REPORT

BIOENGINEERING AND BIOMEDICAL ENGINEERING IN EUROPE
- Overview, Education, Standards and Professional Competences –

E-LEARNING IN BIOMEDICAL ENGINEERING

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1. Bioengineering and biomedical engineering – an overview

1.1. Biomedical Engineering

**Biomedical Engineering** (BME) can be defined as the application of engineering principles and design concepts to medicine and biology. This field seeks to close the gap between engineering and medicine: It combines the design and problem solving skills of engineering with medical and biological sciences to improve healthcare diagnosis, monitoring and therapy [1].

The evolution of biomedical engineering has only recently emerged as its own discipline. The work in this interdisciplinary field consists of research and development, spanning a broad array of sub-areas. Significant biomedical engineering applications include the development of various diagnostic and therapeutic medical devices ranging from clinical equipment to micro-implants, common imaging equipment such as MRIs and EEGs, regenerative tissue growth, pharmaceutical drugs and therapeutic biological.

**Subdisciplines within biomedical engineering** [2]:
- Biomedical Electronics
- Biomechatronics
- Bioinstrumentation
- Biomaterials
- Biomechanics
- Bionics
- Cellular, Tissue, and Genetic Engineering
- Clinical Engineering
- Medical Imaging
- Orthopedic Bioengineering
- Rehabilitation engineering
- Systems Physiology
- Bionanotechnology
- Neural Engineering

Disciplines within biomedical engineering can be classified by their associations with other, more established engineering fields, which can include [3]:
- Chemical engineering - often associated with biochemical, cellular, molecular and tissue engineering, biomaterials, etc.
Electrical engineering and computer engineering - often associated with bioelectrical and neural engineering, biomedical imaging, and medical devices. This also tends to encompass Optics and Optical engineering - biomedical optics, imaging and related medical devices.

Mechanical engineering - often associated with biomechanics, biotransport, medical devices, and modelling of biological systems.

Fig. 1. Ultrasound representation of Urinary bladder and hyperplastic prostate (example of engineering science and medical science working together) [2]

Bionics
Concerned with the intricate and thorough study of the properties and function of human body systems, bionics may be applied to solve some engineering problems. Careful study of the different function and processes of the eyes, ears, and other organs paved the way for improved cameras, television, radio transmitters and receivers, and many other useful tools. These developments have indeed made our lives better, but the best contribution that bionics has made is in the field of biomedical engineering. Biomedical Engineering is the building of useful replacements for various parts of the human body. Modern hospitals now have available spare parts to replace a part of the body that is badly damaged by injury or disease. Biomedical engineers who work hand in hand with doctors build these artificial body parts.

Cellular, Tissue, and Genetic Engineering
One of the goals of tissue engineering is to create artificial organs (for patients that need organ transplants. Biomedical engineers are currently researching methods of creating such organs. Researchers have grown solid jawbones [3] and tracheas from human stem cells
towards this end. Several artificial urinary bladders actually have been grown in laboratories and transplanted successfully into human patients [4]. Bio-artificial organs, which use both synthetic and biological components, are also a focus area in research, such as with hepatic assist devices that use liver cells within an artificial bioreactor construct [5].

Genetic engineering, recombinant DNA technology, genetic modification/ manipulation (GM) and gene splicing are terms that apply to the direct manipulation of an organism's genes. Genetic engineering is different from traditional breeding, where the organism's genes are manipulated indirectly. Genetic engineering uses the techniques of molecular cloning and transformation to alter the structure and characteristics of genes directly. Genetic engineering techniques have found success in numerous applications. Some examples are in improving crop technology, the manufacture of synthetic human insulin through the use of modified bacteria, the manufacture of erythropoietin in hamster ovary cells, and the production of new types of experimental mice such as the oncomouse (cancer mouse) for research [2].

**Neural engineering**

Neural engineering (also known as Neuroengineering) is a discipline that uses engineering techniques to understand, repair, replace, or enhance neural systems. Neural engineers are uniquely qualified to solve design problems at the interface of living neural tissue and non-living constructs.

**Medical devices**

This is a very broad category -- essentially covering all health care products that do not achieve their intended results through predominantly chemical (e.g., pharmaceuticals) or biological (e.g., vaccines) means, and do not involve metabolism [2]. A medical device is intended for use in:

![Fig. 2. Two different models of leg prosthesis [2]](image)
• the diagnosis of disease or other conditions, or
• in the cure, mitigation, treatment, or prevention of disease.
Some examples include pacemakers, infusion pumps, the heart-lung machine, dialysis machines, artificial organs, implants, artificial limbs, corrective lenses, cochlear implants, ocular prosthetics, facial prosthetics, somato prosthetics, and dental implants.

Medical imaging
Medical imaging is a major segment of medical devices. This major field deals with enabling clinicians to directly or indirectly "view" things not visible in plain sight. This can involve utilizing ultrasound, magnetism, UV, other radiology, and other means. Imaging technologies are often essential to medical diagnosis, and are typically the most complex equipment found in a hospital including:

• Fluoroscopy
• Magnetic resonance imaging (MRI)
• Positron emission tomography (PET) PET scans, PET-CT scans
• Projection radiography such as X-rays and CT scans
• Tomography
• Ultrasound
• Optical and electron microscopy

Implants
An implant is a kind of medical device made to replace and act as a missing biological structure. The surface of implants that contact the body might be made of a biomedical material such as titanium, silicone or apatite depending on what is the most functional. In some cases implants contain electronics e.g. artificial pacemaker and cochlear implants.

Fig. 3. An MRI scan of a human head, an example of a biomedical engineering application of electrical engineering to diagnostic imaging [2]
Clinical engineering
Clinical engineering is the branch of biomedical engineering dealing with the actual implementation of medical equipment and technologies in hospitals or other clinical settings. Major roles of clinical engineers include training and supervising biomedical equipment technicians selecting technological products/services and logistically managing their implementation, working with governmental regulators on inspections/audits, and serving as technological consultants for other hospital staff (e.g. physicians, administrators, I.T., etc.). Clinical engineers also advise and collaborate with medical device producers regarding prospective design improvements based on clinical experiences, as well as monitor the progression of the state-of-the-art so as to redirect procurement patterns accordingly [2].

1.2. Bioengineering

Biological engineering, biotechnological engineering or bioengineering (including biological systems engineering) is the application of concepts and methods of biology (and secondarily of physics, chemistry, mathematics, and computer science) to solve real-world problems related to the life sciences and/or the application thereof, using engineering's own analytical and synthetic methodologies and also its traditional sensitivity to the cost and practicality of the solution(s) arrived at. In this context, while traditional engineering applies physical and mathematical sciences to analyze, design and manufacture inanimate tools, structures and processes, biological engineering uses primarily the rapidly developing body of knowledge known as molecular biology to study and advance applications of living organisms [6].
The differentiation between **Bioengineering** and overlap with **Biomedical engineering** can be unclear, as many universities now use the terms "bioengineering" and "biomedical engineering" interchangeably [7]. Biomedical engineers are specifically focused on applying biological and other sciences toward medical innovations, whereas bioengineers are focused principally on applying biology - but not necessarily to medical uses.

![Cellular Automata](image)

**Fig. 5.** Modelling of the spread of disease using Cellular Automata and Nearest Neighbour Interactions [6]

Bioengineering is a science-based discipline founded upon the biological sciences in the same way that chemical engineering, electrical engineering, and mechanical engineering are based upon chemistry, electricity and magnetism, and classical mechanics, respectively [8].

Bioengineering can be differentiated from its roots of pure biology or classical engineering in the following way. Biological studies often follow a reductionist approach in viewing a system on its smallest possible scale which naturally leads toward tools such as functional genomics. Engineering approaches, using classical design perspectives, are constructionist, building new devices, approaches, and technologies from component concepts. Bioengineering utilizes both kinds of methods in concert, relying on reductionist approaches to identify, understand, and organize the fundamental units which are then integrated to generate something new [9]. In addition, because it is an engineering discipline, bioengineering is fundamentally concerned with not just the basic science, but the practical application of the scientific knowledge to solve real-world problems in a cost-effective way.

Although engineered biological systems have been used to manipulate information, construct materials, process chemicals, produce energy, provide food, and help maintain or enhance human health and our environment, our ability to quickly and reliably engineer biological systems that behave as expected is at present less well developed than our mastery over mechanical and electrical systems [10].
ABET [11], the U.S.-based accreditation board for engineering B.S. programs, makes a distinction between Biomedical engineering and Biological engineering; however, the differences are quite small. University of California, San Diego (UCSD) has a bioengineering program that is considered to be among the world's best undergraduate programs. Biomedical engineers must have life science courses that include human physiology and have experience in performing measurements on living systems while biological engineers must have life science courses (which may or may not include physiology) and experience in making measurements not specifically on living systems. Foundational engineering courses are often the same and include thermodynamics, fluid and mechanical dynamics, kinetics, electronics, and materials properties [12], [13].

The word bioengineering was coined by British scientist and broadcaster Heinz Wolff in 1954 [14]. The term bioengineering is also used to describe the use of vegetation in civil engineering construction. The term bioengineering may also be applied to environmental modifications such as surface soil protection, slope stabilisation, watercourse and shoreline protection, windbreaks, vegetation barriers including noise barriers and visual screens, and the ecological enhancement of an area. The first biological engineering program was created at Mississippi State University in 1967, making it the first biological engineering curriculum in the United States [15]. More recent programs have been launched at MIT [16] and Utah State University [17].

Bioengineers are engineers who use the principles of biology and the tools of engineering to create usable, tangible, economically viable products. Biological engineering employs knowledge and expertise from a number of pure and applied sciences, such as mass and heat transfer, kinetics, biocatalysts, biomechanics, bioinformatics, separation and purification processes, bioreactor design, surface science, fluid mechanics, thermodynamics, and polymer science. It is used in the design of medical devices, diagnostic equipment, biocompatible materials, renewable bioenergy, ecological engineering, and other areas that improve the living standards of societies [6].

Biological engineering is also called bioengineering by some colleges and Biomedical engineering is called Bioengineering by others, and is a rapidly developing field with fluid categorization. The Main Fields of Bioengineering may be categorised as [6]:

- **Bioprocess engineering**: Bioprocess design, Biocatalysis, Bioseparation, Bioinformatics, Bioenergy
- **Genetic engineering**: Synthetic biology, Horizontal gene transfer.
- **Cellular engineering**: Cell engineering, Tissue engineering, Metabolic engineering.
- **Biomedical engineering**: Biomedical technology, Biomedical diagnostics, Biomedical therapy, Biomechanics, Biomaterials.
- **Biomimetics**: The use of knowledge gained from reverse engineering evolved living systems to solve difficult design problems in artificial systems.

2. Biomedical engineering education

2.1. Introduction

Biomedical engineers and bioengineers require significant knowledge of both engineering and biology, and typically have a Master's or a Doctoral degree in BME or another branch of engineering with considerable potential for BME overlap. As interest in BME increases, many engineering colleges now have a Biomedical Engineering Department or Program, with offerings ranging from the undergraduate to doctoral levels. As noted above, biomedical engineering has only recently been emerging as its own discipline rather than a cross-disciplinary hybrid specialization of other disciplines; and BME programs at all levels are becoming more widespread, including the Bachelor of Science in Biomedical Engineering which actually includes so much biological science content that many students use it as a "pre-med" major in preparation for medical school. The number of biomedical engineers is expected to rise as both a cause and effect of improvements in medical technology [18].

As with many degrees, the reputation and ranking of a program may factor into the desirability of a degree holder for either employment or graduate admission. The reputation of many undergraduate degrees are also linked to the institution's graduate or research programs, which have some tangible factors for rating, such as research funding and volume, publications and citations. With BME specifically, the ranking of a university's hospital and medical school can also be a significant factor in the perceived prestige of its BME department/program [2].

Graduate education is a particularly important aspect in BME. While many engineering fields (such as mechanical or electrical engineering) do not need graduate-level training to obtain an entry-level job in their field, the majority of BME positions do prefer or even require them [19]. Since most BME-related professions involve scientific research, such as in pharmaceutical and medical device development, graduate education is almost a requirement (as undergraduate degrees typically do not involve sufficient research training and experience). This can be either a Masters or Doctoral level degree; while in certain specialties a Ph.D. is notably more common than in others, it is hardly ever the majority (except in
academia). In fact, the perceived need for some kind of graduate credential is so strong that some undergraduate BME programs will actively discourage students from majoring in BME without an expressed intention to also obtain a masters degree or apply to medical school afterwards.

Graduate programs in BME, like in other scientific fields, are highly varied, and particular programs may emphasize certain aspects within the field. They may also feature extensive collaborative efforts with programs in other fields, owing again to the interdisciplinary nature of BME. M.S. and Ph.D. programs will typically require applicants to have an undergraduate degree in BME, or another engineering discipline (plus certain life science coursework), or life science (plus certain engineering coursework) [2].

Biomedical Engineering is the application of engineering principles and design concepts to medicine and biology in order to improve healthcare diagnosis, monitoring and therapy. It has recently emerged as its own discipline, after being considered an interdisciplinary specialization among already-established fields (engineering, biology & medicine). Prominent biomedical engineering applications include the development of biocompatible prostheses, various diagnostic and therapeutic medical devices ranging from clinical equipment to micro-implants, common imaging equipment such as MRIs and EEGs, regenerative tissue growth, pharmaceutical drugs and therapeutic biological [51].

According to [55], biomedical engineering can be defined as:

- A profession exerted in healthcare institutions: the biomedical (or clinical) engineer is responsible of applying and implementing medical technology to optimise healthcare delivery.
- A profession exerted in the body industries, i.e. every industrial sector developing products where technologies of any kind interact with the human body: medical devices (cardiac valves, hip replacements, etc.), medical technology (Computed Tomography scanners, electrocardiograms, etc.), sport, fitness and wellness equipments (running shoes, training machines, etc.), defense & security (body armours, security scanners, etc.), ergonomics and safety (ergonomic tools, car airbags, etc.), entertainment (motion capture for computer graphic animations and games, etc.). In the future this might also include applications that are currently at the research stage, such as brain-computer interfaces, wearable or implanted technologies (i.e. implanted tags in prison inmates), etc.
- A domain of research, where physical and engineering methods are used to investigate life in general, and human health in particular.
More formally, the General Assembly of the European Alliance of Medical and Biological Engineering & Science (EAMBES) provided the following definitions [55]:

- **Biomedical Engineering** is a synonymous of Medical and Biological Engineering (MBE). The latter is more accurate, and should be preferred in formal contexts. Other terms such as bioengineering, biological engineering, medical engineering, etc. are used in a non-univocal way to indicate partitions of medical and biological engineering.
- **Medical and Biological Engineering** is the application of engineering principles and techniques to produce new knowledge upon and to solve problems relevant to living systems.
- **Medical and Biological Engineering Sciences** is an autonomous scientific research discipline, which generate new knowledge on biological systems using the methods and the approaches that are proper of physical and engineering sciences.

