy and regulation affect BME research [10] and therefore the type of solutions that are developed. The dynamic nature of BME practice and the regular emergence of new sub-disciplines hinder the identification of ethical issues [9] and increase the complexity of policymaking and regulation. Accreditation of BME programs demands certain educational standards to ensure that graduates are able to take into account the social, economic and political context of their professional practice [11]. BME is not, however, an accredited engineering program in all countries where degree programs are offered.

Figure 1 shows the mutual impact between BME education and other factors in its environment.

III. Interventions and mechanisms

In addition to a curriculum covering topics common to many BME programs around the world [12], a key intervention found in the literature is exposure to real-world situations in which BME problem-solving is required. The mechanism for achieving such exposure is typically through forging collaborative linkages and partnerships with governments, NGOs, clinical practices, communities and industry. Partnerships between universities in developed countries and health care providers in developing countries [2] and public-private partnerships that extend from developed country universities and industry to developing country universities [13] have been initiated.

Students are given opportunities to apply engineering expertise and knowledge of medical equipment in a clinical, research, manufacturing or service setting [14]. Experiential training includes research and development in interdisciplinary teams [15]. Disease-based case studies are used to attune BME students to clinical context [8]. Lectures by clinical professionals and interactive observation of surgical procedures provide a clinical perspective [16]. Student-initiated community engagement and peer-to-peer training events and seminars [17] broaden the student experience.

A multidisciplinary BME-design based undergraduate program at an American university covers the following topics in a bioengineering and global health module [2]: current problems in health and how they differ in developed and developing countries; who pays to solve health problems; how technology can be used to solve global health problems; and how technologies move from the bench to the bedside.

Student exposure to science policy and ethics is facilitated by seminars and informal discussion groups [10]. Formal ethics education should address fundamental ethics, to provide a foundation on which to base sophisticated thinking about ethical dilemmas, but also research, professional and social ethics; moral reasoning may be taught using a case study approach [9].

IV. Outcomes

Key outcomes identified in the literature include training biomedical engineers to understand the social, environmental, economic and political context of engineering decisions and enabling them to discuss the broader impact of BME research; giving students real-life practical experience in biomedical engineering practice; and enabling them to work in interdisciplinary teams in which they are able to communicate effectively with collaborators. Students are also expected to emerge with a career interest in global health technology, research or policy.

V. Discussion

BME education in developing countries is tied to survival and sustainability in a unique way, because of public health crises that exist in these countries [18]. BME education in these countries must therefore be guided by the need to address pressing national health threats and challenges. Developing country students with access to higher education in BME are more likely to come from the developed rather than the developing sectors of such countries and may face socioeconomic and cultural gaps when working in marginalized communities.

The need for developed world engineers to have an international perspective in the face of globalization has been emphasized in the literature. Developing country BME programs, on the other hand, should ensure that they incorporate a local perspective, so that their engineers are able to address the needs and consider the constraints of impoverished communities in their environment. It is acknowledged that engineering is most successful when it caters to local design constraints and develops solutions for the local environment [19].

Although awareness of context and exposure to real-world situations are key components of the educational interventions reviewed, the literature often fails to explain how equitable engagement with communities in developmental contexts may be achieved. Real-world exposure often takes the form of student placements in developing country settings. These have been criticized as a new form of colonialism, benefiting the visiting student more than the host community, but have the potential to promote social justice and development, if equitable and sustainable engagement is pursued [20].

Partnerships are emphasized in the interventions, yet not all partnerships are equally developmental. BME programs in developing countries have an opportunity to engage in close long-term partnerships with local communities and

community-based organizations as well as healthcare facilities serving the marginalized, and adapt their curricula to changing community needs so that student involvement benefits not only the student but also the community.

Appropriately chosen partnerships for experiential training, along with other educational interventions used in developed countries to ensure an inclusive perspective in BME graduates, can be used in those developing countries with sufficient educational resources in BME, to emphasize and address the needs of marginalized communities.

REFERENCES

[1] T. Madon, K.J. Hofman, L. Kupfer, and R.I. Glass, "Public health - Implementation science," Science, vol. 318, 2007, pp. 1728-1729.

[2] M. Oden, Y. Mirabal, M. Epstein, and R. Richards-Kortum, "Engaging Undergraduates to Solve Global Health Challenges: A New Approach Based on Bioengineering Design," Annals of Biomedical Engineering, vol. 38, 2010.

[3] K.M. Palamountain, K.A. Stewart, A. Krauss, D. Kelso, and D. Diermeier, "University leadership for innovation in global health and HIV/AIDS diagnostics," Glob Public Health, vol. 5, 2010, pp. 189-196.

[4] S.H. Vermund, V.V. Sahasrabuddhe, S. Khedkar, Y.J. Jia, C. Etherington, and A. Vergara, "Building Global Health Through a Center-Without-Walls: The Vanderbilt Institute for Global Health," Academic Medicine, vol. 83, 2008, pp. 154-164.

[5] E.J. Guilbeau and V.B. Pizziconi, "Increasing Student Awareness of Ethical, Social, Legal, and Economic Implications of Technology," Journal of Engineering Education, vol. 87, 1998, pp. 35-45.

[6] D. Denyer, D. Tranfield, and J.E. van Aken, "Developing design propositions through research synthesis," Organization Studies, vol. 29, 2008, pp. 393-413.

[7] M. Siebes, M. Viceconti, N. Maglaveras, and C.J. Kirkpatrick, "Engineering for health - A partner in building the knowledge economy of Europe," IEEE Engineering in Medicine and Biology Magazine, vol. 26, 2007, pp. 53-59.

