The transition from Agricultural to Biosystems Engineering University Studies in Europe

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ABSTRACT

This paper describes the main result produced by the ERABEE (Education & Research in Biosystems Engineering in Europe) Thematic Network. The ERABEE Thematic Network was a follow-up of a previous Thematic Network called USAEE (University Studies of Agricultural Engineering in Europe) and both were co-financed by the European Community in the framework of the LLP Programme (Lifelong Learning Programme). The innovative and novel goal of the ERABEE Network was to promote the critical and inevitable transition from the traditional discipline of Agricultural Engineering to the emerging discipline of Biosystems Engineering, exploiting along this direction the outcomes accomplished by the earlier USAEE Thematic Network. It also aimed at enhancing the compatibility among the new programmes of Biosystems Engineering, supporting their recognition and accreditation at European and International level and facilitating greater mobility of skilled personnel, researchers and students.

Keywords: Innovation in European University Engineering Studies, Emerging Discipline of Biosystems Engineering, Agricultural Engineering.

1. INTRODUCTION

The establishment of the ERABEE Thematic Network (Education & Research in Biosystems Engineering in Europe) [1] was built-upon and further developed the outputs of a previous Thematic Network called USAEE (University Studies of Agricultural Engineering in Europe) [2] by further restructuring the Agricultural Engineering programs of studies in Europe. Both Networks were co-financed by the European Community in the framework of the LLP Programme (Lifelong Learning Programme). The ERABEE lifetime began on October 1st 2007 and ended on September 30th 2010. The partnership consisted of 35 participants from 27 Erasmus countries, out of which 33 were Higher Education Area Institutions (EDU) and 2 were Student Associations (ASS). 13 Erasmus participants (e.g. Thematic Networks, Professional Associations, and Institutions from Brazil, Croatia, Russia and Serbia) were also involved in the Thematic Network activities through synergies.

The innovative and novel goal of the Thematic Network was to promote the critical transition from the traditional discipline of Agricultural Engineering to the emerging discipline of

Biosystems Engineering, exploiting along this direction the outcomes accomplished by the USAEE Thematic Network. It also aimed at enhancing the compatibility among the new programmes of Biosystems Engineering, supporting their recognition and accreditation at European and International level and facilitating greater mobility of skilled personnel, researchers and students.

In the framework of ERABEE TN, Biosystems Engineering is understood as a field of engineering which integrates engineering science and design with applied biological, environmental and agricultural sciences. It represents an evolution of the Agricultural Engineering discipline applied to all living organisms not including biomedical applications. Therefore, Biosystems Engineering is 'the branch of engineering that applies engineering sciences to solve problems involving biological systems' [1].

The professions related to agricultural engineering have a long tradition in Europe so that all European countries have university studies related to this profession. However due to the fact that the agricultural sector has lost economic importance during the last decades these studies faced important problems such as decrease of student enrolment, reduced prestige, declining funding, etc. In response to these problems and considering the new society's needs for renewable sources of energy, bio-based industrial materials, and environmental stewardship, many engineering departments in the U.S. have been incorporating various components of biological engineering into traditional agricultural engineering programs [3].

This evolution, from the Agricultural Engineering to Biosystems Engineering, started in U.S. in the 60´s. At that time some experts began to recognize that Agricultural Engineering could perhaps be included as a sub-discipline of a broader Biological and Agricultural Engineering discipline [4]. In 1966, a bioengineering committee was formed within the ASAE (American Society of Agricultural Engineers) with the goal of advancing a more broad-based discipline of Biological Engineering [5]. In 1993 ASAE changed its name from "American Society of Agricultural Engineers" to "ASABE: The Society for the Engineering of Agriculture, Food, and Biological Systems". Along these developments many academic departments modified their names to biological engineering or similar.

Young [7] analysed data regarding undergraduate enrolment changes following the adoption of "bio"-type curricula names for traditional agricultural engineering. The data were collected in 2002. The following conclusions were made:

- The annual undergraduate enrolment increases for Biological Systems Engineering, Biological Resources Engineering, and Biological Engineering curricula were statistically significant as a result of the changes made to their name. The increases in enrolments ranged from 9.9% to 30.2 % per year;
- In general, all curricula that had "bio" only in their names had a significant enrolment increase over the traditional curricula of agricultural engineering;
- Curricula that had both "bio" and "agr" in their names did not experience significant increases in their enrolment, regardless of the ordering of the respective terms.