According to [51], the roles of a biomedical engineer in a hospital include:

- Advise and assist in the application of instrumentation in clinical environments.
- Provide leadership, guidance, support and supervision to the section staff and takes responsibility in the day to day operation of the clinics.
- Evaluate the safety, efficiency, and effectiveness of biomedical equipment.
- Ensure that all medical equipment is properly maintained and documented.
- Provide engineering and technical expertise on all matters related to medical technology, especially in the process of planning, review, evaluation, specifications of medical equipment.
- Install, adjust, maintain, and/or repair biomedical equipment. Evaluate, negotiate and manage service contracts.
- Adapt or design computer hardware or software for medical science uses.
- Develop and provide a comprehensive in-service education program on the safe and effective use of medical equipment both medical and nursing staff.
- Advise hospital administrators on the planning, acquisition, and use of medical equipment.
- Develop and implement short and long time strategies for the development and direction of the department to effectively manage medical equipment and technology in the clinics.
- Minimize, investigate and rectify hazard risks associated with medical equipment use.
- Perform other duties within the scope of the job and his technical capacity and expertise.

Biomedical engineers require considerable knowledge of both engineering and biology. Currently there are more and more programs in universities worldwide which offer BME qualifications, at BSc, MSc as well as PhD levels. In the U.S. for example there is an
increasing number of undergraduate programs (over 65), that are also becoming recognized by ABET (Accreditation Board for Engineering and Technology) as accredited bioengineering/biomedical engineering programs [51].

In this context there is also an increased need for e-learning methods, tools and platforms to be used in biomedical engineering education. This is also reflected in the number of European projects launched on this subject in the past few years. In chapter 5 we offer a synthesis of some of these projects (based on the information supplied on the projects’ corresponding websites).

2.3. Biomedical engineering education in Europe

Education in BME varies greatly around the world. By virtue of its extensive biotechnology sector, its numerous major universities, and relatively few internal barriers, the U.S. has progressed a great deal in its development of BME education and training opportunities. Europe, which also has a large biotechnology sector and an impressive education system, has encountered trouble in creating uniform standards as the European community attempts to supplant some of the national jurisdictional barriers that still exist. Recently, initiatives such as BIOMEDEA have sprung up to develop BME-related education and professional standards [20]. Other countries, such as Australia, are recognizing and moving to correct deficiencies in their BME education [21]. Also, as high technology endeavours are usually marks of developed nations, some areas of the world are prone to slower development in education, including in BME.

Educational programmes in the field of BME had their origins in the 1950s when several formalized training programmes were created [22], [23]. By the year 2005, more than 200 universities of applied science, polytechnics, schools, academies and other institutions in Europe offered educational programmes in BME at all academic levels [22], [23]. Thus, many of the BME educational programmes are still under development. In general, engineering education has seen a massive transformation over the last few decades; the purposes have changed from teaching facts to helping students to learn how to find relevant information, how to assess it, how to organize different and distributed information into an entity and how to engage in critical reflection and dialogue [23].

Teaching and learning have moved towards active, student-centred, problem-based, challenge-based, inquiry-based, cooperative and self-directed learning [23]. The practice of using technology to deliver coursework has also created new opportunities for teaching and learning. For example, audio and video records, CD-ROMs and DVDs, personal computers
(PCs), iPods, Internet and Web applications, i.e., wikis, blogs, podcasts [24] have all been adapted for educational purposes [23]. Nowadays, the terms “e-learning” or “virtual learning” are commonly considered as umbrella terms describing any type of learning that depends on or is enhanced by the latest information communication technology [23].

It is possible to develop, implement, test and demonstrate the significance of educational theories, technologies and models through an open, free of charge, modern technology-based, high quality teaching and learning environment. An example of such an environment is the European Virtual Campus for Biomedical Engineering (EVICAB) [23]. It commenced on January 2006 as a two-year European Commission funded project. These actions concern the field of biomedical engineering (BME) and medical physics and are coordinated by the Ragnar Granit Institute at Tampere University of Technology, Tampere, Finland [25]. The objectives of the project were to develop, build up and evaluate sustainable, dynamic solutions for virtual mobility and e-learning in the field of biomedical engineering and medical physics [26]. The solutions had to adhere to the Bologna Process, i.e. [23]:

- mutually support the harmonization of European higher education programmes,
- improve the quality of and comparability between the programmes,
- advance post-graduate studies, qualifications and certification.

A comprehensive study about the BME education in Europe is presented in several reports like [20], [25]. For example, in France, the teaching of BME is spread out to a large number of institutions (over 120). There are University degree courses in medical or biomedical engineering at both the undergraduate and the postgraduate level [20]. A specificity of the French system is the dispatching of the teaching between universities and engineering schools. Most of teaching courses include a training period in a University, Public Research, Industrial or Clinical environment ranging from 3 months to 3 years. Next, some examples are given [20]:

**Bac+2**
DEUST Technico-commercial en appareillage et matériel médical Univ. Grenoble 1
DEUST Technico-commercial dans le domaine biomédical Univ. Dijon
TS en Ingénierie Biomédicale Hospitalière (SPIBH) UTC Compiègne

**Bac+3**
DESTU Maintenance Biomédicale IM2B Bordeaux
DNTS en Instrumentation et Maintenance Biomédicales Lycée Jacquard Paris
DNTS en Instrumentation et Maintenance Biomédicales ENCPB Paris
Bac+4
IngM en Ingénierie, de la Santé IUP Lille 2
IngM en Ingénierie de la Santé (option Technologie de la Santé) IUP Montpellier 1
MST de Génie Biomédical Univ. Lyon 1
MST de Télésurveillance Médicale Univ. Paris 5

Bac + 5
Ding de Ecole Centrale de Paris (option Bio-ingénierie) ECP Chatenay-Malabry
Ding en Génie Biologique (Filière Biomatériaux et Biomécanique) UTC Compiègne
Ding en Informatique industrielle et instrumentation ISTG Grenoble
DESS Dispositifs Médicaux et Médicaments Associés Univ. Grenoble
DESS Génie Biomédical Univ. Lyon 1
DEA Bioingénierie - biomatériaux Univ. Metz Nancy
DEA Biologie, ostéoarticulaire, biomécanique, biomatériaux Univ. Lyon 1
DEA Imagerie Médicale Univ. Paris 11
DEA Informatique Médicale Univ. Rennes
Mastère Equipements Biomédicaux UTC&ENSP Rennes
Mastère en ingéniérie biomédicale Lille

Bac + 7
Doctorat - Ecole Doctorale en Sciences pour lingénieur UTC Compiègne
Doctorat Univ. Lyon
Doctorat Univ. Nancy
Doctorat Univ Paris
Doctorat Univ. Rennes
Doctorat Univ. Toulouse
Doctorat Univ. Tours

Various levels
DIU Dispositifs Médicaux et Produits Biologiques Univ. Paris & Nantes
DU Evaluation et Santé Univ. Paris 5 & 12
DU Evaluation des Technologies Médicales Univ. Paris 5 & 12

Abbreviations [20]:
DEA Diplôme d’Études Approfondies
DESS Diplôme d’Études Supérieures Spécialisées
DEUST Diplôme d’Études Universitaires Spécialisés Technologiques
Ding Diplôme d’ingénieur
DIU Diplôme Inter Université

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Another significant example of the widespread BME education in Europe is represented in Fig. 6, where the map of Universities offering courses for biomedical engineering in Germany, Austria, and Switzerland is depicted [20].

**Fig. 6.** Universities offering courses for biomedical engineering in Germany, Austria, and Switzerland: ■ (Technical) Universities, ▲ Universities of Applied Sciences [20]

### 2.4. Biomedical engineering education in Spain

The official university studies in Spain are specified in curricula that are developed by universities, subject to the rules and conditions that apply in each case. Such curricula are verified by the University Council and approved in their implementation by the relevant region.
Regulated university degrees, such as biomedical engineering, are official and valid throughout the national territory, with effects that enable academic value and, where appropriate, to carry out regulated professional activities.

Structure of official university in Spain

General structure
Spanish university education leading to the award of official qualifications valid throughout the national territory is divided into three cycles: Degree, Master and Doctorate.

Fig. 7. General structure of the Spanish university education

- Degree studies:
Grade teachings, such as biomedical engineering, are aimed at obtaining from the student with a general training in one or more disciplines, aimed at preparing for the exercise of professional activities.

- Master's Degree:
Masters' teachings are intended acquisition by the student of advanced training, specialized or multidisciplinary oriented academic or professional expertise, or to promote the introduction to research tasks.
• Doctoral Degree:
The doctoral programs are aimed at the student advanced training in research techniques may include courses, seminars and other activities aimed at research training and includes the preparation and presentation of a doctoral thesis consisting of an original research project.

Official university degree
The curriculum leading to the award of Bachelor’s degree is prepared by the universities.

Curricula have 240 credits, which contain all the theoretical and practical training the student should acquire: basic aspects of the branch of knowledge, compulsory and optional courses, seminars, internships, tutorials, final project work or other training activities.

These lessons conclude with the preparation and defence of a final project. The University proposes the assignment of the relevant Bachelor's degree graduate in any of the following branches of knowledge:
a) Arts and Humanities
b) Science
c) Health Sciences
d) Social Sciences and Law
e) Engineering and Architecture.

The curriculum contains a minimum of 60 credits of basic training, of which at least 36 are associated with some of the materials for the branch of knowledge that seeks to ascribe the title. These materials are specified in subjects with a minimum of 6 credits each and are offered in the first half of the curriculum. The remaining credits to 60, if applicable, must be configured for basic materials of the same or other branches of knowledge, or other materials where justified its basic character for the initial training of the student or a transverse.

If you program placement, these have a maximum of 60 credits and should be offered preferably in the second half of the curriculum. The final project work is between 6 and 30 credits, must be in the final phase of the curriculum and geared to the skills assessment associated with the degree.

2.5. Biomedical engineering education in Greece

Education in biomedical engineering in Greece is supported for all levels of academic education. A detailed description is given in the following:
Undergraduate level

**Department of Computer Science and Biomedical Informatics of the University of Central Greece** (http://dib.ucg.gr/

The University of Central Greece was founded in 2003. It is a completely self-administrated institution, under the superintendence of the Greek State, which is exercised by the Minister of National Education and Religions. Its foundation aims at the regional growth and decentralization of the Greek Higher Education, and also at responding to social, cultural and developmental needs of the regional community of Central Greece. It is located in Lamia, Greece.

The Department of Computer Science and Biomedical Informatics is operating since the academic year 2004-2005. It is a leading Department in the scientific field of Applied Sciences, as it comes to cover the existing gap in the area of specialization in applications of Informatics in Medicine, Health and Biology.

The course content of the Graduate programs of the Department of Computer Science and Biomedical Informatics is focused on subjects belonging to scientific fields such as Informatics, Biology, Biochemistry and Bioinformatics.

The Curriculum is completed through eight (8) semesters, which, within the weekly hours, include lectures, workshops and projects. The courses are divided in two (2) categories: the compulsory courses and the elective ones. The Curriculum also includes free election courses, which provide general knowledge and humanities, and English courses offering English terminology.

The department facilities include spacious teaching rooms equipped with the latest technology teaching aids and laboratories with a computer network, which offers advanced telematics services and supports the students’ educational needs.

The Department of Computer Science and Biomedical Informatics is an innovative Department in the scientific area of Informatics, as its mission is to face and solve the insufficient specialization of the Informatics Applications in scientific areas such as Medicine, Health and Biology, assuring satisfying career prospects to the graduates, offering them competitiveness and readiness for the labor market’s needs.

The career prospects are possible in the private and also public sector, as well as in the scientific research area.
The Biomedical Engineering Laboratory (BEL) of the Electrical and Computer Engineering School of National Technical University of Athens (NTUA) has completed twenty one years of scientific activity in 2011.

Since 2001, it constitutes an officially founded laboratory (Official Journal of the Hellenic Republic, No of Leaf 66, 6 April 2001), aiming at serving educational and research needs in the field of Biomedical Engineering and its applications, mainly in the following scientific sectors:

- biomechanics
- biorheology - clinical hemorheology
- clinical mechanics
- medical imaging - biosignals and image processing
- biosensors
- telematics
- medical information technology
- neural networks
- interactions of radiation - tissues
- ultrasound technology
- virtual reality
- rehabilitation technology - robotics and automations

The Laboratory's educational and research work takes place within the School of ECE as well as in the Institute of Communications and Computers Systems of NTUA in which BEL participates.

The main activities of the laboratory cover sectors that are related with **basic and applied research** in specialized subjects of biomedical technology. More specifically, the activities of the laboratory are focused in **product development** for final use as well as the **provision of high quality services** in the Health sector.

In terms of its wider dynamic research activity, the Laboratory has developed close collaborations with a large number of Greek and International academic laboratories, companies and Health Organisations. The laboratory also participates in an important number of research, competitive and developmental projects in national and international level.

The main sectors of the Laboratory's scientific research include:

- Medical information Technology
- Development of Medical Data Management Systems
- Telemedicine
- Neural networks in medicine and health
- Biosensors - biometric technologies
- Digital medical image processing
- Digital bio-signals processing
- Robotics applied in rehabilitation treatment
- Biorheology - Clinical Hemorheology
- Virtual reality in medicine and health

As far as its educational activity is concerned, the laboratory teaches 5 undergraduate courses which are part of the “Bioengineering” flow.

Also 3 postgraduate courses are taught, one of which is part of the Postgraduate Study Program of NTUA (Biomedical Mechanics) curriculum while the other two (Biomedical Technology and Information Technology in Life Sciences) in terms of the Interdepartmental Program of Postgraduate Study in Biomedical Technology of NTUA and the Medical School of the University of Patras.

Up to 2008, 220 final year projects and 42 doctoral theses have been completed, while there have been more than 300 paper publications in international magazines and proceedings of international conferences. At this moment 8 doctoral theses are in progress.

Dept. of Medical Instruments Technology of the Technological Educational Institute (T.E.I.) of Athens (http://www.teiath.gr/stef/tio/en_index.html)
The Department of Medical Instruments Technology was established in 1985 and is the only academic institution in Greece providing undergraduate education in the field of biomedical engineering.

Studies cover the field of biomedical technology and subjects delivered concern the areas of mechanical, electrical, electronic and computer engineering, biomedical instrumentation, and medical physics. The curriculum also includes subjects in medicine, management, and economics.