[8] N. Matsuki, M. Takeda, M. Yamano, Y. Imai, T. Ishikawa, and T. Yamaguchi, "Effects of unique biomedical education programs for engineers: REDEEM and ESTEEM projects," Advances in Physiology Education, vol. 33, 2009, pp. 91-97.

[9] J.E. Monzon and A. Monzon-Wyngaard, "Ethics and biomedical engineering education: the continual defiance," Conf Proc IEEE Eng Med Biol Soc, vol. 2009, 2009, pp. 2011-2014.

[10] J.A. Flexman and L. Lazareck, "Biomedical engineering and society: policy and ethics," Conf Proc IEEE Eng Med Biol Soc, vol. 2007, 2007, pp. 6156-6158.

[11] J.E. Monzon, "Engineers in the field: accreditation of BME programs in Argentina," Conf Proc IEEE Eng Med Biol Soc, vol. 1, 2006, pp. 5671-5674.

[12] Z.O. Abu-Faraj, "Bioengineering/Biomedical Engineering Education and Career Development: Literature Review, Definitions, and Constructive Recommendations," International Journal of Engineering Education, vol. 24, 2008, pp. 990-1011.

[13] K.M. Palamountain, K. a Stewart, a Krauss, D. Kelso, and D. Diermeier, "University leadership for innovation in global health and HIV/AIDS diagnostics.," Global public health, vol. 5, Mar. 2010, pp. 189-96.

[14] S. Krishnan, "Collaboration for cooperative work experience programs in biomedical engineering education," Conf Proc IEEE Eng Med Biol Soc, vol. 1, 2010, pp. 2955-2958.

[15] J.D. Humphrey, G.L. Cote, J.R. Walton, G.A. Meininger, and G.A. Laine, "A new paradigm for graduate research and training in the biomedical sciences and engineering," Advances in Physiology Education, vol. 29, 2005, pp. 98-102.

[16] E. Ledet, "Work in progress - clinic to classroom - a new paradign for biomedical engineering education," Proceedings, 38th ASEE/IEEE Frontiers in Education Conference, Saratoga Springs, NY: 2008, p. F3C-9.

[17] A.M. Sagstetter, L.K. Vitzthum, J.R. Meyer, A.J. Nimunkar, and J.G. Webster, "Global engineering education initiative through student organization," Conf Proc IEEE Eng Med Biol Soc, vol. 2009, 2009, pp. 2022-2024.

[18] M. Zaman, "Engineering education in the developing world: the case for biological engineering," Proceedings, IEEE EDUCON Education Engineering, Madrid: 2010, pp. 1047-1050.

[19] B. Newberry, "Engineering globalization: Oxymoron or opportunity?" IEEE Technology and Society Magazine, vol. 24, 2005, pp. 8-15.

[20] J.D.J. Vandersteen, C.A. Baillie, and K.R. Hall, "International Humanitarian Engineering Who Benefits and Who Pays?," IEEE Technology And Society Magazine, Winter, 2009, p. 2009.

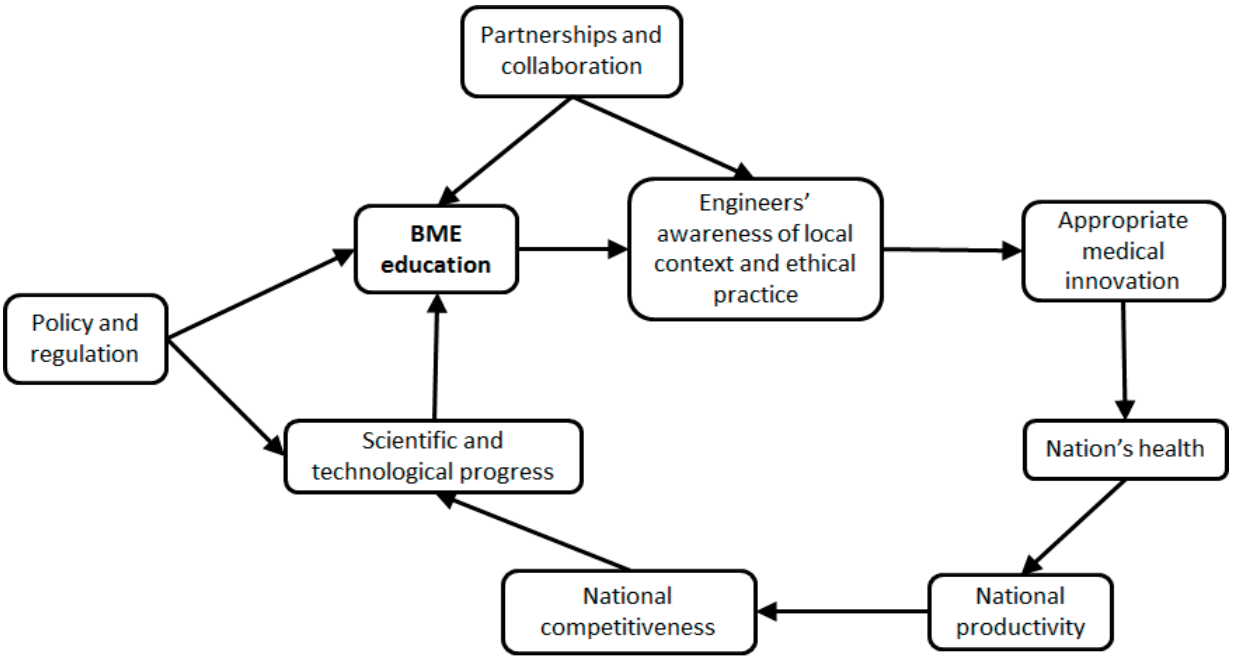

Fig.1. BME education in its socioeconomic context.