This change has occurred much more slowly in Europe lagging behind the corresponding developments in US, Canada and elsewhere. In 2007, when the ERABEE TN was launched, only two institutions were offering university studies in Biosystems Engineering, the University College Dublin and the Catholic University of Leuven. During the life-time of the ERABEE TN project some remarkable developments in the emerging field of Biosystems Engineering were experienced with the establishment of new programs of studies in Biosystems Engineering in Europe. The contribution of the ERABEE TN was decisive in this direction. At this moment there are ten university programs of studies in Biosystems Engineering in Europe emerged from the evolution of previous Agricultural Engineering programs of studies.

In Europe the European Society of Agricultural Engineers (EurAgEng) has not changed its name yet but has included in their objectives to promote the profession of "Biosystems Engineering" at the same level as that of the "Agricultural Engineering". In addition, the scientific journal of this Society is now called "Biosystems Engineering".

2. DEFINITION OF THE EMERGING DISCIPLINE OF BIOSYSTEMS ENGINEERING

The American Institute of Biological Engineers [6] (IBE) defines the biology-based engineering as the discipline that integrates life sciences with engineering in the advancement and application of fundamental concepts of biological systems from molecular to ecosystem levels. In the other hand, ASABE unifies the definitions of Agricultural and Biological Engineering within the following definition: "Agricultural and Biological Engineering is the discipline of engineering that applies engineering principles and the fundamental concepts of biology to agricultural and biological systems and tools, ranging in scale from molecular to ecosystem level, for the safe, efficient and environmentally-sensitive production, processing, and management of agricultural, biological, food, and natural resources systems". However, these definitions have not been broadly adopted and used yet. Scott [8] reported the following key elements with broader consensus of the Biological Engineering discipline:

- "An emerging discipline;
- Biology-based foundation;
- Fundamental concepts of biological systems;
- An appreciation of applications;
- Scale from the molecular to large system".

In an effort to coordinate the corresponding development in the US and Europe, the EU-US project POMSEBES [3] was established aimed at promoting policy oriented measures in support of the evolving Biosystems Engineering studies in USA – EU.

The ERABEE proposed that the definition of the evolving discipline of Biosystems Engineering is based on the results of the relevant systematic work carried out in the framework of the POMSEBES project. In particular:

Biosystems Engineering can be considered as the biological sciences-focused evolution of Agricultural Engineering which

applies to all living organism systems with the exception of human. It combines engineering science and design with applied biological, environmental and agricultural sciences and can be defined as "The branch of engineering that prepares students to apply engineering to solve problems involving biological systems". In the context of this evolution in the EU, Biosystems Engineering should exclude Biomedical Engineering, Bioengineering and Biotechnology. Biotechnology programs of studies do not require an Engineering background as such and so do not require an Engineering core curriculum (as Agricultural or Biosystems Engineering programs do). Biomedical Engineering on the other hand, has already been established as an independent discipline by other classical Engineering Departments in cooperation with Medical Schools. It is not considered feasible to include in one program of studies what is foreseen as Biosystems Engineering plus Biomedical Engineering or Bioengineering. Such a combination might be feasible possibly at the level of a School with several Departments, each offering an independent program of studies, one of which could be Biosystems Engineering.

An equivalent approach but more suitable to the concept of Biosystems Engineering as a discipline evolving from the evolution of the traditional discipline of Agricultural Engineering is given by the Biosystems Engineering Journal [9]: "Remit of Biosystems Engineering: research in the physical sciences and engineering to understand, model, process or enhance biological systems for sustainable developments in agriculture, food, land use and the environment".