Graduates find employment in biomedical industry, hospitals, and clinics, in both the public and private sectors. Graduates are in high demand and employment is rising following the trend of medical technology in Greece. About 10% of the graduates follow postgraduate studies at M.Sc. or Ph.D. level.
The department is involved in delivering postgraduate courses in cooperation with two Greek Universities: (a) M.Sc. on Medical Physics, with University of Patras (http://physics.med.upatras.gr/default.htm) and (b) M.Sc. on Information Technologies in Medicine and Biology, with University of Athens (http://itmb.di.uoa.gr/). A number of our graduates have also currently pursuing or have successfully received Ph.D. degrees. Recently the department has come to agreements with European institutions under Erasmus program.

Graduate master’s level

_European Postgraduate Programme on Biomedical Engineering (BME), University of Patras, Greece_ (http://bme.med.upatras.gr/)

The Postgraduate Programme on Biomedical Engineering is organized since 1989 by the Faculty of Medicine of the University of Patras, the Faculty of Mechanical Engineering and the Faculty of Electrical and Computer Engineering of the National Technical University of Athens in collaboration with more than 20 European universities.

For the last 20 years, the European Union has supported an initiative for the development of a multinational advanced Programme on Biomedical Engineering within the ERASMUS and subsequently also within the TEMPUS program. The Programme draws expertise from a large multinational academic community, with Greek and foreign teachers originated from European Universities addressing a multinational audience from more than 10 European countries. The syllabus, based on the TEMPERE Project recommendations [Towards a European Framework for Education and Training in Medical Physics and Biomedical Engineering, IOS Press, 2001] covers the following four areas of subjects:

- Basic Knowledge & Skills (basic medical & physical sciences in medicine, transferable skills, research methods) 30%
- Conversion courses (0-2 taken from Mechanics and materials, Electronics, Digital signal processing) 0-10%
- Basic Biomedical engineering Topics 40-50%
- Advanced Biomedical engineering Topics 20%

Students may register at any of the collaborating Institutions and follow the whole or part of the Programme according to their needs. Additionally, students registered at the University of Patras may go to another University in order to elaborate their Master Thesis. The European Credit Transfer System is then used for the completion of their studies and the delivery of their degree. The BME Programme has succeeded in instructing more than 500 students up to now. A Quality Assurance system was implemented, aiming to create the necessary
conditions that permit the maximisation of the potential of this co-operative effort and to provide an appropriate framework for mutual recognition amongst the participating institutions. This multinational activity has lead to the conclusion that an advanced Programme on Biomedical Engineering should be regarded as an integral part of the overall process of preparing professionals for the job market. It is therefore necessary to consider all associated issues within a global framework, including prior education, field specific education and training, subsequent accreditation and licensing, as well as continuous professional development. It has been also proved that the concept of a European Programme is viable and can contribute effectively to the integration and harmonisation in the European Union and there is a pressing need to develop the appropriate framework that will facilitate student mobility and mutual professional recognition. This should be in accordance with EU harmonisation policies and without compromising the professional integrity. Such a framework can only emerge from an open, broad discussion among professionals.

**PhD level - post-graduate research**

The PhD is a research degree, achieved after the fulfilment of requirements including courses and the final dissertation during a minimum of four years study. Attendance of PhD courses is permitted to either graduates with a 5-years diploma or to graduates that have already got a Master’s degree. Currently, there are no teams, departments or universities to organise dedicated PhD courses in BME. PhD candidates are enrolled to function in the competence field of the supervisors.

**IEEE EMB Greece chapter** (http://ewh.ieee.org/r8/greece/embs/index.htm)

Although, not directly related to education, it worth to mention the IEEE EMB Greece chapter which is involved in the education process by providing access to state-of-the-art knowledge and permitting links between the tutors and trainees.

The IEEE EMB Greece chapter is part of the Engineering in Medicine and Biology Society (EMBS), which in turn is part of the Institute of Electrical and Electronic Engineers (IEEE). The chapter and society's field of interest is the application of concepts from the physical and engineering sciences to the fields of medicine and biology. EMBS and chapter members are not necessarily electrical engineers, but come from a variety of backgrounds including computer science, medicine, bioengineering and biomedical engineering.

The Chapter is currently chaired by Prof. Dimitrios I. Fotiadis from the Unit of Medical Technology and Intelligent Information Systems, Dept. Materials Science and Engineering, University of Ioannina.
Objectives of the IEEE EMB Greece Chapter are:

- To encourage the development, dissemination, integration, and utilization of knowledge in biomedical engineering and other allied fields among students, faculty, and industry in Greece.
- To expose biomedical engineering students to non-technical issues that they may encounter in the workforce as professional biomedical engineers.
- To act as a link between biomedical engineering students and biomedical engineering faculty and industry.
- To attract industry involvement in chapter activities, by providing a forum for the members to meet others who share their interests, as well as network with professionals in academia and industry, both formally and informally.
- To provide chapter members with up-to-date information about new developments and improvements in biomedical engineering and other allied fields, consistently; therefore, giving them a competitive edge over their peers in the job market.
- To provide support to Student events at EMBS conferences. EMBS hosts a number of conferences each year, including its annual meeting which covers a broad spectrum of topics, as well as special topic conferences on subjects such as neural engineering and information technology. The IEEE EMB Greece Chapter will support students' events during these meetings and conferences.
- To provide support to EMBS summer schools. EMBS hosts four summer schools, providing a great opportunity to learn about topics in biomedical engineering from world experts. Each summer school lasts for one week, bringing together undergraduate students, postgraduate students, postdoctoral fellows, and attendees from industry and academia.
- To support students' projects. The IEEE EMB Greece chapter will support students in project ideas, including the creation of a network of biomedical engineering students at nearby universities, or an online journal for students.
- To provide high quality lectures with the use of the Distinguished Lecturers Program. Through the Distinguished Lecturers Program, the chapter can invite a world-renowned speaker to give a talk at their own university, with financial support from EMBS. EMBS Distinguished Lecturers are all recognized experts in their fields, and known to be wonderful presenters.
2.6. Biomedical engineering education in Romania

Undergraduate Bachelor Degree
The Bachelor’s Degree is awarded after three or four years of education. The undergraduates are qualified as engineers (BEng) or BSc. Their job descriptions show that they are dedicated to practical work on biomedical equipment, to repair, build, maintain and operate the equipment as described by specific medical-related situations and cases [20]. This type of education operates within several universities in Romania, such as:
1. The Technical University of Cluj-Napoca,
2. The “Politehnica” University of Timisoara,
3. The “Politehnica” University of Bucharest,
4. The University of Oradea,
5. The University of Medicine and Pharmacy of Iasi.

Graduate Master’s Degree
The graduate Master’s Degree is conferred in two years of study after the BEng or BSc were obtained; at present the curricula and syllabi are varied and diverse. During the years of study, elective courses are offered in packages (modules) for more specialisation in the domain of medical engineering [20], [27]. This form of education is developed now in several universities in Romania, such as:
1. The Technical University of Cluj-Napoca,
2. The “Politehnica” University of Timisoara,
3. The “Politehnica” University of Bucharest,
4. The University of Medicine and Pharmacy “Gr. T. Popa” of Iasi.

For example, the Faculty of Medical Engineering, from the “Politehnica” University of Bucharest, offers the next Master programmes:
- Medical Engineering
- Biotechnology
- Biomaterials

Another example is the Faculty of Biomedical Engineering, the University of Medicine and Pharmacy “Gr. T. Popa” Iasi, which offers the following Master programmes:
- Advanced medical biotechnologies
- Prosthesis bioengineering
- Clinical bioengineering
- Rehabilitation bioengineering
PhD Degree
The PhD is a research degree, generally extended over the duration of four years. Normally, only graduates who have already got a Master’s degree are permitted to attend PhD courses. But at present there are no teams, departments or universities to organise PhD courses in BME. PhD candidates are enrolled to function in the competence field of the supervisors. Annually, quite a significant number of dissertations are focused upon biomedical engineering topics [27].

3. Standards and professional competences in biomedical engineering

3.1. Standards and professional competences in Spain

As in all engineering, first-year subjects in biomedical engineering studies are focused on mathematics, physics, chemistry, biology and statistics. From the second year the training is more specific and related to the professional areas, such as medical imaging, biomechanics, biochemistry, nuclear medicine or medical informatics.

Some of the competences that it are expected to get from biomedical engineering studies are the following:

A) General competences
- Capacity for analysis and synthesis.
- Ability to acquire, analyze, interpret and manage information.
- Ability to evaluate and compare decision-making criteria and exercise leadership.
- Ability to prepare reports and make judgments based on a critical analysis of reality.
- Ability to define, develop and elaborate regulatory own area.
- Ability to understand the social, technological and economic condition the practice.
- Develop creativity and imagination.
- Ability to argue orally and in writing to both specialist and non-specialist.
- Ability to communicate in their own language and in English, and to work in a multilingual environment.
- Ability to write and present technical reports and projects.
- Ability to communicate using graphic and symbolic languages.
- Capacity for teamwork in a multidisciplinary and multicultural environment.
- Ability to understand, anticipate and assume social responsibility, ethics and professional and socio-economic effects and environmental practice derived.
- Ability to organize, plan and manage the initiative, entrepreneurship and leadership.
- Motivation for quality and professionalism.
- Ability to learn new techniques and tools of analysis, modeling, design and optimization.
Ability to adapt to new situations.

B) Specific competences

- Basic knowledge in health sciences and molecular cell biology, anatomy, physiology, biochemistry and human pathophysiology.
- Having knowledge of the underlying science and technology in which medical technology is based on different levels: macro, micro and nano.
- Being able to understand the technical and functional characteristics of the systems, methods and procedures used in the prevention, diagnosis, therapy and rehabilitation.
- Ability to analyze and evaluate health technologies.
- Ability to develop, plan and apply mathematical methods in the analysis, modeling and simulation of the functioning of living organisms and the systems and processes used in biology and medicine.
- Ability to design, develop, deploy and manage experimental procedures, tools and systems to acquire, analyze and interpret data from living systems using engineering tools.
- Ability to plan, design, develop, install, operate and maintain procedures, devices, equipment and systems for the prevention, diagnosis, treatment and rehabilitation.
- Ability to model, interpret, select, perform and evaluate concepts and technological developments related to biomedical engineering and its application.
- Ability to efficiently use tools for analysis, design, calculation and testing in the development of biomedical products and services.
- Ability to plan, organize, direct and control systems and processes in the field of biomedical engineering.
- Basic knowledge of cardiovascular, neurological, metabolic, immunologic, infectious and assisted reproduction, as well as diseases and processes of locomotor apparatus. Specific
- Capacity for organization and planning in the field of business, health centers and government agencies concerned with medical technology, based on principles and procedures of quality.
- Ability to interpret and apply the laws and regulations, both national and international, to own different application areas.
- Capacity to innovate in products and biomedical services.
- Entrepreneurial capacity in the biomedical sector.
- Possess knowledge of the fundamentals of mathematics, physics, chemistry, graphic expression, mechanics, strength of materials, fluids, electronics, computers, signal analysis, automatic management and business administration.
- Ability to communicate with health professionals and understand their needs in relation to biomedical products and services.
- Ability to integrate into working with medical professionals to work in biology and experimentation and the development of new products and services in the field of biomedicine.
Possess knowledge bioelectromagnetics, implementation and analysis of biomedical signals and images, biomaterials, biomechanics, tissue engineering and regenerative medicine, modeling of cells, tissues and physiological systems, information systems and bioinformatics, telemedicine, medical robotics, clinical engineering, healthcare models and hospital management.

- Capacity for self-learning, consolidation and updating of new knowledge in the area of biomedical engineering, and to undertake further study with a high degree of autonomy.
- Ability to consolidate, expand and integrate knowledge of basic sciences (basic sciences and health sciences) in biomedical engineering.
- Ability to adapt to new knowledge about the functioning of living organisms and the evolution of medical technology.
- Possess knowledge of computer tools to analyze, calculate, display, perform and get the information needed to support the tasks of analysis, calculation, design, development and management related to biomedical engineering.
- Have knowledge of systems and production and manufacturing processes in the field of medical technology.
- Have knowledge of the organization and management of health care systems, healthcare and technology industries and health services, as well as legislation, regulations and standards applicable in the field of biomedical engineering.
- Ability to integrate multidisciplinary knowledge related to engineering, biology and medicine.
- Ability to identify, formulate and solve problems at the interface between technology and health sciences, biology and medicine.

Professional opportunities

The professional activity of biomedical engineers in Spain mainly covers four areas:

1) Diagnosis and treatment. Advice on the selection of equipment to provide efficient and economical solutions to health problems, assist in diagnosis and treatment that require the use of electrical instruments, mechanical and acoustic and performs quality control and operating conditions of all types of prostheses.

2) Medical equipment. Provide, install and test equipment used in hospitals and research institutes and kept at optimal level of functioning. Furthermore, supervise and coordinate repair.

3) Medical Research. Conducting studies on how biological systems are interrelated body and physical systems. Designed prostheses, artificial organs, machines to maintain or extend life as respirators. They study many of the signals transmitted by organs such as the brain, heart and skeletal muscle.
4) Management of medical technology. Design and deliver training programs to train medical personnel. Surveys conducted in relation to biomedical technologies and systems perform management technology as well as equipment maintenance scheduling.

The biomedical engineer therefore often work in hospitals and public or private health centers, designing, building and launching equipment tailored for specific medical needs, including both instrumental (hardware) and its programming (software). They also work in regional ministries and the Public Health Institute, in medical equipment manufacturers, involved in the construction, sale and "marketing" of their teams, research centers or self-made advice and consultancy in the government sector and productive health.

3.2. Standards and professional competences in Greece

The Biomedical Engineering sector in Greece is rather controversial. On one hand medical devices production is restricted to a few tens of device types, resulting in a market based almost entirely on imported products, on the other, the fact that there is a very active scientific community and the co-existence of faculties of Science, Engineering and Medicine in four Greek universities, has already given evidence of good potential for the promotion of R&D and educational activities in the field.

The radical change in the National Health System (NHS) in the 80’s, which resulted in a growth of the public sector with large investments equally distributed between new buildings and equipment, has been followed by a policy, at the end of the last decade, that indirectly promoted the development of the private sector. The latter, by placing its emphasis on profit making, initially invested largely in high tech biomedical diagnostic equipment, but more recently is also growing quite rapidly in hospital based health care delivery.

Given the lack of medical device industry in Greece, it is not surprising that standardisation and regulatory initiatives in the sector (with the exception of radiation protection regulations), as well as participation and active involvement in international standardisation activities, have been limited. Following the introduction of the EU directives on medical devices, however, Greece has implemented them and through its national standardisation body, ELOT, is now following the developments and the activities in CEN related to medical device sector.

The development of biomedical engineering in Greece is closely related to that of medical physics. The latter made its appearance in specialised Greek hospitals in the late 1950s and grew steadily in the following years. It was therefore already well established to form the basis for the development of BME in the mid-1970s. So far, there are close ties between the
two fields and much of the research and teaching in bioengineering takes place in the university medical physics departments.

