

# Biomedical Engineering as an educational option at the Faculty of Electrical Engineering, POLITEHNICA University of Bucharest

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**Abstract** – The educational program in Biomedical Engineering at the Faculty of Electrical Engineering, POLITEHNICA University of Bucharest started in 1994. Since then it develops as a dynamic project, adapted to the perceivable international progress of this interdisciplinary domain, and to the notable changes in the Romanian health care system, which is more and more responsive to new technologies and modern equipment. The Biomedical Engineering program represents a minor optional specialization for the senior undergraduate students in Electrical Engineering. In this paper we present the curriculum and resources made available to the students, the educational methods and the professional competence that they are expected to acquire in Biomedical Engineering.

**Index Terms** – biomedical engineering education.

## I. INTRODUCTION

In science and engineering enterprises boundaries between and among classical disciplines eventually vanish. Rewarding opportunities are often found in interdisciplinary domains, where the knowledge in one field may answer questions raised in another field. This is especially true in areas that embrace complexity such as Biomedical Engineering (BME), which is an interdisciplinary domain where Engineering and Technological sciences merge into solving the problems that arise in Biology and Medicine. All sectors of activity benefit from the recent, fast growing engineering technology: modern medical hardware is produced and utilized with technical engineering assistance; modern, highly accurate investigation methods through visualization and measurements demand a specialized, modern instrumentation; renewed therapy calls for assistance in adapting and individualizing the treatment schemes prior to their application, etc.

A recent survey of the current trends and effectiveness of the educational process towards career oriented goals shows that the BME professional education has to rely on the modern engineering curricula, yet to be focused on specific aspects of BME. This approach corresponds also to the national goal of integration in the European academic and career-related policies and structures.

## II. SHORT HISTORY AND PRESENT GOALS OF THE ACADEMIC PROGRAM

In 1994 the Electrical Engineering Department at POLITEHNICA University of Bucharest initiated an

optional educational program for the final semesters (eighth and ninth), aimed at offering the senior undergraduate Electrical Engineering (EE) students a minor specialisation oriented to EE applied in medicine and biology – called Biomedical Engineering (BME). The pending studies include topics such as:

- electro-physiology (natural and stimulating) phenomena,
- electrical and electronic measurements in the medical diagnosis and therapy,
- electrical drives and equipment used in medicine,

to culminate with a diploma thesis (presented after the tenth semester) and awarded with the title of *Diplomat Engineer* (equivalent to Master of Science) in EE.

It is worth mentioning that our EE Department offers six other similar minor studies in several applied EE areas.

As the BME program is offered at the EE Department, it is firmly based on the background given by classical EE disciplines: electromagnetism, electric and electronic measurements, electrical materials and specific topics related to technology and equipment; in the same time, it is complemented by modern educational tools offered by computer use in mathematical modelling.

The program started as a genuine experience, but each year brought adjustments caused by and stimulated through direct contact with educational problems and usefulness criteria.

The BME program is concerned with orienting students interest and knowledge to applied electrical engineering in medicine and biology, which means:

- approaching electro-physiological phenomena from the engineering perspective,
- using their EE major specialization based on classical electromagnetic theory and applications in understanding and creating the design of medical equipment,
- adjusting professional education to the specific medical environment (basic knowledge, concepts and vocabulary, healthcare needs and priorities, specific technologies and instrumentation).

## III. ACCESSIBLE RESOURCES FOR BME EDUCATION AT THE FACULTY OF EE

The growing interest in electrical aspects of biomedical engineering motivated a team of academic staff from our department to undertake the challenges arising from the re-orientation of the educational curriculum offered by the

Department of Electrical Engineering at POLITEHNICA University of Bucharest. Currently, a major educational grant (1999-2002, offered by CNFIS – the National Council for High Education Support) sustains our efforts of profiling and substantiating what is thought and intended as a consistent academic program of EE oriented to BME applications.

It is important to underline the main components to approaching the objectives of the program and the achievements attended to the end:

*The EDUCATIONAL component.* The re-evaluation of the educational program and the structure of BME specific disciplines led to the curricula detailed further.

*The RESEARCH component.* It emphasizes the integration of scientific research in the educational program, due to the rapid technological progress and the dynamic changes specific to BME.

