2021 43rd Annual International Conference of the
IEEE Engineering in Medicine & Biology Society (EMBC)
Oct 31 - Nov 4, 2021. Virtual Conference

Present and Future Challenges in Educating Biomedical Engineers, part 1

Joaquin Azpiroz Leehan, Senior Member, IEEE; CI3M, Universidad Autónoma Metropolitana

***Abstract*— It has been around 50 years since the undergraduate programs started worldwide, and now there are hundreds of programs that are being offered worldwide. Their aims, approaches and structures are all very different. This Special Session will include contributions from professors and program coordinators from different institutions that will weigh in on how to approach these challenges in the next few years.**

I. Introduction

It could be argued that the first evidence of BME applications are the working toe prostheses found in the mummified remains of humans in Egypt thousands of years ago, but the field really started to develop in the 1800s with the development of the quartz electrometer, and later when surplus electronic equipment from WWII started to be used in medical applications. In the mid 1970s, the first undergraduate BME programs were founded, first with help from the research community in the U.S., the NIH and several foundations with the aim to promote the development of instrumentation, research and a Biomedical device industry. Almost at the same time, several programs were founded in different countries with different aims. For example, in Mexico the need was to manage and maintain the growing medical equipment infrastructure in Social Security institutions. The example of Mexico, that started with two universities in 1973-1974 and now has over 60 institutions that offer the undergraduate degree in BME is typical of what has been happening around the world. With so many options worldwide, there is now a great number of programs with different aims, structures and approaches, as well as with different levels of international recognition and ranking.

After half a century of development of the profession, the evolution of technology and the increasing importance of healthcare worldwide, it is important to evaluate how BME education has evolved and to question whether the BM undergraduate programs are appropriately meeting the present challenges. This is the purpose of this special session.

There is quite a lot of literature regarding BME curricular design, starting probably in the 70s [1-5]. The main questions have been around the aims, the core competencies, the structure of the program, and the need to balance new multidisciplinary subjects with traditional basic sciences, mathematics and engineering (mostly electrical engineering).

J. Azpiroz Leehan is with the Centro de Investigación en Imagenología e Instrumentación Médica (CI3M), a National Laboratory at UAM-Iztapalapa, Mexico e-mail: jazp@xanum.uam.mx).

II. Background

At present there are three main streams of thought regarding the appropriate curricular structure that have been proposed for the U.S. which are those proposed by the defunct VaNTH BME curriculum project, the Whitaker Foundation BME Summit meetings and ABET.

However, in many countries, programs follow either Ad hoc structures or are adapted to specific needs. Several countries place emphasis on the development of competencies dedicated to servicing biomedical equipment or or the management of medical device technology in a hospital, favoring practical considerations over engineering design. Other programs are derived from traditional Electrical Engineering pyramidal structures where BME subjects are taught only after two years of basic courses. Many others do not require the completion of a capstone or design project in order for the students to graduate.

III. Discussion & Conclusion

The rest of this special session will include contributions from professors and professionals who will discuss how different local needs are shaping the curricula and whether it is necessary to reestablish a discussion regarding core competencies or even if there is a need to separate programs into some that are more technically-clinically oriented and others that are dedicated to the design and development of biomedical devices, as well as new fields in micro-nano and molecular bioengineering.

References

[1] L. D. Harmon, "Biomedical Engineering Education: How to Do What, with Which, and to Whom," in IEEE Transactions on Biomedical Engineering, vol. BME-22, no. 2, pp. 89-94, March 1975, doi: 10.1109/TBME.1975.324424.

[2] T. R. Harris, "Recent advances and directions in biomedical engineering education," in IEEE Engineering in Medicine and Biology Magazine, vol. 22, no. 4, pp. 30-31, July-Aug. 2003, doi: 10.1109/MEMB.2003.1237488..

[3] Abu-Faraj, Ziad. (2014). Biomedical Engineering Education in the Middle East and North Africa. 10.1109/MECBME.2014.6783268.

[4] Linsenmeier RA, Saterbak A. Fifty Years of Biomedical Engineering Undergraduate Education. Ann Biomed Eng. 2020 Jun;48(6):1590-1615. doi: 10.1007/s10439-020-02494-0. Epub 2020 Apr 6. PMID: 32253615.

[5] J. Azpiroz-Leehan, F. M. Licona, E. G. Urbina Medal, M. C. Méndez and E. Sacristán Rock, "Critical assessment and outlook for the 50 biomedical engineering undergraduate programs in Mexico," 2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), Milan, 2015, pp. 3973-3976, doi: 10.1109/EMBC.2015.7319264.