The first electronics technicians in state hospitals made their appearance at the beginning of the 1960s. Their primary responsibility was to maintain and repair medical devices and they were employed by the plant engineering and central supply department. Although it became clear, early in the 1970s, that high technology health care required more specific equipment support, public authorities remained inactive and with the exception of a few big hospitals (mainly involved in cancer treatment), clinical engineering departments were not developed. Thus, corrective maintenance of equipment as well as training of users was mainly left to the manufacturers and their dealers. Up to 1982, the number of electronics technicians working in public hospitals was less than 100, most of them trained on the job.

On the other hand, preventive maintenance and quality control was not usual and acceptance and safety tests rather non-existent (with the exception of ionising radiation equipment). It should also be mentioned that decisions concerning the purchase of new equipment were and, to a large extent still remain, under the control of medical specialists.

Today, about one-third of the hospitals have a kind of in-house-service but only some of them have well-organised biomedical technology departments with experienced technical staff. The majority of hospitals are obliged to rely on the private sector, which in many cases is very inconvenient and leads to higher cost and longer breakdown time. At present, there are about 300 medical physicists working in Greece, compared to less than 200 biomedical engineers holding a university degree. As far as biomedical equipment technologists are concerned, the number working in Greek hospitals has increased to about 100, according to their association. The private sector, dealing with medical devices, employs another approximately 500 specialised BMETs mainly responsible for maintenance tasks.

A public enterprise for the construction of state hospitals (DEPANOM) was established in 1984 to plan and supervise hospital construction projects with activities focused on the constructional aspects rather than the sector of biomedical equipment. Its first task was the supervision of a turn-key project concerning the construction of 3 university hospitals with 700 beds each. This multi-million EURO project was successfully completed about 4 years later and all installed equipment was tested for acceptance prior to commissioning. This pilot project proved successful and the valuable experience that was gained has since been used in the construction of more than 15 new hospitals over the last 15 years.

In 1990, the Greek Ministry of Health created a Biomedical Technology Division, mainly dealing with the planning and allocation of budget for equipment acquisition at a national level. Additionally, it handles strategic issues in equipment maintenance for rural health
centres and small hospitals, lacking their own support services. As the first EC directives became operative in January 1993, this division also assumed the role of the Competent Authority in March 1993. Since 1999 the responsibility for the implementation of the directives and the supervision of the market has been passed to the Hellenic Drug Organisation (EOF) which became the Greek CA (Competent Authority).

Professional opportunities

The professional activity of biomedical engineers in Greece range in the following possibilities:

- In the Public or Private Sector as Informatics specialists.
- In the Public Sector, as personnel in charge of: a) Health Information Systems development, b) Hospital electronic file management system, c) Choice of Medical equipment, d) monitoring research and Development programmes in ministries.
- In Institutions and Research centers, as associate teaching - research staff in research areas such as gene analysis, the modulation of solid structure patterns etc.
- In the Private Sector as the scientific staff in charge of: telemedicine, computer applications in biosignal processing or image analysis, design and research in departments of large enterprises for the design and upgrade of new medical apparatus of artificial organs.

3.3. Standards and professional competences in Romania

Biomedical engineering is regulated in some countries, such as Australia, but registration is typically only recommended and not required [28]. In the UK, mechanical engineers working in the areas of Medical Engineering, Bioengineering or Biomedical engineering can gain Chartered Engineer status through the Institution of Mechanical Engineers. The Institution also runs the Engineering in Medicine and Health Division. Beyond governmental registration, certain private-sector professional/industrial organizations also offer certifications with varying degrees of prominence [2].

In Romania, the standards, qualifications and competencies in education are regulated through RNCIS (National Higher Education Qualifications Registry). In this system, information such as: Qualification title and name; Graduation title; Qualification name; Identification elements for the qualification; Qualification summary (professional and transversal competencies); Possible occupations for the owner of the diploma, etc. are given.

As examples, the competencies in two undergraduate (four years) BME programmes are given in appendices 2 and 3 (RNCIS [29]):

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.
1. Medical engineering (Fundamental domain: Engineering sciences, Study domain: Applied engineering sciences);
2. Bioengineering (Fundamental domain: Engineering sciences, Study domain: Applied engineering sciences);

4. E-Learning Overview

4.1. Definitions, Strengths and Weaknesses of E-Learning

Today's society is subject to various social and economical changes, referred to as "mega trends". These describe phenomena such as globalization, internationalization and furthermore the change to a knowledge and information based society. The social, technological and economical changes as well as the continuously changing demands of the market make it necessary for individuals to continuously develop and improve their competences. Learning can be seen as an investment into the future. Moreover, learning in times of dynamic change calls for methods which teach large audiences up-to-date topics in a cost efficient way. E-learning solutions are perceived as a possibility to increase the quality of education, while simultaneously lowering costs [34].

E-learning is the unifying term to describe the fields of online learning, web-based training, and technology-delivered instruction. E-learning is a very dynamic domain, in continuous growth, which refers to educational content or learning experiences delivered or mediated by means of digital technologies. The development of this domain will lead to a growth in the quality of instruction, cost reductions and a more efficient implementation of distance and life-long learning.

Definitions abound:

- The convergence of the Internet and learning, or Internet-enabled learning.
- The use of network technologies to create, foster, deliver, and facilitate learning, anytime and anywhere.
- The delivery of individualized, comprehensive, dynamic learning content in real time, aiding the development of communities of knowledge, linking learners and practitioners with experts.
- A phenomenon delivering accountability, accessibility, and opportunity to allow people and organizations to keep up with the rapid changes that define the Internet world.
- A force that gives people and organizations the competitive edge to allow them to keep ahead of the rapidly changing global economy [54].
Therefore e-learning can be understood as learning which is supported and made possible through information and communication technologies. The American Society of Training and Development (ASTD) defines e-learning as a term: “covering a wide set of applications and processes, such as Web based learning, computer-based learning, virtual classrooms and digital collaboration. It includes the delivery of content via Internet, intranet/extranet (LAN/WAN), audio- and videotape, satellite broadcast, interactive TV and more” [48].

For a long time the main emphasis was placed on the "e" (electronic) as a success guarantee of innovative technologies. The "learning" part of the term was often seen as a secondary matter. Didactical concepts were frequently missing, which limited the possibilities of e-learning. Today, a crucial role is attributed to the actual learning part within e-learning [34].

E-learning can incorporate many elements that make learning new material, a new process or a new program more fun. Making learning more fun -- or interesting -- is what makes it more effective. The keys to successful e-learning include:

- **Varying the types of content** - Images, sounds and text work together to build memory in several areas of the brain and result in better retention of the material.

- **Creating interaction that engages the attention** - Games, quizzes and even just required manipulation of something on the screen creates more interest, which in turn builds better retention.

- **Providing immediate feedback** - E-learning courses can build in immediate feedback to correct misunderstood material. The more immediate the feedback the better, because each step of learning builds upon the previous step. If no feedback is given, then the next step may be building upon an incorrect interpretation.

- **Encouraging interaction with other e-learners and an e-instructor** - Chat rooms, discussion boards, instant messaging and e-mail all offer effective interaction for e-learners, and do a good job of taking the place of classroom discussion. Building an online community significantly influences the success of online programs [40].

**Strengths and weaknesses of e-learning**

It is very important to be aware of the advantages and drawbacks of e-learning before developing an e-learning system, in order to insure successful integration and minimization of shortcomings. The following list contains the most frequently cited advantages and disadvantages of e-learning in literature, as summarized by [34].

**Strengths of e-learning:**

- Cost reduction – Especially within companies, e-learning can help to cut down on travel expenses. Also e-learning makes it possible to mediate contents to more learners using less personnel resources and therefore smaller costs.
Independence of time and location – E-learning makes it possible to take part in a course anytime and anywhere. This makes it easy to reach for a target group that is separated geographically.

Focus on the learner – Personal learning speed and individual preferences can be respected. The learning is facilitated when trainees can learn according to their personal learning rhythm. This can save up to 40% of learning time compared to a traditional face to face course. This also contributes to satisfaction, for trainees are less frustrated.

Consistency of contents – All learners are exposed to the exact same learning resources. These can be updated from one central department thus leading to a homogenous knowledgebase for all learners. This ensures that contents are always up-to-date.

Variety of learning methods – E-learning covers diverse methods and applications, which can be used flexibly and dependently on the situation and people involved.

Reusability – The so-called “learning objects” (any digital resource that can be reused to support learning) provide small learning units. These units can be reused in the same or in a different context.

Control of interaction – Learners have more control over interaction than in traditional face to face education. Asynchronous communication and anonymity can reduce fear and increase the communication possibilities of introverted and shy people.

Additional motivation – General attractiveness of computers is already one source of additional motivation in some cases. Using computers as learning instruments in schools or higher education settings increases the probability that learners will use computers in future situations.

Tracking of learning progress – Continuously monitoring trainees' progress and results makes it possible for a better adaptation of the learning path to match students' needs.

Weaknesses of e-learning:

Requirements of high motivation – E-learning requires self-disciplined and motivated learners. The learner himself is responsible for the learning process.

Great amount of prerequisite knowledge necessary – The learner must be familiar with certain methodologies and strategies to be able to successfully use e-learning. Besides knowing about the subject he teaches, the teacher using e-learning must also be educated to handle the new media perfectly.

Mandatory special communication competences – Communication within virtual settings is dependent on special competences from all people involved. There are less communication channels within computer mediated communication than there are in face to face communication. This can lead to an unequal involvement in the communication process between the people communicating. It is the teacher’s task to compensate the lack of social closeness. If he doesn’t succeed the participants may feel left alone, which can then cause a higher dropout rate.
- Requirement of high bandwidths – Using multimedia learning software requires high bandwidths. Slow access can de-motivate learners. This is why bandwidth is still considered to be a crucial restriction when producing learning contents.
- High demands concerning infrastructure – E-learning calls for a high-performance technological infrastructure. Functioning technology is the basis for the efficient use of e-learning. Both the teacher and the learners need to have access to high-performance technology e.g. PC, high speed internet connection, quality software etc.
- Insufficient security – Since e-learning technologies are often based on the use of the Internet, security concepts are very important to guarantee that contents can only be viewed by authorized people. Issues of data security concerning the learners are often complex and costly but have to be respected by all means [34].

4.2. Learning Management Systems

Today’s e-learning is dominated by the **Learning Management Systems** (LMS), such as Moodle [58], Atutor [49], Sakai [60], ILIAS [57], Dokeos [53], Blackboard [50], Desire2Learn [52]; these represent integrated systems which offer support for a wide area of activities in the e-learning process. Some of the functionalities usually offered by a LMS are:

- communication and collaboration tools: discussion forum, chat, internal messaging and e-mail, file sharing, assignment drop box, video conference, whiteboard, announcements, RSS feeds, wiki, survey
- administrative tools: user management, authentication, course authorization tools (assign specific access privileges to course content and tools based on specific user roles), registration tools (administrator/instructor enroll/drop trainees/students or self-registration), security features, technical support (documentation, assistance)
- curriculum design support: course templates, authoring tools (built-in HTML editor, WYSIWYG editor, equation editor, test authoring tools), import/export facilities, content sharing/reuse by means of digital content repositories
- trainee/student involvement tools: trainee portfolio, self-assessment, trainee community building, progress tracking, bookmarks, calendar/schedule, searching facilities, glossary, context sensitive help
- instructional standards compliance (SCORM, IMS)
- assessment support: on-line testing (multiple choice, fill-in-the-blanks, timed quizzes etc), automated grading, online gradebook
- trainee tracking and reporting, statistics
- groupwork support – facilities for group message sending, dedicated forums, team creation.
Thus teachers can use LMS for the creation of courses and test suites, for communicating with the trainees, for monitoring and evaluating their work. Students/trainees can learn, communicate and collaborate by means of LMS.

Moodle (Modular Object-Oriented Dynamic Learning Environment) is the most widely-used learning management system, employed in universities, schools, private companies, NGOs etc. It is currently translated in over 80 languages, being used in 220 countries [58]. It offers a framework for developing and using modern educational materials and methods, as well as adopting a creativity-stimulating pedagogy. It is implemented in PHP and uses a MySQL as Database Management System. The requirements for installation on any platform are:

- a Web server offering PHP support (e.g. Apache)
- PHP application server
- A database server (MySQL or PostgreSQL)

Some current Moodle statistics are included in Fig. 8. Figures 9 and 10 include screenshots of the platform used for various demo courses [59].

### Moodle Statistics

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<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Registered sites</strong></td>
<td>68,112</td>
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<tr>
<td><strong>Countries</strong></td>
<td>220</td>
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<tr>
<td><strong>Courses</strong></td>
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<td><strong>Users</strong></td>
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<td><strong>Teachers</strong></td>
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<td><strong>Enrollments</strong></td>
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<tr>
<td><strong>Forum posts</strong></td>
<td>107,832,903</td>
</tr>
<tr>
<td><strong>Resources</strong></td>
<td>58,899,603</td>
</tr>
<tr>
<td><strong>Quiz questions</strong></td>
<td>125,999,947</td>
</tr>
</tbody>
</table>

**Fig. 8.** Current Moodle statistics (September 2012) [58]
Fig. 9. Screenshot from a Moodle demo course (teacher view) [59]

Fig. 10. Screenshot from a Moodle demo course (student view) [59]
4.3. Web 2.0 and Education

In the last few years, Web 2.0 tools gained a lot of attention and started to be used in educational settings. These are also referred to as "social software" and include a wide range of tools for social networking (e.g., Facebook, LinkedIn), media sharing (e.g., YouTube, Flickr), social bookmarking (e.g., Delicious), blogging (e.g., Wordpress, Blogger), wikis (e.g., Wikipedia). This interest comes from the fact that the principles Web 2.0 is based on are in line with modern educational theories such as socio-constructivism [47]: knowledge cannot be transmitted but has to be constructed by the individual, by means of collaborative efforts of groups of learners [46].

Grodecka presents [36] practical guidelines for the use of Web 2.0 technologies to support teaching and learning, illustrating them with actual pedagogical scenarios. Blogs for example can be seen as a means for trainees to publish their own ideas, essays and homework and as a space where they can reflect on their learning process (i.e., a kind of "learning diary"). Furthermore, posting comments to blog articles represents a means of social interaction, as well as an opportunity to provide critical and constructive feedback. Also, blogs help create a sense of community among trainees with similar interests ("educational blogosphere"). Similarly, wikis can be used as a means of collaborative creation of knowledge artifacts, Wikipedia being a prominent example. In educational settings, wikis can be successfully used for collaborative writing tasks among the members of a team, as well as for creating and maintaining learning content, both by trainees/students and teachers. Social bookmarking tools can be used for storing and sharing links to resources of interest for the course (i.e., a kind of "personal knowledge management tool"). Trainees can share bookmarks they have discovered with their peers and also tag and rate the collected resources. A comprehensive review of papers reporting actual applications of Web 2.0 technologies and tools in formal learning settings can be found in [37].