University / Country / Language / Web site	**Department**	**Program of Studies**		
		Scope of Program	**Undergraduate Curriculum**	**Graduate Studies**
University College Dublin (Ireland) Language: English http://www.ucd.ie/	School of Agriculture, Food Science and Veterinary Medicine (Master) Engineering and Materials Science Centre (Bachelor)	Biosystems Engineering	Biosystems Engineering	Research Programme in Biosystems Engineering
Universidad de León (Leon-Spain) Language: Spanish and English http://www.unileon.es/ficheros/acceso/master/triptico_master_inv_biosistemas.pdf	Ingenieria y Ciencias Agrarias	Investigación en Ingeniería de Biosistemas (Research in Biosystems Engineering)	--------	Master Universitario de Investigación en Ingeniería de Biosistemas (Research University Master in Biosystems Engineering)
Universidad Politécnica de Cataluña (Politechnic University of Cataluña) (Spain) Language: Spanish http://www.upc.edu/aprender/estudios/ambitos/biosistemas?set_language=es	Escuela Superior de Agricultura de Barcelona (High Agricultural School of Barcelona)	Biosystems Engineering	Four bachelor degrees in the field of Biosystem Engineering	Six Masters in the field of Biosystems Engineering
Universidade de Évora (Evora- Portugal) Language: Portuguese http://www.der.uevora.pt/noticias_e_informacoes/informacoes/geral/mestrado_em_engenharia_biossistemas	Departamento de Engenharia Rural	Engenharia de Biossistemas (Biosystems Engineering)	----------	Maestrado em Engenharia de Biossistemas
University of Maribor (Slovenia) Language: Slovenian http://fk.uni-mb.si/index.php?id=29	Faculty of Agriculture and Life Sciences	Biosystems Engineering - Professional Bachelor Study	Biosystems Engineering	
Stonian University of Life Sciences (Estonia) Language: Estonian http://www.emu.ee/		Biosystems Engineering	Biosystems Engineering	
Technical University of Cluj-Napoca (Romania) Language: Romanian http://utcluj.ro/educatie/master.php	Facultatea de Mecanică (Faculty of Mechanics)	Biosystems Engineering for Agriculture and Food Industry		Master's Degree on Biosystem Engineering for Agriculture and Food Industry
Aarhus University (Denmark) Language: Danish http://mit.au.dk/coursecatalogue/index.cfm?elemid=38940&topid=38940&sem=E2010&udd=&art=&hom=		Biosystems Engineering		Master´s Degree in Biosystems Engineering
Katholieke Universiteit Leuven (Catholic University od Leuven) (Belgium-Flanders) Language: Nederlands http://onderwijsaanbod.kuleuven.be/opleidingen/n/SC_51016779.htm	Facultaire informatie-Faculteit Bio-ingenieurswetenschappen (Faculty of Bioscience Engineering)	Biosystems Engineering		Master´s Degree in Biosystems Engineering
Uludag University Language: Turkish www.uludag.edu.tr	Faculty of Agriculture	Biosystems Engineering	Biosystems Engineering	

Table 1: University Studies in Biosystems Engineering in Europe

3. EUROPEAN PROGRAMS OF STUDIES IN BIOSYSTEMS ENGINEERING

Within the works of ERABEE Thematic Network, new programs of studies in Biosystems Engineering all over the world were identified and described. ERABEE had a relevant influence in the creation of these new studies; in fact, most of the European ones were established by the partner universities of the Network. At the beginning of these works only two institutions were offering university studies in Biosystems Engineering, the University College Dublin and the Catholic University of Leuven, but at the end they were ten. These degrees are tabulated below (Table 1).

4. BIOSYSTEMS ENGINEERING ACREDITATION

During the period 2002-2006 the Thematic Network USAEE [2] was initiated with the fundamental goal of improving and harmonising the Engineering content of Agricultural/Biosystems Engineering curricula in European universities. In this line, USAEE TN developed a basic core curriculum in Agricultural and Biosystems Engineering "Core Curricula of Agricultural/Biosystems Engineering for the First Cycle Pivot Point Degrees of the Integrated M.Sc. or Long Cycle Academic Orientation" For the first time a critical mass of human resources and European Institutions/Universities offering such programs of studies has been mobilised in a systematic way, carrying out a coordinated intensive work in an effort to establish basic Agricultural Engineering core curricula to be used as benchmark and recognised/accredited at a European level.

The final version of the Core Curricula for Agricultural/Biosystems Engineering programs of studies in Europe with the corresponding learning outcomes and course descriptions was approved by the EMC (European Monitoring Committee) of FEANI [11] (European Federation of National Engineering Associations) in January 2007. This outcome not only underlines the successful and historical steps made by USAEE-TN, but it also represents a great advancement for the establishment of harmonised Core Curricula of Agricultural/Biosystems Engineering studies in Europe that may now be recognised as such at the European level by two European professional associations, FEANI and EurAgEng (European Society of Agricultural Engineers).