*The INFRASTRUCTURE component.* That refers to acquisition of adequate laboratory and computational hardware and software, publications, etc. In three years, the Laboratory of Electrical Engineering in Medicine (LEEM), located at the Faculty of Electrical Engineering [1] improved constantly its patrimony (with support from CNFIS grant and other sources) and offers educational facilities described further.

*The INFORMATIVE component.* It represents a constant concern for information regarding the labor market trends and academic exchanges aimed at learning the educational experience of other universities interested in implementing similar programs. This includes participation at workshops and conferences with scientific and educational contributions; our Laboratory of Electrical Engineering in Medicine organizes also scientific workshops and provides for continuous education courses for students and instructors, both in engineering and medicine.

The *Laboratory of Electrical Engineering in Medicine* (LEEM) is a multifunctional unit that may host several types of educational activities:

- lectures and conferences - multimedia tools are available: videoprojector and several educational software tools for instruction in BME, medicine and biology (Adam – Human Physiology, Human Anatomy, educational soft tools on CD-ROM support);
- experimental laboratory – acquisition of physiologic signals with BIOPAC MP30 system and ECG signals simulator/generator;
- numerical laboratory – scientific computation and data processing software (MATHEMATICA, Matlab+ Simulink), software packages for electromagnetic field and coupled problems computation (FemLab, FIDAP, GAMBIT, ANSYS, QuickField), software for signal analysis (BSL PRO) and image processing (3DSlicer, EnSight, SigmaScan), software for biostatistics (MedCalc);
- library – scientific publications (electromagnetism, mathematics, biology, medicine and related topics) and

several international journals acquired during the past seven years;

- computer network connected via RoEduNet at the Internet, scanning and printing terminals.

The *Laboratory of Electric Measurements (LEM)* and the *Laboratory of Electromagnetic Compatibility (LEMC)* with specific experimental and computational facilities host applications at specific disciplines, as further shown in the educational program section.

#### IV. THE EDUCATIONAL PROGRAM

The disciplines specific to the minor specialization in BME are scheduled for the eighth and ninth semesters, following the general engineering program (mathematics, physics, chemistry, computer sciences, numerical analysis, mechanics, electronics, systems theory, etc.) and several basic EE disciplines (electrical circuits and electromagnetic field theory, electrical materials, electrical and electronic measurements, electrical machines, apparatus, static converters, electrical drives, microprocessors, etc.) [2].

The specialization module consists of nine specific disciplines and goes in parallel with a few other general stem EE disciplines. Specialized practical work, projects and labs sustain all this courses; a consistent rate of the final grade is covered through individual or team homework. The applications are held at the university, at the specialized technical laboratories (LEEM, LEM, LEMC) and at several research and medical institutions.

The first contact with biomedical engineering is brought by two elective disciplines.

*Introduction to Biomedical Engineering* that introduces at a global scale the basic concepts of ecology, biology, cellular systems, thermodynamics of living systems, artificial organs, implants, and biocompatibility.

*Medical Imaging* is a more specific course that means technical and medical problems in medical diagnosis and therapy based on image processing. This is a very important course because it exposes the students, for the first time, to basic anatomy and physiology information. It is continued with a study of the exposure of organisms to ionizing radiation and medical testing methods based on Roentgen, gamma radiation, ultrasounds and finally magnetic resonance imaging and endoscopy.

Both courses benefit of medical support from the University of Medicine and Pharmacology “Carol Davila”, “Coltea” Clinic Hospital, through lectures that are presented by medical instructors and practitioners and through a program of visits in the clinic environment, focused on diagnostic techniques based on image processing. Medical Imaging continues to be a strong attraction, not only for students, but also for EE instructors, through the personal contact and specific medical knowledge shared with medical practitioners.

The BME curriculum continues with three courses aimed to cover more specific knowledge for the specialist in BME.

*Basic Biochemistry and Biophysics* starts from the main structures in Earth Biosphere, and continues with fine molecular structures and properties of bio-molecules: water, proteins, lipids, etc., metabolic processes in plants and animal organisms. Laboratory

work and several visits to biological and medical research units complement the lectures.

*Mathematical Modeling in BME* is an introduction in physical aspects and numerical analysis of several biological and medical phenomena and systems: analysis of physiological signals, non-linear dynamics associated with biomedical phenomena, introduction to numerical image processing. The theoretical instruction is applied through several numerical experiments within the framework of LEEM.