In a recent study [41], we wanted to investigate two important issues related to the use of Web 2.0 tools in a Romanian university context: what is students' familiarity level with Web 2.0 tools and what is their subjective evaluation of applying these tools in the learning process?

While the general belief is that today's students are familiar with Web 2.0 sites and enthusiastic users, there are also studies which prove that this is not necessarily the case [31, 38]. Therefore, the first objective of our study was to clearly establish the level of familiarity of our students with various Web 2.0 tools, as well as their usage habits (time spent, frequency of accesses, purpose of use). Furthermore, even if students are familiar with these tools, does this mean they are willing to use them in educational settings or do they see them
simply as entertainment tools? Are students able to transfer their Web 2.0 skills and knowledge to the new context of formal learning? [32]

In order to answer this question, we provided the students with an environment in which they had to use two such tools (blog and wiki) for educational purposes, more specifically for a team project assignment. Next, we asked students to fill in a questionnaire, describing their experience of interacting with the blog and wiki in terms of ease-of-use, perceived usefulness, advantages and disadvantages. Finally, once students acquired a hands-on experience with Web 2.0 tools in the learning process, we polled them again regarding the prospective large-scale use of these tools in educational settings. "What are the main benefits?", "What are the drawbacks?", "What would be the best educational use for each of these tools?" were some of the questions that students gave their opinion about.

All students reported having Internet access from home. The average amount of time spent online is 25.83 hours per week: 35.8% of this time is spent for leisure, 39.27% for study and assignments and 22.31% for work (since some of the students also have part time jobs).

Next, students were asked to rate their familiarity with various Web 2.0 tools, providing also the average time spent using that tool and the frequency of accesses. The results are summarized in Tables 1 and 2 respectively.

Table 1. Students' familiarity with Web 2.0 tools

<table>
<thead>
<tr>
<th>Response options</th>
<th>Blog</th>
<th>Wiki</th>
<th>Social networking</th>
<th>Social bookmarking</th>
<th>RSS</th>
<th>Podcasts</th>
<th>Media sharing sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very good</td>
<td>16.67%</td>
<td>16.67%</td>
<td>23.33%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>43.33%</td>
</tr>
<tr>
<td>Good</td>
<td>36.67%</td>
<td>26.67%</td>
<td>26.67%</td>
<td>23.33%</td>
<td>13.33%</td>
<td>10%</td>
<td>23.33%</td>
</tr>
<tr>
<td>Average</td>
<td>20%</td>
<td>36.67%</td>
<td>36.67%</td>
<td>30%</td>
<td>16.67%</td>
<td>20%</td>
<td>30%</td>
</tr>
<tr>
<td>Poor</td>
<td>16.67%</td>
<td>6.67%</td>
<td>10%</td>
<td>33.33%</td>
<td>20%</td>
<td>26.67%</td>
<td>3.33%</td>
</tr>
<tr>
<td>Very poor</td>
<td>6.67%</td>
<td>13.33%</td>
<td>3.33%</td>
<td>10%</td>
<td>40%</td>
<td>13.33%</td>
<td>0%</td>
</tr>
<tr>
<td>Don't know at all</td>
<td>3.33%</td>
<td>0%</td>
<td>0%</td>
<td>3.33%</td>
<td>10%</td>
<td>30%</td>
<td>0%</td>
</tr>
</tbody>
</table>
Table 2. Usage patterns of Web 2.0 tools

<table>
<thead>
<tr>
<th>Response options</th>
<th>Blog</th>
<th>Wiki</th>
<th>Social networking</th>
<th>Social bookmarking</th>
<th>RSS</th>
<th>Podcasts</th>
<th>Media sharing sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Several times per day</td>
<td>3.33%</td>
<td>20%</td>
<td>16.67%</td>
<td>0%</td>
<td>0%</td>
<td>3.33%</td>
<td>43.33%</td>
</tr>
<tr>
<td>Once per day</td>
<td>3.33%</td>
<td>13.33%</td>
<td>16.67%</td>
<td>3.33%</td>
<td>6.67%</td>
<td>3.33%</td>
<td>10%</td>
</tr>
<tr>
<td>Several times per week</td>
<td>36.67%</td>
<td>33.33%</td>
<td>23.33%</td>
<td>16.67%</td>
<td>6.67%</td>
<td>16.67%</td>
<td>26.67%</td>
</tr>
<tr>
<td>Once per week</td>
<td>16.67%</td>
<td>10%</td>
<td>16.67%</td>
<td>13.33%</td>
<td>6.67%</td>
<td>6.67%</td>
<td>13.33%</td>
</tr>
<tr>
<td>One-two times per month</td>
<td>26.67%</td>
<td>0%</td>
<td>20%</td>
<td>26.67%</td>
<td>20%</td>
<td>16.67%</td>
<td>3.33%</td>
</tr>
<tr>
<td>Never</td>
<td>13.33%</td>
<td>23.33%</td>
<td>6.67%</td>
<td>40%</td>
<td>60%</td>
<td>53.33%</td>
<td>3.33%</td>
</tr>
<tr>
<td>Hours per week</td>
<td>1.83</td>
<td>3.27</td>
<td>3.22</td>
<td>0.77</td>
<td>0.45</td>
<td>0.62</td>
<td>5.55</td>
</tr>
</tbody>
</table>

The self-rating scores on Web 2.0 knowledge are in accordance with the findings reported in [31, 33]; students are relatively familiar with Web 2.0 tools, but generally they are not expert or sophisticated users. The highest level of familiarity is reported for media sharing sites (with 96.67% of the students having at least average knowledge), followed by social networking sites (with 86.67% of the students having at least average knowledge). The blog and wiki are ranked next, while the social bookmarking sites, RSS and podcasts seem to be less known by the students. These results are also reflected in the usage patterns of the students, with the highest amount of time spent on the media sharing and social networking sites, and the least amount of time spent using social bookmarking, RSS and podcasts. It is worth mentioning that the amount of time spent on the wikis is second highest (marginally higher than the time spent on social networking sites).

When asked about why they are using these Web 2.0 sites, the most cited reasons were (ordered according to their frequency of appearance in students' answers): i) entertainment, fun, playing; ii) keep in touch with friends and make new ones; iii) social networking; iv) search for information; v) exchange thoughts and ideas; vi) find latest news; vii) study, do homework; viii) job-related tasks; ix) get feedback from other users.

Next, we wanted to find out the role students generally assume on media sharing sites. 20% of the students reported never uploading any content, 60% rarely uploading content and 20% sometimes uploading content. This confirms the findings reported in [33], that students are mainly consumers rather than producers of Web content.
Since blogs and wikis were the tools used in the WAD course, the next questions focused on students' experience with these technologies. More specifically, we wanted to find out whether students have their own blogs and have written on a wiki before. Only 5 students reported currently keeping or having kept a blog in the past, with subjects ranging from IT to holidays and personal thoughts for friends and families. One student mentioned using his blog as an archive for when he wants to remember something later, and another one mentioned using blog APIs for a recent programming assignment.

As far as the wiki is concerned, again only 5 students reported having contributed to a wiki in the past: one used it at work for writing the documentation, 3 edited pages on Wikipedia (some related to IT) and one created and edited pages on a wiki dedicated to a community of programmers.

The second questionnaire (applied after the students experimented with the Web 2.0 tools in the framework of a course) comprised three sections: i) questions regarding the use of blog; ii) questions regarding the use of wiki; iii) questions regarding students' general opinion about the use of various Web 2.0 tools in education. In what follows, we will treat the first two sections in parallel.

As you can see from Table 3, both the blog and the wiki were considered quite easy to learn and use by the students, with wikis being perceived as slightly more difficult.

Table 3. Perceived ease of learning and ease of use for the blog and wiki

<table>
<thead>
<tr>
<th>Response options</th>
<th>Blog</th>
<th>Wiki</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ease of learning</td>
<td>Ease of use</td>
</tr>
<tr>
<td>Very easy</td>
<td>46.67%</td>
<td>53.33%</td>
</tr>
<tr>
<td>Easy</td>
<td>46.67%</td>
<td>40%</td>
</tr>
<tr>
<td>Neutral</td>
<td>3.33%</td>
<td>6.67%</td>
</tr>
<tr>
<td>Difficult</td>
<td>3.33%</td>
<td>0%</td>
</tr>
<tr>
<td>Very difficult</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

As far as encountering problems when using the tools, only one student reported having problems with the blog (i.e., "publish button wouldn't work all the time") and 5 students with
the wiki ("the server failed one time", "if we write something wrong and modify it, the old page is still kept, which is annoying", "I had a problem when adding photos to the project documentation").

According to Table 4, the main purposes fulfilled by the blog were (ordered based on the importance assigned by the students): i) exchange experience; ii) learn how to use a blog; iii) facilitate communication and collaboration between team members; iv) receive feedback; v) increase interest and motivation; vi) reflect on one's own learning experience and the experience of others; vii) increase involvement. Similarly, the main purposes fulfilled by the wiki are: i) help organize knowledge; ii) learn how to use the wiki; iii) improve collaborative skills; iv) facilitate communication and collaboration between team members.

**Table 4.** Main roles fulfilled by the use of blog and wiki in the WAD project

<table>
<thead>
<tr>
<th>Role</th>
<th>Blog</th>
<th>Wiki</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learn how to use a blog/wiki (if not used before)</td>
<td>66.67%</td>
<td>60%</td>
</tr>
<tr>
<td>Help organize knowledge</td>
<td>30%</td>
<td>70%</td>
</tr>
<tr>
<td>Receive feedback</td>
<td>53.33%</td>
<td>30%</td>
</tr>
<tr>
<td>Give feedback</td>
<td>40%</td>
<td>20%</td>
</tr>
<tr>
<td>Exchange experience</td>
<td>70%</td>
<td>40%</td>
</tr>
<tr>
<td>Reflect on your own learning experience and the experience of others</td>
<td>50%</td>
<td>30%</td>
</tr>
<tr>
<td>Improve critical thinking skills</td>
<td>16.67%</td>
<td>20%</td>
</tr>
<tr>
<td>Improve writing skills</td>
<td>36.67%</td>
<td>23.33%</td>
</tr>
<tr>
<td>Improve collaborative skills</td>
<td>40%</td>
<td>53.33%</td>
</tr>
<tr>
<td>Increase interest and motivation</td>
<td>53.33%</td>
<td>30%</td>
</tr>
<tr>
<td>Increase involvement</td>
<td>50%</td>
<td>40%</td>
</tr>
<tr>
<td>Increase competitiveness</td>
<td>36.67%</td>
<td>23.33%</td>
</tr>
<tr>
<td>Facilitate communication and collaboration between team members</td>
<td>63.33%</td>
<td>53.33%</td>
</tr>
<tr>
<td>Facilitate communication and collaboration between different teams</td>
<td>26.67%</td>
<td>33.33%</td>
</tr>
</tbody>
</table>
Subsequently, we wanted to identify the main drawbacks of using blogs and wikis from the point of view of the students. While a large majority indicated no perceived disadvantages of blogging (66.67%), two issues were mentioned by several learners: i) low level of involvement from some of the team colleagues; ii) high amount of time needed for blogging. Another student mentioned that "everyone can see your posts and can criticize them. So you must be very informed about that subject before posting". As far as the wiki is concerned, time was again mentioned as a disadvantage, together with the lack of cooperation from the peers and with the somewhat cumbersome editing functionalities (since no WYSIWYG editor was available). However, the large majority of the students didn't mention any drawbacks of using the wiki (63.33%).

The final section of our questionnaire referred to students' general opinion about the place of Web 2.0 tools in education. As can be seen from Table 5, 93.33% of the students declared themselves in favor of the use of these tools in formal learning settings.

Table 5. Students' answers to the question
"Do you think Web 2.0 tools should be used in the educational process?"

<table>
<thead>
<tr>
<th>Response options</th>
<th>Percentage of students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definitely yes</td>
<td>43.33%</td>
</tr>
<tr>
<td>Probably yes</td>
<td>50%</td>
</tr>
<tr>
<td>Neutral</td>
<td>3.33%</td>
</tr>
<tr>
<td>Probably not</td>
<td>3.33%</td>
</tr>
<tr>
<td>Definitely not</td>
<td>0%</td>
</tr>
</tbody>
</table>

When asked to cite the main advantages of using these tools, the most frequent answers were: i) "easily checking the progress of the team"; ii) "organizing and sharing documentation and other resources"; iii) "more fun and interesting", "increased motivation and involvement"; iv) "increase the efficiency of the team work"; v) "better communication"; vi) "increased competitiveness between teams"; vii) "share experiences"; viii) "receiving feedback". Among the most cited disadvantages there were: i) "some students may not have access to the Internet and they may feel neglected"; ii) "some students may post incorrect information, either due to lack of knowledge or even on purpose"; iii) "lack of face-to-face interaction"; iv) "all these tools may sometimes be distracting from the actual task"; v) "lack of safety and privacy of the
information"; vi) "too many tools may cause confusion and using all of them may be a time issue".

Finally, students were asked to provide a short description of how they would like Web 2.0 tools to be used in education. The most common answers are summarized below:

- Blogs: "write an activity report"; "writing comments and ideas about the project"; "share experiences"; "ask and give solutions to problems"; "communicate between team members".
- Wikis: "online platform for the documentation"; "share information"; "share lecture notes"; "organize and structure information and resources"; "give solutions to problems, tips & tricks, etc."; "a common document to be updated collaboratively by the team members".
- Social networking sites: "stay connected with the others", "communicate with students having the same interests", "create a specialized subgroup, for a specific interest"; "interact with your contacts and exchange content"; "get to know your peers better".
- Social bookmarking sites: "save interesting pages related to the course"; "discover more sites related to a particular subject"; "organize and annotate online resources"; "share interesting links with team colleagues".

In what follows we present a summary of the main findings of our study:

1. Students have a relative familiarity with Web 2.0 tools, but they are not necessarily advanced users. Most of them are mainly consumers, not producers of Web content (with only 5 students having kept blogs and 5 students having contributed to a wiki before the course). Hence the need for a clearly guided approach, with detailed instructions and explanations from the teachers, as pointed out in [31].

2. While entertainment and keeping in touch with friends are the most common uses of Web 2.0 sites, some students also rely on them for finding information (especially in case of Wikipedia), as well as for various study and job-related tasks.

3. Both blogs and wikis were easy to learn and use by the students, with virtually no technical problems encountered.

4. Both blogs and wikis were found very useful by the students, facilitating communication and collaboration between team members, increasing interest, motivation and involvement, helping to organize knowledge, supporting experience exchange and feedback from peers.