Based on this previous experience ERABEE members have developed accreditation criteria for the Bachelor's degree programmes in Biosystems or Agricultural and Biological Engineering. This document has been developed as a basis for the accreditation agencies and the universities' quality assessment schemes and the European Accreditation framework for engineering programs of studies EUR-ACE [12].

The core curriculum of Biosystems Engineering study programmes has been based on that elaborated in the framework of the USAEE Thematic Network enriched with new modules related to bio-energy and bio-based materials.

5. BIOSYSTEMS ENGINEERING CURRICULA

In the web site of ASABE [13] the following speciality areas for the Biological and Agricultural Engineers (BAE) can be found:

- Biological Engineering: BAEs applies engineering practice to problems and opportunities presented by living things and the natural environment.
- Natural Resources: BAEs understand the complex mechanics the resources, so that they can be used efficiently and without degradation.
- Power Systems and Machinery Design: BAEs in this specialty focus on designing advanced equipment, making it more efficient and less demanding of our natural resources.
- Structures and Environment: BAEs design animal housing, storage structures, and greenhouses. They also devise better practices and systems for storing, recovering, reusing, and transporting waste products.
- Food and Bioprocess: BAEs understand microbiological processes and use this expertise to develop useful products, to treat municipal, industrial and agricultural wastes, and to improve food safety.
- Information and Electrical Technologies: Geographic information systems, global positioning systems, machine instrumentation and controls, electromagnetics, and -"bioinfomatics"- biorobotics, machine vision, sensors, spectroscopy, etc.
- Forest Engineering: BAEs apply engineering to solve natural resource and environment problems in forest production systems and related manufacturing industries.
- Energy: BAEs are at the forefront of the effort to identify and develop viable energy sources - biomass, methane, and vegetable oil, to name a few - and to make these and other systems cleaner and more efficient
- Aquacultural Engineering: BAEs help design farm systems for raising fish and shellfish, as well as ornamental and bait fish. They also work with aquatic animal harvesting, sorting, and processing.
- Nursery & Greenhouse Engineering: nursery and greenhouse operations are similar to large-scale production agriculture, but have other engineering needs like those related to equipment for transplantation; control systems for temperature, humidity, and ventilation, plant biology issues, such as hydroponics, tissue culture, seedling propagation methods, etc.
- Safety and Health: BAEs analyze health and injury data, the use and possible misuse of machines, and equipment compliance with standards and regulation.

In Europe, the European Society of Agricultural Engineers [14] (EurAgEng) consider the following areas in the professional activity of the Agricultural/Biosystems Engineers:

- Power Systems and Machinery: Agricultural tractors, combines, implements, transportation equipment, turf and landscape equipment, equipment for special

crops, irrigation equipment, farmstead equipment and food processing equipment.

- Information and Electronics: Global positioning systems, machine instrumentation and controls, data acquisition, bioinformatics and electromagnetics.

- Safety and Ergonomics: Compile and analyse health and injury data, standardize equipment for component compatibility, encourage safe use of machinery, equipment, and materials through better design and better communication.

- Energy: Devising new ways of meeting the energy needs of agriculture and meeting the energy needs of the general population by using agricultural products and by-product (biomass, methane, vegetable oils and wind and solar energy).

- Natural Resources: Wetlands protection, water control structures (dams, reservoirs, floodways), drainage, erosion control, pesticide and nutrient runoff, crop water requirements, water treatment systems and irrigation.

- Greenhouse and Nursery: irrigation, mechanization, disease and pest control, temperature, humidity, ventilation control and plant biology (tissue culture, seedling propagation, hydroponics)

- Structures and physical environment: animal housing, grain storage, waste management, climate, ventilation, disease control systems.