*Electrical Equipment in Bioengineering* opens the technological part of the BME education. This is where the students learn about automatically drive systems, micro-transformers, defibrillation, electro-therapy and magneto-therapy equipments. The practical work is sustained at some specific research locations, institutions and companies, and benefits of the assistance of engineers, biologists and physicists, who produce, promote or use medical equipment as their daily work.

The final part of this educational module presents other four disciplines:

*Bioelectromagnetism* encompasses the study of natural and induced electric and electromagnetic phenomena in biological tissues, as well as topics on non-ionizing electromagnetic field exposure of organisms characteristic to several medical procedures and in everyday life environment. The applications consist of laboratory work based on numerical models and measurements specific to electrophysiologic phenomena, and it relies on the resources offered by LEEM (multimedia educational tools, computer software for presentations and calculus, documented library and Internet access).

*Measurements and Instruments in Biomedical Engineering* introduces methods and instruments for acquisition of biological information by mean of sensors and transducers and ends with analogical and digital processing of data. Laboratory work, in the LEM, is directed to measurement and numerical processing of data.

*Electromagnetic Compatibility* offers basic principles useful in avoiding electromagnetic interference of medical devices with other electric equipment and gives solutions for adequate shielding and compensation. The LEMC at the faculty of EE offers specific support for the experimental lab work.

*Design of Medical Instrumentation* gives practical answers and solutions to the conception and design tasks posed by several medical electrically driven devices: artificial heart, cardiac stimulators, electro-therapy and electro-surgery equipment and microelectronic command of prostheses. Homework and design projects help students learn the practical side of medical instrumentation.

A very important aspect of the educational process is to correctly assess the level of acquired knowledge. This is why an important part of the evaluation is homework and laboratory activity where students can project a better view of their knowledge and skills. Written assignments, and reports on assigned self-conducted instruction are also requested.

## V. EDUCATIONAL METHODS AND TOOLS

Classical methods that mean *ex cathedra* lectures and handwritten homework make still the major part of the

educational process, but the resources available at LEEM complete in a modern and attractive way the classes. Multimedia hardware and software tools and the usage of computer in applications and in presentations is more and more part of the lectures and practical work. Usually, the lectures and applications are open to an interactive way of sharing knowledge; that means students participate in debates (scheduled in advance, so that they elaborate their point of view) and the exposures alternate between lecture and questions & answers sessions. Students' participation in open debates and public presentations of homework are encouraged through the assignment system.

Most courses use, as main reference, textbooks and laboratory books written (in Romania) by the instructors. Here are some examples:

*Medical Imaging* (CD ROM edited in the LEEM as multimedia tool, 2001) – elaborated by Dr. Minerva Muraru and Dr. Corina Homencovschi

*Biomedical Engineering Problems. Numerical Models*, MatrixRom, Bucharest 2001, 160 pp., ISBN 973-685-321-7 – authors Prof. Mihaela Morega, Prof. Alexandru Morega, Sl. Adina Andreea Gheorghe, Sl. Alina Machedon

*Bioelectromagnetism*, MatrixRom, Bucharest 1999, 250 pp., ISBN973-685-056-0 – author Prof. Mihaela Morega

*Design elements in Bioengineering* – UPB, Bucharest 1999, 79 pp. – author Assoc. Prof. Vasile Manoliu

*Numerical Modeling for Boundary Value Problems in Engineering*, MatrixRom, Bucharest 1998, 338 pp., ISBN973-9390-05-6 – author Prof. Alexandru Morega

*Modeling in Bioengineering. Applications Handbook*, UPB, 1998, 80 pp. – authors Prof. Mihaela Morega and Prof. Al. Morega

*Instrumentation for biosignals*, Ed. ICPE, Bucharest 1998 – authors Prof. Radu Negoescu and Prof. Costin Cepisca

The up-to-dated library at LEEM offers a consistent on-site support to students and instructors; it is useful to updating the lectures, and helps students in preparing their homework and debates. The access to new technical and medical books, magazines and multimedia materials in the field covered by and related to the dynamic evolving discipline of BME, helps the self-conducted continuous education.

The summer training period offers the students the opportunity to visit sites where BME may find its usefulness: research institutes (both in engineering and biologic field – ICPE, Pasteur Inst., Cantacuzino Inst.), medical clinics (Coltea and University hospitals), companies that promote medical equipment. The students have contact with real-life BME problems and get a sense of the working conditions and specific level of BME demand on Romanian job market. The contact with medical practitioners, facilitate the access to clinic expertise and technical needs, improve communication between technical and medical specialists and broadens the perspective for collaboration in scientific research. The topics for the Diploma projects are usually related to real-life problems that arise in the medical environment.