5. A few drawbacks were also pointed out: team work may sometimes be disadvantaging for students if they have to rely on the work of their peers who refuse to cooperate. As far as the high amount of time needed, this can be explained by the fact that this experiment was a premiere for the students, so they needed some time to get accustomed with the required tasks and the new collaborative work approach. Finally, exposing one's work, ideas and thoughts to the others may be frustrating for some (although usually it has the contrary effect: increased motivation and competitiveness).
6. The high majority of the students showed willingness and enthusiasm towards the large-scale introduction of Web 2.0 tools in the instructional process.
7. Many students found useful and creative purposes in education for the tools they have already interacted with in practice (i.e., blog and wiki).
8. For the other tools (which they have not yet experimented in educational settings), students could think of fewer ways of repurposing them. A couple of students even mentioned that they "cannot see their place in education", experiencing what Clark et al. called digital dissonance (i.e., a certain tension associated with the use of Web 2.0 tools in formal educational contexts) [32]. Hence the need to find methods for releasing this dissonance, blending the out-of-school Web 2.0 activities with the formal learning settings.

5. E-learning in BME Education

5.1. E-learning in BME Education in Romania, Spain and Greece

E-Learning in biomedical engineering education in Romania

The use of e-learning in Romanian higher education institutions is continuously expanding. The universities are adapting their curriculum to allow the creation of new technology-enhanced learning settings in various areas [61]. There are both small-scale research initiatives (e.g. [41, 42]), as well as large-scale uses of dedicated platforms, such as learning management systems. The most widely used LMS in Romania is Moodle (http://www.moodle.ro/), with 248 sites currently using it (according to the official Moodle statistics: https://moodle.org/sites/index.php?country=RO – Oct. 2012). Many of these installations belong to universities (e.g. University of Bucharest, Politehnica University of Bucharest, "Aurel Vlaicu" University of Arad, Transilvania University of Brasov). In this context, a resource center was initiated by TEHNE – Centre for Innovation and Development in Education, namely eLearning.Romania (http://www.elearning.ro); the initiative works as a national communication channel in the field, disseminating best practices and significant local e-learning experiences, providing relevant announcements and promoting available solutions and services for e-learning.

As far as biomedical engineering area is concerned, the e-learning approach is not well-developed in Romania. Dedicated undergraduate programs are offered at the Faculty of Medical Bioengineering, G.T Popa University of Medicine and Pharmacy Iasi (http://www.bioinginerie.ro/), but they don’t include technology-enhanced distance learning settings.
E-Learning in biomedical engineering education in Spain

Blended learning (B-learning)

- Master's Degree in Biomedical Engineering from the Polytechnic University of Valencia (UPV)-IBV

Biomedical engineering is the discipline that applies the principles and methods of engineering to understanding, defining and solving problems in biology and medicine. The demand for engineers in the conception, design, installation and training in the use of medical equipment and instruments has grown in line with the advances in medical technology. These essential aspects of health technologies are currently covered by the EU directives and the laws of all developed countries. The contents of this Joint Master have been prepared by the departments of the technical colleges of Industrial and Telecommunication Engineering at the Polytechnic University of Valencia and the faculties of Medicine and Physical Sciences at the University of Valencia, with order to provide a quality blended learning in the field of biomedical engineering.

The objective of this proposal is to train qualified biomedical engineers for the project and team development and health systems and medical instrumentation technology support positions in hospitals, health industry and research centers.

- Master's Degree in Biomedical Engineering from the University of the Basque Country (UPV)

In this master is to bring technology and instrumentation studies biomedical graduates from different fields of both engineering and biomedicine for the management, evaluation and implementation of health technology in the field of health. It has a strong supranational vocation, where Spanish and Paraguayan experience in the field of Biomedical Engineering is conjugated to offer graduate interested in this comprehensive training, and especially competitive globalized. The course is structured in three parts: one theory that is taught completely on-line (40 ECTS credits), one Practicum in Technology companies (6 ECTS) and a Master's Thesis (14 ECTS credits) that is defended in person. It involved 70 teachers from four universities (19 university departments), the Basque Health Service / Osakidetza and two technology parks.

- Masters in Biomedical Engineering from the UPC-Technical School of Industrial Engineering of Barcelona
This Master offers technical training and practical scientific and technological, as appropriate to the basic disciplines of medicine, that develops professionally in the field of industry, health, research, development and innovation.

This biomedical engineering course is offered in a blended way, in Barcelona, and has a total duration of 3000 hours. It is aimed at professionals in biology, pharmacy, physics, medicine, chemistry and engineering. Its main objective is to give the student a scientific and technically training to be able to work in industry, health care and research. The curriculum consists of courses such as biomedical instrumentation, biomechanics, hospital engineering, among others.

Students must take during the first semester 20 ECTS equalization (biomedical or technical aspects) according to their degree of origin. Among the rest of the first semester and the second semester students take compulsory courses totalling 40 ECTS. In the third semester students choose between three specialties (Medical Technology, Clinical Engineering and Research). Between the third and fourth quarter are required to take six electives (30 ECTS) and the End of Studies Project (30 ECTS).

- Degree in Biomedical Engineering from the Universidad Europea de Madrid

The title of Biomedical Engineering, UEM combines engineering and the world of Medicine and Health. The studies last for four years with 240 ECTS and is taught 100% in English. The mode of study is in person, although it is possible to conduct 20 courses 100% online. Training is completed with a stay in the specialties of International Business Management, Medical Informatics and Electro, which also includes work experience in a European country. Students specializing in biotechnology can do all your training if desired, in Madrid.

Appendix 1 presents a list with web-based learning providers in medical and biomedical engineering education in Spain.

E-learning in biomedical engineering education (in Greece)

A main instrument for the development and implementation of e-learning at Greek Universities is offered by the non-profit civil company called "ACADEMIC NETWORK" (GUnet: http://www.gunet.gr/index_en.php) which was founded in September 12th 2000. GUnet members are all the Higher Education and Academic Institutions (20 Universities and 16 TEI) in Greece. GUnet offers to interested institutions the e-Class (http://eclass.gunet.gr) course management platform which can host for free courses developed by the teaching staff of Greek universities. Currently there are 270 courses on offer in 10 different topics. Most of them are open to anonymous users to browse and only a few are for registered users. The
general picture of the open courses is that (at least for most of them) they are at an experimental stage and they do not really offer any e-learning service to their prospective users. In some of them the tutors appear to use the functionalities of the platform to deliver and receive course documents and assignments.

GUnet also offers a variety of support services to interested members of the academic community. For example GUnet has its own teleconferencing room and can contribute to the coordination and support of teleconferences through the network of teleconferencing and multimedia centres of the universities across Greece. GUnet also offers digitization services, and technical advice on various issues related to implementations of ICT in higher education. GUnet is also involved in the “e-University” pilot action with the participation of the University of the Aegean and the University of Crete. This project among others aims at the development of the U-Portal, an on-line environment with e-learning management functionalities. The proposed portal is aiming to become a widely adopted solution that will replace existing portals or static web sites of individual universities. The rationale is that the different universities will be served best if they adopt a common policy regarding on-line information and administration services offered to the public and as a consequence a common platform that will ensure conformity to the same standards.

Another project that GUnet is involved in is the “Advanced Telematics Services for the Institutions of GUnet” which is constituted of three axes of actions:

- The coordinated development of advanced telematics services (services of catalogue, security, voice-over-IP), directly exploitable by the academic community.
- The development of digital content with accent on the Information and Communication Technologies, aiming at the appointment and exploitation of the activities and content of the Greek Academic Institutions.
- The development of synchronous and asynchronous tele-education services and the implementation of projects for the acquisition of know-how in the new technologies of telematics and networks by the members of the Network Operations Centers (NOC).

This project is complementary to the actions of measure 3.3 of the Operational Program "Information Society", supporting the encouragement of organization and production of innovative products and processes, particularly in the sector of new technologies and e-learning.

Based upon the afore mentioned technological support along with current state-of-the-art web technologies, a set of e-learning exemplars are given in the following that relate to medical and biomedical engineering education that partially or fully rely on e-learning.
**Case A: Postgraduate medical education**

This is a case from a course on Medical Informatics taught at a postgraduate level at the Medical school of Democritus University of Thrace in Alexandroupolis. Emphasis is placed not only in creating and promoting information, but also how to best utilise Web 2.0 as an active support mechanism towards a problem (or case) based learning. In this approach, students and instructors use the web as a virtual place to collaborate and create new knowledge and new educational experiences. Three web 2.0 applications are utilized, namely, discussion forums, collaborative wikis, and blogs. Forums were used in addition to the wiki and several (topic/tag marked) personal blogs within a specific problem related to Electronic Health Records. Every student had to complete each task in their own personal blogs and when they felt the answer was complete, they had to publish it to the wiki. All students were able to see each other’s blogs and comment in there. In this way, these tools are not utilized to create, store and provide information, but as active tools to support problem based learning (PBL) in medicine.

The approach is summarized as follows. Instructors collaboratively develop a problem in the wiki. Discussion is initiated via the problem’s discussion forum, where students and instructors collaborate to analyse the problem, identify conquered knowledge and argue about possible solutions. Then students search and collaborate to solve the case. Student progress and gained experience and competences are recorded, shared and commended on via their personal blogs, while updates of the collaborative class wiki with “each student’s final solution” presumably enhance the problem solving capacity and skill acquisition of the students even further.

**Case B: Continuing Medical Education & Professional Development**

New ideas and tools have also been exploited to enhance Continuing Medical Education (CME) and professional development. In this case an e-learning environment may consist of links to evidence by use of mashup technologies and interlinked content web sites/portals. However, this by itself is a mere advanced compilation of conventional Web functionality, while it fails to exploit the full potential of Web 2.0, and in particular dynamic collaborative content development by a number of distributed contributors and/or educators. A wiki or a blog here may function as medical case repositories. The cases may be initialized by one or more experts but may be continued, updated, corrected, enriched and argued by the same or other experts in an effort to collaboratively seek for the best possible prognosis or diagnosis, treatment plan, or follow up guidelines. Such an effort, taken from a smoking cessation network developed at the Medical School of the Aristotle University of Thessaloniki, Greece. A blog dedicated to a relevant case repository together with a collaborative wiki for defining relevant medical terms, pharmaceuticals, epidemiology techniques etc, accounts for the
aforementioned collaborative content development for this specific online learning community.

Overall, many university departments, research institutes such as FORTH and academic researchers are involved in e-learning projects at national and EU levels. However, these are r&d activities and the implementation of e-learning activities remain on a pilot stage. The most widespread use of ICT for teaching/learning purposes is taking place in computer laboratories of the universities and tertiary technical education institutes, in courses that typically require practice with desktop applications and professional software (data analysis software for example). Learning materials that are uploaded on the university web portals are in most of the cases digitised versions of texts that are also distributed to the students in paper. The “e-content” developers are usually the tutors of the courses.

Last but not least, the General Secretariat for Research and Technology (GSRT) has been directed towards funding national projects related to professional training via e-learning. Among them, a relevant to health professionals’ programme is ‘VRES - Virtual environment for training and certification of clinical skills’.

**Web-based learning providers in medical and biomedical engineering education (in Greece)**

<table>
<thead>
<tr>
<th>DEGREE</th>
<th>UNIVERSITY</th>
<th>TYPE</th>
<th>DEGREE TYPE</th>
<th>CENTER</th>
<th>CITY</th>
</tr>
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<tbody>
<tr>
<td>Degree in Medicine</td>
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<td>Public</td>
<td>Official</td>
<td>Faculty of Medicine</td>
<td>Alexandroupolis</td>
</tr>
<tr>
<td>Degree in Biomedical Engineering</td>
<td>University of Patras</td>
<td>Public</td>
<td>Official</td>
<td>Faculty of Medicine</td>
<td>Patras</td>
</tr>
<tr>
<td>Degree in Biomedical Engineering</td>
<td>Aristotle University of Thessaloniki</td>
<td>Public</td>
<td>Official</td>
<td>Faculty of Medicine</td>
<td>Thessaloniki</td>
</tr>
</tbody>
</table>

**5.2. European Projects in Biomedical Engineering Education**

**BIOAPP (Biodesign for health) - Teach students in biomedical engineering to innovate**
Website: [http://www.bioapp.eu](http://www.bioapp.eu)
Duration: 2 years (Nov. 2011 – Oct 2013)
Program: FP7 Lifelong Learning Programme, ERASMUS Multilateral Projects

Consortium:
• University College Cork (UCC), Department of Electronic Engineering and School of Medicine, Ireland (coordinator)
• Open Universiteit Nederland (OUNL), CELSTEC, Heerlen, Netherlands
• Katholieke Universiteit Leuven (KU - Leuven), School of Engineering, Leuven, Belgium
• Semmelweis University (SEM), First Department of Paediatrics, Budapest, Hungary
• Open Innovation Partners Ltd (OIP), Cork, Ireland
• Newsweaver, Cork, Ireland

BioApp is a novel educational module which offers practical, interdisciplinary and effective learning opportunities to undergraduate engineering and medical third level students across Europe. The aim of the BioApp module is to improve health by leading the development, and accelerating the application of biomedical technologies. Engineering and medical undergraduate students are taught biomedical device design-targeted knowledge and problem-solving skills, and participate in team-based projects that prepare them for today’s multidisciplinary work environment. In addition to the technical aspects of design and engineering, the module includes discussion and direct experience of the clinical environment via clinical immersion, discussion of user needs, as well as the integration of these factors in design planning.

The main objectives of the project are:

- To enable students to conduct interdisciplinary analysis of a real-world clinical problem in an open-learning environment using a problem-based learning approach – this integrative approach helps students to engage in perspective taking, perceive connections between medicine and engineering, integrate knowledge and modes of thinking drawn from both, and produce an interdisciplinary understanding of a complex problem.
- Enhance co-operation in a multidisciplinary team activity by provision of a clinical immersion experience for students, as well as mentored learning.
- Development of an innovation plan for a well-defined biomedical engineering problem, involving development of design skills within the constraints of technical design and clinical utility.
- Participation in a conceptual design process using a structured innovation tool.
- Improvement of non-specific domain competencies in the areas of team learning, leadership skills, presentation, communication and written skills and project management.