In the previously mentioned document of the ERABEE Thematic Network relating to the accreditation of Bachelor's degree programmes in Biosystems or Agricultural and Biological Engineering the following table (table 2) was included [15]. This table shows the Core Curricula of Agricultural / Biosystems Engineering for the First Cycle Degrees of Integrated First and Second cycles (i.e. Pivot Point Degree) or for Long Cycle Academic Orientation Programs of Studies. As far as the First Cycle B.S. Degrees Programs of Studies the proposed Core Curricula of Agricultural/ Biosystems Engineering allows for 18 ECTS (European Credit Transfer and Accumulation System) units (out of a total of 180 ECTS) to be devoted to applied Agricultural Engineering subjects while most of the Agricultural Engineering specialisation subjects will be offered during the second cycle program of studies. ECTS credits are based on the workload students need in order to achieve expected learning outcomes. In this way, one academic year corresponds to 60 ECTS-credits that are equivalent to 1500–1800 hours of study.

COURSE TYPE	NON TECHNICAL ECTS CREDITS	
	FEANI EMC comments	AGRICULTURAL / BIOSYSTEMS ENGINEERING PROGRAMME IN COMPLIANCE WITH THE FEANI EMC comments
Basic Sciences	36 (min) (min. 20% of total)	36-45
Mathematics	24 (min)	24 (min)
Physics	12	12 (min)
Chemistry		
Informatics		
Electives	18 (min)	18- 27
Economics & Humanities	18 (10% of total)	18 (min)
SUBTOTAL: Basic Sciences+Electives	54 (min)	54-72

COURSE TYPE	TECHNICAL ECTS CREDITS	
	FEANI EMC comments	REVISIONS OF USAEE PROGRAMME IN COMPLIANCE WITH THE FEANI EMC comments
Engineering Sciences		72 (min)-81
Core Basic Engineering Sciences		44-51
Module Engineering Sciences		28-30
Agricultural/Biological Sciences		36 (min)-45
Core Basic Agricultural/Biological Sciences		20-25
Module Agricultural/Biological Sciences		16-20
SUBTOTAL-Core curriculum: Engineering Sciences + Agricultural/Biological Sciences	108 (min) (min. 60% of total)	108 (min) -126
Applied Agricultural Engineering Sciences: not included in the core curriculum	-	18 (max)
TOTAL 1st CYCLE	180	180

Table 2: Core Curricula of Agricultural / Biosystems Engineering for the First Cycle Degrees proposed by ERABEE

6. CONCLUSIONS

The traditional field of Agricultural Engineering is now evolving into the Biosystems Engineering field, which is a science-based engineering discipline that integrates engineering science and design with applied biological, environmental and agricultural sciences, broadening in this way the area of application of Engineering sciences not strictly to agricultural sciences, but to the biological sciences in general, including the agricultural sciences. In response to this development, the Thematic Network ERABBE was established. This development is a response to the new society's needs in view of the emerging bio-based economy, such as renewable sources of energy, bio-based industrial materials, and environmental stewardship.

In the University Studies this evolution is materializing in the extension of agricultural studies to Biosystems studies, by including these new emerging disciplines. This change seems to be a solution to some current problems of these studies due to the loss of importance like agricultural sector. In the majority of the cases the transition from agricultural engineering studies to biosystems engineering studies has improved some important aspects like student enrolment, prestige, funding, etc. The existing European studies on Biosystems Engineering are described in this paper.

ERABEE Thematic Network has developed accreditation criteria for the Bachelor's degree programs in Biosystems or Agricultural-Biological Engineering. This document has been developed as a basis for the accreditation agencies and the universities' quality assessment schemes and may now be recognized as such at the European level by two European professional associations, FEANI and EurAgEng and the European Accreditation scheme for engineering programs of studies EUR-ACE.

Despite the concepts of Biosystems or Biological-Agricultural disciplines are very similar in US and Europe, significant differences still remains. Therefore coordinated networking activities like those carried out by the ERABEE network are very important to unify criteria, follow the international developments in this emerging discipline and, as a consequence, facilitate the international recognition of these studies and the exchange of students and professors.

Scope and main contents of Biosystems Engineering studies has been described in this paper. The showed data are based on the main professional associations of Agricultural and Biosystems Engineers in US and Europe and on the work carried out by the USAEE TN, POMSEBES project and the ERABEE Thematic Network. The work of the ERABEE Thematic Network continues now through the ERABEE Network established by the partners Institution of the ERABEE TN following the end of the Thematic Network project.

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