BME is one of the domains that progress rapidly, therefore education through research has to be part of an academic program – this is the only efficient way to stimulate creativity in an interdisciplinary domain. Students are encouraged to participate in research work, and they report their results as projects, diploma projects and within the framework of the scientific session dedicated to students'

research that are yearly organized by POLITEHNICA University. A special section dedicated to BME exists since 1995.

Despite the disparity in the degrees of interest that exists between generations of students, not equally inclined toward BME research, there is a perceivable positive trend in their research performance, and here are some of the topics of interest for 2002 graduates:

- investigation of electrophysiologic phenomena – electric signal measurement and processing, nonelectric measurements using specific transducers,
- numerical computation of electromagnetic field associated to natural and stimulated physiologic phenomena,
- physical and numerical models for anatomo-physiologic systems – dynamic analysis,
- design, optimization and conception of medical instrumentation,
- computational assistance for medical therapy through image and signal processing, and through electromagnetic field analysis,
- investigation of human exposure to electromagnetic field in medical therapy and in life environment.

Research has been proven to develop skills such as technical learning, problem-solving openness, creativity, teamwork and communication qualities that facilitate appropriation of concepts and abilities essential to a career in healthcare or the medical technology industry.

## VI. FUTURE PERSPECTIVE AND PERMANENT OBJECTIVES

Worldwide evolution of BME shows that there is a real demand to develop a new interdisciplinary workforce that should be able to understand and facilitate reliable quantitative approaches and answers to the major integrative biomedical challenges. Nowadays it seems impossible to put into action qualified medical therapy without modern technology, and EE finds a wide opening for its specific applications, both in equipment production and in technical assistance of the medical practice. Taking into account the multiple problems and especially the financial conditions that damp the technological evolution in Romanian medical assistance, we cannot ignore the centers of excellence at central clinics, with highly qualified specialists that use state of the art therapeutic methods, based on modern equipment and technology. It is a reality that students in medicine have contact with this modern environment and the future practitioners are educated to take advantage of it; this is one strong reason to enforce BME education.

The structure of our BME module and its insertion as a minor study within the EE basic education was inspired also by the experience of many other universities in Europe and USA. The curriculum is yearly adapted following several criteria:

- the demand and level of students' expectations,
- the availability and expertise of qualified academic personnel,

- the permanent feedback through the relation with medical body, including the demand for young qualified working force in Romania.

In order to provide for the competitiveness and to facilitate the mobility of our graduates on European job market we consider the following objectives:

- to strengthen the relations with similar academic institutions that develop BME programs for the mutual dissemination and sharing of experience;
- to analyze and update the curriculum and educational methods, in order to acquire recognition at the European level, following IFBME (International Federation for Medical and Biological Engineering) criteria proposed for accreditation of BME programs of education and to be compatible to ECTS (European Community Course Credit Transfer System) in BME education.

According to IFBME classification [3] our BME program is a "type 3 interdisciplinary program, with a BME module that is evenly balanced with a non-BME specialization" – Electrical Engineering in our case. This is the case of many other BME academic programs, which emerged as optional specializations from classical engineering fields.

The electronically database organized through the EU funded Leonardo Program "Medical Engineering Listed Education & Training Information" ([www.inbit.gr/meleti](http://www.inbit.gr/meleti)) provides for information on more than 100 educational programs in BME offered by European, USA and South African universities and polytechnic schools, at all academic levels. Their majority offer Master and PhD programs in BME and, apparently, exclusively BME oriented undergraduate programs are not that popular in Europe as they are in the USA. The main reason for this is the specific demand on the job market.

Currently, the curriculum offered by our BME program does not divert the education of our graduates from the main stream EE profile and we consider this fact as benefic for their carrier opportunities, as well as for the need to gain the fundamental skills required to address new developments and changing practices.

Following the tendency in BME education in Romania and worldwide, we may predict the strengthening of its importance and an increase in the demand for admission at this profile, both in high education and postgraduate or continuous education programs. We also consider that continuing BME education at master or doctoral level is suitable and could be benefic for some of our graduates.

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