978-1-7281-1178-0/21/$31.00 ©2021 IEEE

Biomedical Engineering Educational Models: Challenges and Solutions

Shankar M. Krishnan, Life Sr Member, IEEE, WIT, Boston

Advances in technologies are occurring rapidly on multiple fronts and several of these advances are adopted in the healthcare domain to provide solutions to emerging complex problems. Biomedical engineers play a vital role in research, design, development and implementation of effective solutions. The demands for appropriately trained biomedical engineers (BME's) have been steadily increasing globally. Preparing BME's with competencies in interdisciplinary skill sets through suitable education programs poses numerous challenges for the academics. This presentation describes the difficult challenges associated with educating future BME's and proposes solutions with the framework for a few BME program models, especially at the undergraduate level.

The BME domain has been continually expanding with new interfaces, thus making the task of designing a comprehensive education program within four years formidable. Important criteria such as the breadth and depth of BME coverage, distributed emphasis on theory, lab and practice, interdisciplinary prerequisites and courses, focused efforts to meet graduation and accreditation requirements, job-ready preparation, dedicated faculty with varied expertise and attracting and retaining students constitute major challenges in BME education worldwide. Strong support from leadership for needed lab spaces and equipment as well as funding for research, project work, innovative pedagogies, learning management systems and collaboration with healthcare experts are essential for successful programs.

The BME curriculum must be designed with diligent balancing of mathematics, physical and life sciences, engineering and computing with core and elective courses in biomedical engineering. Product design and prototyping, problem-based and project-based learning, cooperative experiential learning and internships, clinical immersion and industry visits, coupled with inclusion of ethics, regulatory affairs, humanities and social sciences enhancing communication skills will contribute to the success of the program. Suitable BME elective courses must be included in synchrony with the emerging healthcare needs such as artificial intelligence, mobile and digital health, wearables, robotics, nanotechnology, IoMT, sports and regenerative medicine, for sustainable growth in the program as well as to produce job-ready graduates for gainful employment and career growth.

The framework for a few models solving the stated BME curricular design challenges is proposed based on general or track-based, site-specific baccalaureate curriculum models, coupled with incorporation of industry, government or hospital-based training to add real life experiences. The proposed solutions are based on the success of a few site-specific BME programs.

Program Model A is generally designed for large research-intensive universities. Program Model B is designed for four-year colleges or small universities, placing heavy emphasis on teaching, including integral cooperative experiential learning modules. In Program Model C, students are accepted with an earned Associate or a Polytechnic degree and trained in appropriate courses to earn a B.S. degree. The format could serve full time and part-time students, with varying durations depending on students' background and experience. In Program Model D, the curriculum is designed to accept transfer students from other engineering disciplines as well as life sciences or other fields and provide them foundation, core and elective courses in BME to meet the graduation requirements. BME Program in each institution must be synchronized with its short term and long-term goals.

Well-designed, comprehensive BME programs will offer benefits to the students, administration and the entire BME field. With continued collaboration with the stakeholders in academia, industry, government agencies, NGOs, and professional societies, Biomedical Engineers will be educated to be gainfully employed in medtech and healthcare delivery industry providing effective technological solutions and thus, ultimately improving the quality of human life worldwide.

In conclusion, several challenges to design comprehensive curricula are described and a few models for BME programs are described. In order to achieve sustainable success, the BME programs must be deigned to meet the institutional mission, to be adaptive to the emerging regional and global needs, to collaborate with industry partners and to operate to meet the accreditation requirements, aimed to produce effective future biomedical engineers.

[3]

BME Skills Diversity Needs New Employment Opportunities

Prof. Martha Zequera, Pontificia Universidad Javeriana, Member, IEEE

The definition of Biomedical Engineering has been changing with the global context, as it is a discipline in continuous evolution. Some authors consider it as a branch of engineering, oriented to provide solutions to problems related to Biology and Medicine, with the application of advanced technologies. Biomedical Engineering uses the knowledge of the exact sciences combined with those of the biological sciences to apply them ingeniously in solutions for health care [1]. Today it includes various emerging fields of application such as biotechnology, cell and tissue engineering, Biomaterials, Data Science, Nanotechnology, Medical Device Development, Drug Development, Regulations, Neural Engineering and Telemedicine, among others, making it one of the engineering fields with the greatest growth potential, whose training demands new technical and soft skills for future generations who wish to join new job offers offered by the global market [2], [3]. Its importance is based on the development of solutions to improve the quality of life of human beings, through the conception, design and development of digital ecosystems integrated by devices, acquisition and processing of large volumes of data in real time in the cloud and the application of artificial intelligence tools for prediction and support in diagnoses and interventions in order to facilitate the work of specialists in various areas of the health sector to achieve timely and quality patient care in the health system of each country.