CRH-BME – Curricula Reformation and Harmonisation in the field of Biomedical Engineering
Website: http://www.crhbme.uptaras.gr
Program: Joint Project within the TEMPUS IV program (95% financed by the Commission of the European Communities)
Duration: 2009-2012

Consortium - 17 institutions from EU and 6 institutions from Partner Countries

- University of Patras, Greece (coordinator)
- Vrije Universiteit Brussel, Belgium
- Technical University of Varna, Bulgaria
- Masaryk University in Brno, Czech Republic
- Tallinn University of Technology, Estonia
- University of Oulu, Finland
- Institute of Biomedical Technology, Greece
- Technical University of Crete, Greece
- Budapest University of Technology and Economics, Hungary
- University of Bologna, Italy
- University of Naples – Federico II, Italy
- Riga Technical University, Latvia
- West Pomeranian University of Technology, Poland
- University “POLITEHNICA” of Bucharest, Romania
- University of Ljubljana, Slovenia
- Universidad Politécnica de Madrid, Spain
- Karolinska University Hospital, Sweden
- University of Zagreb, Croatia
- Faculty of Electrical Engineering, Serbia
- Orbeli Institute of Physiology, Armenia
- Khazar University, Azerbaijan
- Georgia Technical University, Georgia
- The Hebrew University of Jerusalem, Israel

The main objective is to update existing curricula in the field of Biomedical Engineering in order to meet recent and future developments in the area, address new emerging interdisciplinary domains that appear as a result of the R&D progress and respond to the Biomedical Engineering job market demands. The generic Biomedical Engineering programs will assist participating Institutions to restructure their existing programs in full compliance with the Bologna Declaration and the ECTS and especially those that are in their initial stage of their educational system reform. This main objective will be reached by: i) extensive review of the curricula in the countries of consortium members in the field of BME education; ii) investigation of the current and future demands in the medical device industry market; iii) preparation of a generic program on graduate and postgraduate education in BME, with core and elective courses. The new programs will focus on present and forecasted need for competencies and skills of biomedical engineers based on job requirements. Additionally, an
analysis of the relationships between competence, learning outcomes and credits will be performed in order to propose the most efficient ways to reach the goals.

Other objectives that will be addressed by the project are: i) Promotion of the development of new study programs in partners countries; ii) Investigation of the possibilities and support in the establishment of joint degrees; iii) Provision of a template guidance document for Quality Assurance (QA), to be used for implementation in the field of BME education; iv) Promotion of international exchange of teachers and of mobility of students; v) Creation of links with the medical device industry in Europe; vi) Recreation of the TEMPERE thematic network and its enlargement.

The target groups of the project consist of undergraduate and postgraduate students and academic staff from all participating Institutions. Administrative staff will be involved in the management and planning of the activities, as well as in the quality control of the project. Academic staff and students will be exchanged during the second and the third project years through the respective mobility programs. The teaching exchange staff scheme is: one academic staff from each EU Institution to visit for one week one selected Institution from Partner countries; two academic staff members from each Partner country Institution to visit for two weeks one participating EU Institution. The adopted scheme for student mobility is: one student from each Partner country Institution to be trained at an EU Institution for three months during the third project year. The project is not aiming to develop new teaching methodology or teaching material. However, the design of the generic programs that will come out will take into account new trends in teaching (use of open and distance learning, and modern technologies such as ICT, computer simulation, Internet, information from web, mobile computing environment, computer networks).

OSTEOform (E-learning tool about surgical fracture management for orthopedic surgeons and biomedical engineers)
Website: http://www.osteoform.org
Duration: 2 years (Nov 2009 – Oct. 2011)
Program: Leonardo da Vinci Multilateral Projects ‘Transfer of Innovation’
Project Consortium:
- IBV (Biomechanics Institute of Valencia, Spain) (coordinator)
- Maurice E. Müller Foundation, Spain
- CFP (organism in charge of the organization and coordination of the postgraduate courses in the Universidad Politécnica de Valencia), Spain
- BGU Murnau, Germany
- Komag, Poland
- Adapting, Spain
The project provides an e-learning platform that offers its users training courses specialized in the field of bone fractures and osteosynthesis, as well as permanent access to practical modules that allow students to improve their knowledge. This initiative is focused on long bones fracture, and their diagnosis and treatment, including implants used in their restoration.

OSTEOform contents integrate advanced knowledge in the Medicine and Biomedical Engineering fields, mainly addressed to:

- Orthopedic surgery departments of Schools of Medicine.
- Departments of biomedical engineering in technical universities and postgraduate degrees in biomedical engineering.
- Public hospitals with doctors in training.
- Public or private hospitals with doctors who want to extend or renew their knowledge on new technologies linked to spine surgery.
- R+D and sales departments of orthopaedic implant manufacturers that want to offer continued training to their employees.

The system offers:

- Specialized training courses.
- A database of anonymized clinical cases that is continuously updated with presurgical and postsurgical patient information.
- A virtual community of skilled professionals (discussion boards, chats, faqs, blogs, etc).
- A news service and an associated newsletter.
- Usage of the simulation services with generic implants.
- A tool to practice bone fracture diagnosis.

**orthoTRAINING (E-learning tool about spine surgical techniques for orthopedic surgeons and biomedical engineers)**

Website: [http://www.orthotrain.com](http://www.orthotrain.com)

Duration: 2 years (Nov 2009 – Oct. 2011)

Program: Leonardo da Vinci Multilateral Projects ‘Transfer of Innovation’

Consortium:

- Instituto de Biomecánica de Valencia (IBV), Spain (coordinator)
- Adapting, S.L. Software consultancy and advanced web development company, Valencia, Spain
- Laboratoire de BioMécanique (LBM) / SERAM, Paris, France
- BGU Murnau und PMU Salzburg, Bavaria Germany
- Sociedad de Traumatología y Ortopedia de la Comunidad Valenciana (SOTOCAV), Surgeon’s regional society, Valencia, Spain
Universidad Politécnica de Valencia (UPV) - Centro de Formación de Posgrado. Postgraduate Learning Centre of the Polytechnical University, Valencia, Spain

orthoTRAINING was aimed at providing a new educational service for the orthoSIM platform (the European Simulation Service Provider for Orthopaedic Surgery). The objective of this project was to ensure access to a continued learning in the fields of Orthopaedic Spine Surgery and spine biomechanics for surgeons and engineers who focus their attention to the design of implants for surgery. Training contents are based upon teaching of some aspects related to medicine and engineering disciplines. These contents are undertaken to give a larger comprehension of surgical techniques linked to spine pathologies which are related to implant use. Also, these modules give information about the biomechanical response to a specific treatment.

Training material is placed on a telematic learning campus which comprises both theoretical modules about medicine and biomechanics, and practice contents for the students to make exercises to secure their learning. Theory documentation consisted in transferring previous training material that is already developed by the consortium partners and transforms it into a digital application which will be accessible to any European student. Preparation of practice documentation consisted in transforming the results of the orthoSIM platform, together with clinical cases obtained by the clinical teams within the consortium, into a practical and comprehensive training tool.

Virtual Physiological Human Network of Excellence
Website: http://www.vph-noe.eu/
Program: FP7-ICT-2007
Core members:
- University College London, UK
- University of Oxford, UK
- CNRS, France
- Universite Libre de Bruxelles, Belgium
- The French National Institute for Research in Computer Science and Control (INRIA), France
- University of Nottingham, UK
- University Pompeu Fabra, Spain
- University of Auckland, New Zealand
- European Molecular Biology Laboratory, Germany
- University of Sheffield, UK
- Karolinska Institutet, Sweden
The project aims to support and progress European research in biomedical modeling and simulation of the human body. This will improve our ability to predict, diagnose and treat disease, and have a dramatic impact on the future of healthcare, the pharmaceutical and medical device industries. Its aims range from the development of a VPH ToolKit and associated infrastructural resources, through integration of models and data across the various relevant levels of physiological structure and functional organisation, to VPH community building and support. The VPH NoE aims to foster the development of new and sustainable educational, training and career structures for those involved in VPH related science, technology and medicine.

In this context, a **Multi-Institutional Graduate Programme for Virtual Physiological Human Scientists (VPH-MIP)** was proposed. The project was funded under the Lifelong Learning Programme, Curriculum Development, and started in October 2010 (to be completed in December 2012). Its aim is to develop a framework for VPH graduate programmes, focusing on the essential characteristics of the discipline, such as heterogeneous data fusion, multi-scale and multi-physics modelling of physiopathology, and simulation of complex clinical work-flows. The main objectives of this project are to:

- Identify VPH-relevant modules offered in graduate programmes within participating institutions, and develop alignments to enable students at one institution to take related but complementary modules at a second institution.
- Design extensibility principles by which additional institutions could participate in this programme in the future, considering complementarily to partners, and ensuring mobility of students and staff.
- Identify gaps in current provision and develop exemplar VPH Core Modules as on-line resources that can be followed by all students participating in the programme, and which will become the backbone of training in this field.
- Do so in a manner that is compatible with educational systems throughout the EU.
- Address legal, administrative, and political issues required to facilitate mobility.

**On-Line Ortho - On-line Performance Support Environment for Minimally Invasive Orthopaedic Surgery**

Website: [http://onlineortho.dipsei.net/](http://onlineortho.dipsei.net/)
Program: Leonardo da Vinci ‘Transfer of Innovation’
Duration: 2 years (Oct. 2008 – Sep. 2010)
Consortium:

- ECIT, Plovdiv University, Bulgaria (coordinator)
- Department of Orthopaedics & Traumatology, Medical University Plovdiv, Bulgaria
- Department of Orthopaedics, “VITA” Hospital, Bulgaria
- MAHSHO Ltd., Bulgaria
- Department of Computer Science, Unit of Medical Technology and Intelligent Information Systems,
- University of Ioannina, Greece
- Institute of Biomedical Research & Technology (BIOMED), Greece
- Department of Anaesthesia & Intensive Care Medicine, HSE Cork University Hospital, Wilton, Cork, Ireland

This project focused on transfer of innovative training approach and courses developed within the Leonardo da Vinci project for training and disseminating modern aspects of computer assisted surgery in the public health care sector. Its aim was to meet the training requirements of medical staff which have arisen due to developments in biomedical engineering and information and communications technology. In particular, new developments in applications ranging from image processing to robotics lead to new approaches to diagnosis (image processing and analysis) and minimally invasive surgery (arthroscopy). To this end, the project set up an integrated system for the dissemination of innovative techniques and training. A set of training courses developed by the Greek partners within the EPICUROS project for new technologies in minimally invasive surgery was transferred and adapted to the new user needs, structured in a web-database and a communications network for video conferencing and live distance training on new procedures and operations. Through the system, training in new approaches, practices and techniques in the biomedical engineering field was provided to doctors, medical staff and technicians. It provided the users (orthopaedists, surgeons and anaesthetists) with instant and on-site access (at hospitals, clinics) to information about the techniques and methods used in diagnosis and computer assisted surgeries.

**European Virtual Campus for Biomedical Engineering (EVICAB)**

Website: [http://www.evicab.eu/](http://www.evicab.eu/)

Duration: 2 years (1.1.2006 till 31.12.2007)

The project was funded by the European Commission under the program Education and Training.

Partners:

- Mediamasteri Group (coordinator)
- Tallinn University of Technology (Biomedical Engineering Centre)
- Kaunas University of Technology (Biomedical Engineering Institute)
- Linköping University (Department of Biomedical Engineering)
- Brno University of Technology (Department of Biomedical Engineering)

EVICAB was aimed at providing a virtual university platform for a biomedical engineering program. Both the partner universities as well as other cooperating universities outside the consortium offer BME courses to EVICAB. The courses must be recognized by at least one university to be used in Bachelor/Master/PhD studies. Once the courses are accepted by the EVICAB Steering Group, any university from or outside the curriculum can use them.

**BIOMEDEA (Biomedical and Clinical Engineering Education, Accreditation, Training and Certification. Medical/Biological/Clinical Engineering Providing a Safe Health Care Environment)**
Website: [http://www.biomedea.org](http://www.biomedea.org)

The objective of BIOMEDEA, launched in 2004, was to develop and establish consensus on criteria, guidelines and protocols for the harmonization and accreditation of high quality Medical and Biological Engineering and Science programs, and for the training, certification and continuing education of professionals working in the health care systems with the goal to insure mobility in education and employment as well as the highest standards for patient safety. BIOMEDEA was a mainly European project in which more than 60 universities and other academic institutions participated. The initiative, with the University of Stuttgart as the lead institution, was supported by the International Federation for Medical and Biological Engineering (IFMBE) and the European Alliance for Medical and Biological Engineering. It closely cooperated with the World Health Organization.

There has been general acceptance of the BIOMEDEA guidelines for BME programs, their accreditation and the training as well as continuing education of clinical engineers even beyond Europe. The resulting documents were:

- Criteria for the Accreditation of Biomedical Engineering Programs in Europe
- Criteria for the Training of Clinical Engineers in Europe
- Protocol for the Certification of Clinical Engineers in Europe
- Protocol for Continuing Education of Clinical Engineers in Europe
- Protocol for an Internationally Recognized CE Certification System and Register

### 5.3. Project-Based Learning in BME Education

Project-based learning (PBL) is a student-centered instructional approach, in which learning is organized around projects. These projects involve complex, challenging and authentic tasks, on which students work relatively autonomously (with the teacher playing the role of
facilitator) and over extended periods of time. The students collaborate in various design, problem-solving, decision making and investigative activities, the final goal being a realistic product or presentation [42, 56].

Thomas [45] identified five characteristics which define PBL and make it different from other models that involve projects:
1. Projects are central, not peripheral to the curriculum (the project does not serve to provide examples, practical applications or extensions of concepts previously taught by other means; instead, students learn the main concepts of the curriculum via the project)
2. Projects are focused on questions or problems that drive students to encounter (and struggle with) the central concepts and principles of a discipline (the “driving question” should ”be crafted in order to make a connection between activities and the underlying conceptual knowledge that one might hope to foster” [30])
3. Projects involve students in a constructive investigation (the project activities should involve construction of knowledge, new understandings and new skills by the students, not simply an application of already-learned information or skills)
4. Projects are student-driven to some significant degree (projects are not scripted by the teacher, do not take predetermined paths and do not have predetermined outcomes; students have more autonomy and responsibility towards their own learning)
5. Projects are realistic, not school-like (projects are authentic, real-life challenges in terms of topic, tasks, student roles, context of work, artifacts, final product, evaluation criteria).

Thomas [45] presents a comprehensive review of studies on PBL, categorized according to their research goal: i) evaluating the effectiveness of PBL; ii) describing the implementation process and the associated challenges; iii) assessing the role of individual student differences in PBL; iv) improving the efficiency of PBL by various interventions. Based on all these studies, PBL appears as a popular, beneficial and effective instructional method, enhancing the quality of students’ learning (who are more capable of applying the knowledge in novel contexts), as well as their planning, communicating, problem solving, and decision making skills. Some drawbacks are also acknowledged: students may have difficulties in self-directed situations (e.g., initiating inquiry, directing investigations, managing time), especially in complex projects, so providing support to students in “learning how to learn” is essential [45].

PBL has its roots in constructivism, constructionism, cooperative and collaborative learning, active learning, expeditionary learning, as well as situated cognition [45, 56]. PBL is also closely related to problem-based learning and the line between them is frequently blurred; however, they are not identical: PBL focuses on the end-product and on the skills acquired during the production process, while problem-based learning has as goal finding the solution to the ill-defined problem and usually includes a tutorial ingredient (students are guided by a
facilitator who plays the role of a coach). However, they are both led by the following constructivist principles: i) understanding is an individual construction and comes from our interactions with the environment; ii) learning is driven by cognitive conflict or puzzlement; iii) knowledge evolves through social negotiation [43].

