

# Biomedical Engineering Education: New Curricula, New Experience

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*Abstract*— In the paper, we focus on the analysis of the experience acquired during the first run of new curricula in biomedical engineering (BME) at the Czech Technical University in Prague, Faculty of Electrical Engineering. In 2004 and 2005 new legal regulations were adopted that define completely new position of biomedical engineers in the health service system. Following these regulations we had to develop new curricula in biomedical engineering as a two-year Master study program. The experience acquired during the first run can be divided into several parts: education; students' projects and theses; students' stays in hospitals; research; co-operation with universities, research institutes and industrial companies both in the Czech Republic and at the international level. It is obvious that in such a fast developing area as biomedical engineering it is necessary to integrate research and education not only by introducing new pieces of knowledge to students but also by active involvement of the students into the research projects and both faculty staff and students involvement in practically oriented projects.

*Keywords*— biomedical engineering, education, practical training.

## I. INTRODUCTION

Biomedical engineering applies engineering methods, science and technology to problems in medicine and biology, and is a growing field that will continue to have a significant impact on health care. It also involves learning about biology in new ways and developing new tools to diagnose disease and to repair or replace diseased organs.

Biomedical engineers work with other medical health care professionals as members of a team. Exciting advances in medicine, such as the artificial heart, pacemakers, medical imaging techniques, lasers, prosthetic implants, life support systems are the result of a team effort by biomedical engineers and other professionals.

During recent years many things have changed and we have acquired new experience in the area of BME. This experience can be divided into several parts: education; students' projects and theses; research; co-operation with universities, research institutes and industrial companies both in the Czech Republic and at the international level. However, these parts are not strictly divided; they interact and influence each other very positively. Other important issues in BME are social and legal aspects of the domain. They must be considered in all above mentioned activities.

The aim was to design such undergraduate study programs in biomedical engineering that could help students develop the knowledge and capabilities needed to meet the challenges of modern society.

## II. LEGAL FRAMEWORK IN THE CZECH REPUBLIC

In the Czech Republic it was necessary to define certain framework for BME education, and especially occupation profiles for the health care service. In the past the biomedical engineers were not recognized as equal to medical health care service occupations. Therefore during the last years the legal provisions were prepared and finally in 2004 and 2005 new law and related regulations became effective. The Law No. 96/2004 Coll. on non-medical health care service occupations [1] defines the framework and basic requirements. It is followed by several regulations that regulate details about holding all required examinations and examination rules for these examinations; define credit system for issuing certificate to performing health care service occupations without expert supervision, and educational activities for that credit points can be awarded and number of credit points; specify activities of health care service professionals and other employees; define fields of specialized education and specification of the expertise of health care service professionals; and specify minimum requirements for educational programs leading to qualification to act as health care service professional. The law and related regulations define completely new position of technical personnel in the health care service system.

1. The qualification of the health care service professional and health care service specialist is required for technical personnel, where technical professional or technical specialist comes into the contact with a patient or when he/she can through his/her activities directly influence patient's health state.

2. The Law No. 96/2004 Coll. specifies the following types of educations:

- undergraduate, i.e. bachelor and master study (minimum requirements are given by the official regulations No. 39/2005 Coll.);
- accredited qualification course;
- lifelong education (this education is obligatory for all health service professionals and also for those working

in the category another professional in health care service).

In this context, it is necessary to stress that in addition to standard accreditation of a study program or field of undergraduate education performed by the Accreditation Board of the Ministry of Education, Youth and Sports of the Czech Republic, the biomedical study programs or fields must get the accreditation of the Ministry of Health Care of the Czech Republic in the sense of the law No. 96/2004 Coll. and related regulations.

### III. BIOMEDICAL ENGINEERING AT CTU FEE PRAGUE

After the above mentioned legal regulations came into power we applied for accreditation of restructured curricula of Master study program in Biomedical engineering. This program satisfies all requirements defined by those legal regulations. These minimum requirements are list of theoretical and practical areas necessary for practising regulated profession in the health care system. It is necessary to stress that the Ministry of Health Care accredits only those study programmes satisfying the requirements.

The curricula were developed in close cooperation with clinical engineers working in hospitals and medical doctors. So they are based on long-term practical experience. The structure was described in more detail in [2] and content of all courses is available at [3].

The program also contains practical training in university hospitals and specialized clinics as a very important part of education. Before the students start this practical training they pass courses where they acquire information about all the devices and medical data and signal processing they will then experience in the hospitals. They have also courses on medical terminology, first aid, anatomy, physiology and pathophysiology taught by medical doctors from the First School of Medicine of the Charles University Prague. In that way they have the first contacts with medical doctors, their style of work and communication which is very important for the training in the hospitals.

The students come into direct contact with patients, advanced technology, medical doctors, nurses, and engineers working in the hospital. The students learn to be team members, team leaders, to provide information, educate and perform health care education of individuals and groups and take on responsibility for provided health care. The practical training is closely linked with the work in individual and team projects so that the students can experience more complex view on the problems to be solved. For example, a task in medical image processing

starts with on-site visit at MR, CT or PET, recording the images, then processing and evaluating them.

At the end of their studies the students should have an idea about the complex chain starting from a patient over measurements, analysis to diagnosis and subsequent therapy based on the latest technological development in electronics and information technology, thus using all diagnostic, measuring and evaluating systems that may be used in medicine. They should be able to orientate themselves in both technical and non-technical problems linked with technology application in medicine as well.