The presence of the global pandemic changed the course of the fields of application of Biomedical Engineering and thus the discipline consolidated itself as the profession of the future due to the relationship it establishes between medicine and technology. This has a great positive impact on the recent developments of the health sector, which have been brought forth by the global COVID 19 pandemic which has affected the living conditions of human beings. These have generated new methods of health care, new strategies for diagnosis, control and monitoring of diseases which are mediated by emerging technologies and an accelerated development of digital transformation in the health system and the productive development of the digital transformation in the health system and the productive sector.

Innovation and technological development are required to achieve greater coverage of care to the population due to the rapid expansion of the pandemic and the population of affected older adults has increased significantly.

The biomedical engineers of the future in Latin America will have to face new challenges and a more oriented training to develop their soft skills, that are highly demanded by the labor market, such as assertive communication, leadership, teamwork, social and ethical sense, critical spirit and adaptation to different scenarios due to the large number of interactions with the different actors of the health system and a great capacity of conception, design, development and optimization of innovative technologies, implementing methodologies such as CDIO, Design Thinking, agile methodologies in an environment focused on the biotechnology industry, regulated medical devices and processes based on G4 industry where process automation is required and the interaction with collaborative intelligent robots is increasingly frequent to promote less contact with patients affected by COVID 19. In addition to computer skills, electronics, correct use of social networks, among other skills for their successful linkage [4], [5].

On the other hand the new BME programs may teach design thinking to students as a skill-based tool to prepare them for problem solving in complex healthcare environments required from the global marketing; and use innovative e-learning education strategies in collaboration with industry for solving real digital health problem.

Martha Zequera, is a Professor at the Electronics Department, Pontificia Universidad Javeriana, Bogota, Colombia.

References

[1] J.Bonzino, “Management of Medical Technology”. 1992. Butterworth & Heinemann. Boston.

[2] ABETStudentOutcomes:https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2019-2020/#GC3.

[3] https://link.springer.com/journal/43683/volumes-and-issues

[4] A. Lantada, J. Olmedo, A. Felip, J. Fernandez, J. Garcia, R. Alonso, et al (2016). CDIO Experiences in Biomedical Engineering: Preparing Spanish Students for the Future of Medicine and Medical Device Technology. 10.2016 12th International CDIO Conference, Turku, Finland.

[5] Design in Health Care. Mayo Clinic Center for Innovation website. http://centerforinnovation.mayo.edu/design-in-health-care/. Accessed on 1 June 2017.

Safety Issues in Innovative Medical Devices in Times of COVID-19 Pandemics

Ratko Magjarević
University of Zagreb, Faculty of Electrical Engineering and Computing,
Department for Electronic Systems and Information Processing, Zagreb, Croatia

Following the outbreak of novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the World Health Organization (WHO) declared a Public Health Emergency of International Concern (PHEIC) on 30 January 2020 [1]. The workload of healthcare professionals experienced an tremendous increase due to unexpected challenges associated with the coronavirus (COVID-19) disease rapid spreading and demanding treatment. The role of medical technology in the process of combating the pandemics and the contribution of biomedical engineers in the process have been recognised worldwide [2, 3]. Biomedical engineers as a part of multidisciplinary teams from academia, research and industry collaborate to develop and provide innovative and rapid solutions for successful testing, diagnosis, therapy, contact tracing and isolation to reduce spreading of COVID-19 [4]. Accelerated development of technologies raises concerns on safety of the newly developed technology and of privacy protection, therefore the importance of emergency use authorizations policies increases [5].

References

[1] WHO. 2020. Statement on the second meeting of the International Health Regulations (2205) Emergency Committee regarding the outbreak of the novel coronavirus (2019-nCOV). World Health Organization, 30 January. https://www.who.int/news/item/30-01-2020-statement-on-the-second-meeting-of-the-international-health-regulations-(2005)-emergency-committee-regarding-the-outbreak-of-novel-coronavirus-(2019-ncov)

[2] Biomedical Engineers: The hidden heroes of the COVID-19 crisis! https://www.bcu.ac.uk/health-sciences/about-us/school-blog/biomedical-engineers-the-hidden-heroes-of-the-covid-19-crisis
Hospital heroes: being a biomedical engineer during COVID-19. https://www.latrobe.edu.au/news/announcements/2020/hospital-heroes-being-a-biomedical-engineer-during-covid-19

[3] Shankar Krishnan and Ratko Magjarević: Engineering innovations to combat COVID-19 and improve human health, in: UNESCO Report: 'Engineering for the SDGs', 2021, pp 59-66

[4] Emergency Use Authorizations for Medical Devices, https://www.fda.gov/medical-devices/emergency-situations-medical-devices/emergency-use-authorizations-medical-devices

Ratko Magjarević is with the University of Zagreb, Faculty of Electrical Engineering and Computing, Department for Electronic Systems and Information Processing, Zagreb, Croatia