PBL is widely used in BME education, with several papers reporting successful experiences in recent years, e.g.:

- Krishnan [39] presents a PBL scenario with international collaboration for training biomedical engineers. Despite the difficulties encountered with the formation of a collaborative team with international partners, the collaborative project greatly enhanced the student learning outcomes. Results showed an enhancement in long term retention of multidisciplinary material and high-order cognitive activities such as analysis, synthesis and evaluation. Furthermore, the project promoted the development of professional contracts and global networking. The author concludes that, despite the initial challenges, a PBL scenario with international collaboration has strong potentials to be valuable in the training of biomedical engineering students [39].

- Gambi and Peme [35] investigate the application of PBL on the subject Hospital Facilities, by means of three intervention projects developed in health centers. The following issues are analyzed: a) context knowledge (the complex health system where biomedical engineers will develop their profession); b) team work (essential for a highly interdisciplinary field); c) regulations (awareness and application thereof); d) project evaluation (analyzing the contribution of PBL to the actual training of the biomedical engineers).

- Smeesters [44] describe a successful PBL course which includes 8 bioengineering units, composed of 3 core competences: i) human anatomy and physiology (knowledge); ii) bioengineering modeling (skill); iii) bioengineering instrumentation (skill). These are integrated together through a 4th “design (skill), integration (skill) and communication (attitude)” competence by means of a common clinical, research or development problem. Each unit is taught by a team of 3 professors and it includes demonstrations, laboratories and/or hospital visits, on top of selected readings from textbooks and/or journal articles. This PBL scenario led to decreased dropout rates, improved anatomy grades, as well as the possibility to use integration problems and exam questions.

5.4. Overview of Bodies, Publications and Conferences in Biomedical Engineering

**Relevant Bodies in BME**

IEEE Engineering in Medicine and Biology Society (EMBS) is the world's largest international society of biomedical engineers. The organization's 9,100 members reside in
some 97 countries around the world. EMBS provides its members with access to the people, practices, information, ideas and opinions that are shaping one of the fastest growing fields in science.

Website: http://www.embs.org

The International Federation for Medical and Biological Engineering (IFMBE) is primarily a federation of national and transnational societies. These professional organizations represent interests in medical and biological engineering. The IFMBE is also a Non-Governmental Organization (NGO) for the United Nations and the World Health Organization (WHO), where we are uniquely positioned to influence the delivery of health care to the world through Biomedical and Clinical Engineering. The IFMBE’s objectives are scientific and technological as well as educational and literary. Within the field of medical, biological and clinical engineering IFMBE's aims are to encourage research and application of knowledge, and to disseminate information and promote collaboration. The IFMBE joins the International Organization for Medical Physicists (IOMP) in a Union called the International Union for Physical and Engineering Sciences in Medicine (IUPESM).

Website: http://www.ifmbe.org/

European Alliance for Medical and Biological Engineering & Science (EAMBES) is a no-profit international organization incorporated according to the Belgian law, that federates most scientific societies and academic and research institutions located in Europe and involved with Biomedical Engineering or as it is more appropriately defined Medical and Biological Engineering and Science. The main objective of EAMBES is to improve the health, wealth, and well being of the citizens of Europe by the application of Medical and Biological Engineering and Science. EAMBES today represents 24 national and 5 transnational scientific societies, as well as 26 academic and research institutions; through its member organisations, approximately 8000 European experts in the domain of Medical and Biological Engineering and Science (MBES).

Website: http://www.eambes.org/

Relevant Publications in BME

- BioMedical Engineering OnLine (http://www.biomedical-engineering-online.com/about)

- Medical & Biological Engineering & Computing (MBEC), Springer (http://www.springer.com/biomed/human+physiology/journal/11517)
**Relevant Conferences in BME**

- Mediterranean Conference on Medical and Biological Engineering and Computing (MEDICON) - [www.aiimb.it/medicon-conferences.html](http://www.aiimb.it/medicon-conferences.html)
- International Symposium on Biomedical Engineering and Medical Physics - [http://www.bini.rtu.lv/isbemp/index.html](http://www.bini.rtu.lv/isbemp/index.html)
- IEEE-EMBS- International Conference on Biomedical Engineering and Sciences (IECBES) - [http://myembs.org/index2.php/iecbes2012/index](http://myembs.org/index2.php/iecbes2012/index)
- Nordic-Baltic Conference on Biomedical Engineering and Medical Physics - [http://www.dmts.dk/nbc15/](http://www.dmts.dk/nbc15/)

**6. Conclusions**

**Biomedical Engineering** (BME) and **Bioengineering** are modern and interdisciplinary fields, which consist of a broad array of sub-areas. A lot of impact sub-areas can be enumerated in order to emphasize the nowadays importance of these engineering branches: Biomedical Electronics; Biomechatronics; Biomaterials; Biomechanics; Bionics; Cellular, Tissue, and Genetic Engineering; Clinical Engineering; Medical Imaging; Orthopedic Bioengineering; Rehabilitation engineering; Neural Engineering and so on. The applications of these areas contribute to the huge improvement of healthcare diagnosis, monitoring and therapy.

However, there is a differentiation between **Bioengineering** and **Biomedical engineering**, even if many universities now use the terms "bioengineering" and "biomedical engineering" interchangeably. Biomedical engineers are specifically focused on applying biological and
other sciences toward medical innovations, whereas bioengineers are focused principally on applying biology - but not necessarily to medical uses.

Taking into consideration the above mentioned importance of BME, it is of great interest the development of proper education systems and procedures in this field. Education in BME varies greatly around the world. Biomedical engineers and bioengineers require significant knowledge of both engineering and biology, and typically have a Master's or a Doctoral degree in BME. As interest in BME increases, many engineering schools in Europe now have a Biomedical Engineering Department or Program, with offerings ranging from the undergraduate to doctoral levels. The BME programs at all levels are becoming more widespread, including the Bachelor of Science in Biomedical Engineering. The number of biomedical engineers is expected to rise as both a cause and effect of improvements in medical technology.

The BME education in Spain, Greece and Romania has some common characteristics: it is organised for all levels of academic education (undergraduate, graduate Master’s level and PhD level), similar standards and professional competences for BME education are developed in all these countries, and incipient e-learning systems for BME education are implemented. However, there are also some differences, which are related mainly to the economic level of these countries and to the degree of cooperation between academia and hospitals.

Since most BME-related professions involve scientific research, such as in pharmaceutical and medical device development, graduate education is almost a requirement (as undergraduate degrees typically do not involve sufficient research training and experience). This can be either a Masters or Doctoral level degree; while in certain specialties a Ph.D. is notably more common than in others, it is hardly ever the majority (except in academia). In fact, the perceived need for some kind of graduate credential is so strong that some undergraduate BME programs will actively discourage students from majoring in BME without an expressed intention to also obtain a masters degree or apply to medical school afterwards.

Graduate programs in BME, like in other scientific fields, are highly varied, and particular programs may emphasize certain aspects within the field. They may also feature extensive collaborative efforts with programs in other fields, owing again to the interdisciplinary nature of BME.

The rapid developments in the last years not only require a well-prepared work force but also rapidly adapting training programs. In this case, distance learning is a viable alternative, motivating the development of a number of web-based learning environments. In this context
there is also an increased need for e-learning methods, tools and platforms to be used in biomedical engineering education. This is also reflected in the number of European projects launched on this subject in the past few years.

As it is mentioned in numerous studies concerning BME education, the implementation of e-learning systems and platforms seems to be a promising and modern method which can lead to the improvement of training for biomedical engineers.

“Continuing professional development” is an important concept for all professions. Very fast developments of the society and technology require professionals connected to the latest findings that may carry out properly work.

Today's society is subject to various social and economical changes, referred to as "mega trends". These describe phenomena such as globalization, internationalization and furthermore the change to a knowledge and information based society. The social, technological and economical changes as well as the continuously changing demands of the market make it necessary for individuals to continuously develop and improve their competences. Learning can be seen as an investment into the future. Moreover, learning in times of dynamic change calls for methods which teach large audiences up-to-date topics in a cost efficient way. E-learning solutions are perceived as a possibility to increase the quality of education for orthopedists and bioengineers.

The rate of success in professional work is directly proportional to the amount of experience. This principle is directly applied to all fields, for engineering and medicine too. In orthopedics, diagnosis and treatment depend of the clinical accumulated experience, and intensive training with new technologies is required. Probably the fastest changes appear in engineering, which is facing a challenge by development of the new multidisciplinary fields. One of them is biomedical engineering. We can speak of a real clinical engineering, as a branch of biomedical engineering dealing with the actual implementation of medical equipments in hospitals or other clinical settings, especially in the orthopedic field.

For this reason we need to form specialists with specific expertise related to the assessment, correction or replacement of functions that affect motility. This can be achieved only by understanding the basic concepts, technological principles and their interdisciplinary application. The ability to make measurements and interpret data from motion analysis through bioengineering techniques should be associated with the ability to identify, formulate and solve problems faced by patients and determining the most appropriate treatment.
Due to the new technologies and technical devices the role of a biomedical engineer increased. The biomedical engineers advise and assist in the application of instrumentation in clinical environments; evaluate the safety, efficiency, and effectiveness of biomedical equipment; ensure that all medical equipment is properly maintained; install, adjust, maintain, and/or repair biomedical equipment; adapt or design computer hardware or software for medical science uses and so on.

The integration of e-learning into medical/bioengineering education can catalyze the shift toward applying adult learning theory, where educators will no longer serve mainly as the distributors of content, but will become more involved as facilitators of learning and assessors of competency.
Appendix 1.

A list with web-based learning providers in medical and biomedical engineering education in Spain

<table>
<thead>
<tr>
<th>DEGREE</th>
<th>UNIVERSITY</th>
<th>TYPE</th>
<th>CENTER</th>
<th>CITY</th>
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<tbody>
<tr>
<td>Degree in Biomedical Engineering</td>
<td>University of Barcelona</td>
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<tr>
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<td>Polytechnic University of Valencia</td>
<td>Public</td>
<td>official degree</td>
<td>Superior Technical Faculty of Industrial Engineering</td>
</tr>
</tbody>
</table>

Other centers:
- IUSE / Barcelona Business School. Private University in English
- Fundació UPC Barcelona. Affiliated University Centre, trilingual (Spanish - Catalan - English)
- Universidad Alfonso X El Sabio. Private University in Spanish
- University of the Basque Country, Bilbao. Public University, bilingual (Spanish - Basque)
- Autonomous University of Barcelona. Spanish Public University
- Technical University of Catalonia. Public University. Bilingual (Spanish - Catalan). Research Center for Biomedical Engineering at Polytechnic University of Catalonia
- University of Zaragoza (UNIZAR). Public University. English.
Appendix 2. Medical engineering (qualification) in Romania [29]

<table>
<thead>
<tr>
<th>Qualification title and name</th>
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<tbody>
<tr>
<td>Graduation title</td>
<td>Engineer</td>
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<tr>
<td>Qualification name</td>
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<td>Qualification code</td>
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<td>Contact person</td>
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<td>Contact ACPART</td>
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Identification elements for the qualification

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<thead>
<tr>
<th>Study level:</th>
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<tbody>
<tr>
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<td>Study domain:</td>
<td>Applied engineering sciences</td>
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<tr>
<td>Study program name:</td>
<td>Medical engineering</td>
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<tr>
<td>Credits:</td>
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<tr>
<td>Study duration:</td>
<td>4 years</td>
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<tr>
<td>Prerequisites:</td>
<td></td>
</tr>
<tr>
<td>Details:</td>
<td></td>
</tr>
</tbody>
</table>

Qualification summary

Professional competences:
- Adequate utilization of theoretical fundamentals of applied engineering sciences
- Utilization of information systems for data processing and management
- Modeling of biological systems / biomechanical structures and model implementation in medical investigation
- Conception, design, execution and maintenance of medical devices
- Operating with medical devices in safety conditions for patients and medical staff
- Design and production of devices for substituting several functions / assisting persons with disabilities

Transversal competences:
- Application, with respect to legislation, of the copyrights and intellectual rights (including technological transfer), of the methodology for the certification of the products, principles, norms and values of professional ethical code within the own rigorous and efficient work strategy
- Identification of the roles and responsibilities within a team, and the application of relationships and efficient work in the frame of the team
- Identification of continuing formation opportunities and the efficient valorization of resources and learning techniques for individual development

Possible occupations for the owner of the diploma

Possible COR occupations: Clinical engineer - 221401; Medical bioengineer - 222907; commercial representative - 341502; medical representative - 341503;
New occupations not included in COR: medical engineer; research assistant in medical engineering; technical advisor in medical engineering; technological engineer in medical engineering; design engineer of medical devices

Access methods to the qualification

Related qualifications
Appendix 3. Bioengineering (qualification) in Romania [29]

<table>
<thead>
<tr>
<th>Qualification title and name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graduation title</td>
</tr>
<tr>
<td>Qualification name</td>
</tr>
<tr>
<td>Qualification code</td>
</tr>
<tr>
<td>Contact person</td>
</tr>
</tbody>
</table>

**Identification elements for the qualification**

- Study level: Bachelor
- Fundamental study domain: Engineering sciences
- Study domain: Applied engineering sciences
- Study program name: Bioengineering
- Credits: 240
- Study duration: 4 years
- Prerequisites:
- Details:

**Qualification summary**

**Professional competences:**
- Adequate utilization of theoretical fundamentals of applied engineering sciences
- Utilization of information systems for data processing and management
- Modeling of biological systems / bioengineering structures
- Conception, design, implementation and maintenance of bioengineering components or systems
- Operating with bioengineering systems in ethical conditions and work safety
- Conceiving and coordination of experiments in the field of bioengineering

**Transversal competences:**
- Application, with respect to legislation, of the copyrights and intellectual rights (including technological transfer), of the methodology for the certification of the products, principles, norms and values of professional ethical code within the own rigorous and efficient work strategy
- Identification of the roles and responsibilities within a team, and the application of relationships and efficient work in the frame of the team
- Identification of continuing formation opportunities and the efficient valorization of resources and learning techniques for individual development

**Possible occupations for the owner of the diploma**

Possible COR occupations: Clinical engineer - 221401; Medical bioengineer - 222907; Teaching advisor - 235201; Education specialist - 235204; Education trainer - 241205; Acquisition analyst / providers’ advisor - 241401; Company manager - 241939; Standardization assistant - 242313; Research assistant in physio-kineto-therapy - 255106; Prosthetic orthotics technician - 323001; Technical and commercial representative - 341501; Commercial representative - 341502; Medical representative medical - 341503; Sales agent - 341904; New occupations not included in COR:

**Access methods to the qualification**

**Related qualifications**

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.
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