### IV. EXPERIENCE FROM THE FIRST RUN OF NEW CURRICULA

This year the first students graduated from the restructured program of Biomedical engineering. We asked them about their view on the content of individual courses, mutual relations between the courses, ratio of theoretical and practical courses, courses led by engineers and medical doctors, and practical training in hospitals.

They evaluated positively those courses that were closely related to practically oriented tasks. For example, the course on biological signals includes laboratory work where the students measure on themselves the individual types of biological signals and successively process the measured signal. So they see immediately what the results are and whether they did the measurement correctly (see Fig. 1).



Fig. 1 Measurement of biological signals

The course on medical devices introduces broad spectrum of devices. However, only some of them can be used in laboratory work. The students work, for example, with ECG, EEG, spirometer, ECG Holter, blood pressure Holter, ultrasound device. It is impossible to have only for

educational purposes such large and complex equipment as CT, MRI, or PET. Therefore the practical training in hospitals represents also a good opportunity for students to see this advanced technology working. This part of education was highly appreciated. The Faculty of Electrical Engineering of the Czech Technical University in Prague signed agreements with two Prague hospitals that are equipped with the latest technology. So the students see not only CTs, MRI, PET, digital RTG, but also surgical robot, Leksell gama knife, rf ablation equipment, angiography, systems for navigated heart catheterization, etc. Moreover, they see the equipment working. They can talk with medical doctors and nurses. So they also get used to medical language and environment which is rather different from the purely technical environment.

In some courses we invite engineers from companies producing medical devices. They can show the other side of the biomedical field, namely the whole path from an idea, over design, prototype up to a product. However, this is not the end because the regulations require testing including clinical testing before the product can be applied either for diagnostics or treatment of patients. After listening to such presentations the students realize that even certain knowledge of legal issues is necessary. One course in curricula is namely devoted to organization of health care system and legal issues. At the beginning the students found this course unnecessary and boring. But in context of practical problems they changed their view.

The students also like project-oriented education. In this respect we are lucky because medical doctors supply us with many practical problems that can be solved by future engineers. Involvement of students in such projects has two main effects, namely they acquire various skills necessary for their future professional career and the study is made more attractive for them because it is not purely passive reception of large volumes of knowledge.

Another important aspect is close contact with clinical engineers working in hospitals that participate actively in educational process and provide us with useful feedback about knowledge and skills necessary for the clinical practice.

## V. POTENTIAL JOBS FOR GRADUATES

It is obvious that medicine is not the only application area for BME graduates. They can use their knowledge in other branches, e.g. in the development of new medicaments in the pharmaceutical industry where it is very important to use the latest electronic technology. The same holds true for a number of other areas having close links to biotechnology, ecology and the development and

production of electronic systems. There are many companies producing equipment and devices for health care and they are interested in graduates of biomedical engineering because they possess the interdisciplinary knowledge and skills and are able to communicate with medical doctors.

Even the most sophisticated devices can be used on their own or as part of a more complex system. One aim of education in BME is to give students this system approach so they are able to integrate individual devices into larger systems working on a qualitatively higher level than a single device. In this way it is possible to integrate already operating stand-alone devices that were bought in the past. Usually the potential of these devices is not fully used because the doctors do not understand all the technical details and therefore use just the basic functions. The electrical engineers can contribute to broader and even more efficient utilization of such a device or system.

## VI. CONCLUSIONS

The law No. 96/2004 Coll. and all related legal regulations and provisions have a number of consequences both for undergraduate study and for postgraduate study and lifelong learning. Biomedical technicians and engineers who are working in the Health Care sector are involved in a system of education and lifelong learning for acquiring specialized competence that is similar to present system of education and training of medical doctors. The greatest benefit of this system is that it clearly defines skills and knowledge that biomedical engineers should have. Especially for the potential employers it is necessary to know which competences the biomedical engineers possess.

It is evident that the relationship between education and research in BME must be very close. The relationship not only comprises of research results from electrical engineering and information technology but also from medicine and other relevant areas - how new diagnostic methods and devices are introduced into practice. It is necessary to include all these developments into courses for students so that they are informed about these trends and after graduation are able to work with the advanced technology in practice. It means that very good coordination is required between many different institutions, as technical universities, hospitals, and schools of medicine are. Joint education between the FEE CTU and First School of Medicine, Charles University Prague means mutual inspiration and enrichment. An engineer's view on an approach to problem solving is usually different than that of a doctor. Their practical experience is different. Thus mutual exchange of experience and knowledge means new

approach and contribution to solving joint practical problems.

When we designed the curricula in BME, we tried to take into account all the aspects of modern ways of education and the fact that BME is an interdisciplinary area. Therefore we introduced project-oriented education wherever it was possible. The students must have possibility to acquire team skills, including collaborative, active learning abilities, communication skills, leadership skills, and a multidisciplinary perspective during their study. Thanks to involvement in departmental and medical research, both basic and applied through the individual and team projects, they can experience research and engineering work. This type of education is well accepted by the students. They appreciate when they can participate in solving real-life problems and become real team members. It brings certain aspects of competition into the educational process and the students are motivated for better performance. Our graduates are required and well accepted in hospitals and companies developing and producing medical devices or medical software.

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## REFERENCES

1. Legal documents of the Czech Republic at <http://www.mvcr.cz/clanek/sbirka-zakonu.aspx>
2. Lhotska L (2007) Biomedical Engineering as Health Care Profession. Engineering in Medicine and Biology Society, 2007. EMBS 2007. 29th Annual International Conference of the IEEE, 2007 Page(s):5936 – 5939
3. Curricula of Biomedical engineering master study program at <http://www.feld.cvut.cz/education/bk/obory/obor99.3.N.P.2259.html>

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