



2950 Niles Road, St. Joseph, MI 49085-9659, USA  
269.429.0300 fax 269.429.3852 hq@asabe.org www.asabe.org

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## **Undergraduate Design Experiences in the Trans-Atlantic Biosystems Engineering Network (TABE.NET)**

### **Thomas P. Curran**

Biosystems Engineering, UCD Agriculture & Food Science Centre, University College Dublin, Belfield, Dublin 4, Ireland. Email: tom.curran@ucd.ie.

### **Pilar Barreiro**

Universidad Politecnica de Madrid, Avda Complutense s/n 28.040 Madrid, Spain. Email: pilar.barreiro@upm.es

### **Giuliano Vox**

Department DISAAT, University of Bari, via Amendola 165/A, 70126 Bari, Italy. Email: giulius.vox@agr@uniba.it .

### **Theo A. Dillaha**

Department of Biological Systems Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061-0303, USA. E-mail: dillaha@vt.edu

### **Stephen C. Zahos**

Department of Agricultural and Biological Engineering, University of Illinois Urbana-Champaign , Agricultural Engineering Sciences Building, 332 AESB, MC-644, 1304 W. Pennsylvania Avenue, Urbana, IL 61801, USA. E-mail: szahos@illinois.edu

### **Richard S. Gates**

Department of Agricultural and Biological Engineering, University of Illinois Urbana-Champaign , Agricultural Engineering Sciences Building, 360C AESB, MC-644, 1304 W. Pennsylvania Avenue, Urbana, IL 61801, USA. Email: rsgates@illinois.edu

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**Abstract.** *A Trans-Atlantic Biosystems Engineering Network (TABE.NET) has been established with the overall goal to advance internationalization of Biosystems Engineering (BSEN) curricula and develop a global awareness within the discipline. The participating institutions are Virginia Polytechnic Institute and State University (VT), University of Illinois at Urbana-Champaign (UIUC), University College Dublin (UCD), Agricultural University of Athens (AUA), Universidad Politecnica de Madrid (UPM), and University of Bari (UniBar). A working group is exploring the potential to develop an international collaborative design project for undergraduate students in the participating institutions. This paper summarizes the first step in the process by examining current course structures and design experiences across the network.*

*There is a clear trend towards problem-based learning in real-life type design projects in team environments. There is potential for a collaborative undergraduate design activity across the network but further discussion and analysis is required.*

**Keywords.** Engineering, Agricultural, Biological Systems, Biosystems, International, Undergraduate, Education

## Introduction

A Trans-Atlantic Biosystems Engineering Network (TABE.NET) has been established with the overall goal to advance internationalization of Biosystems Engineering (BSEN) curricula and develop a global awareness within the discipline. The participating institutions are Virginia Polytechnic Institute and State University (VT), University of Illinois at Urbana-Champaign (UIUC), University College Dublin (UCD), Agricultural University of Athens (AUA), Universidad Politecnica de Madrid (UPM), and University of Bari (UniBar).

Activities include identifying core threads of the discipline, creating a database of multinational examples that will globalize core BSEN courses, and developing several innovative courses. A working group is exploring the potential to develop an international collaborative design project for undergraduate students in the participating institutions. This paper summarizes the first step in the process by examining current course structures and design experiences across the network. The details from Agricultural University of Athens (AUA) are not included in this article due to extenuating circumstances.

## Course Structures and Design Experiences

This section highlights the course structures and the design experience for undergraduate students in the participating institutions.

### *University College Dublin (UCD)*

The Bachelor of Engineering (BE) degree in Biosystems Engineering at University College Dublin (UCD) consists of a four year course of 240 credits. It is accredited by the professional body Engineers Ireland. From 2013, the educational requirement to achieve Chartered Engineer status will be a Masters level course, typically five years in total. A degree in Engineering Technology (BAgrSc) is also currently available at UCD. Currently, each BE student takes 60 credits each year, made up of 12 modules across two semesters. Each standard module (five credits) is equivalent to between 100 and 125 hours of work. Table 1 shows the project-based modules at UCD, which contribute towards the development of key design skills.

Table 1. Project-based modules at University College Dublin

Year of Study	Credits	Module	Individual/Group	Description
1	5	BSEN10010 Biosystems Engineering Design Challenge	Group	Design and build a bench-scale solution to a problem
2	5	BSEN20040 Biosystems Engineering Research Trends	Individual	Literature survey
3	10	BSEN30250 Biosystems Engineering Design Project	Individual	Design a system, process or object
4	15	BSEN30270 Biosystems Engineering Major Project	Individual	Experimentation, systems analysis and/or design

Up until the middle of the last decade, students were not particularly exposed to design concepts until the third and fourth years of the course. However, this has changed due to the introduction of the module BSEN10010 Biosystems Engineering Design Challenge. This level one module is aimed at first year (freshman) students but students from more advanced stages in other disciplines may also take it as an elective. The module provides an opportunity for students to learn about engineering design, project management and teamwork (Curran et al., 2007). Enrolled students are split into teams of up to seven and meet an assigned mentor each week during a semester (12 weeks) to solve a specified problem. The objectives thus far have focused on water-driven electricity generation, treatment of gray water from domestic buildings, biofiltration of malodors from food waste and oil recovery from water. The assessment criteria include teamwork, minimization of expenditure, device design, innovation, operational safety, system performance, report writing and appropriate use of biological and recycled materials. External experts evaluate each entry and cash prizes are awarded to the top teams. Students receive individual academic grades based on their contribution. Feedback on the module has been very positive from both inside and outside the University. O'Donnell et al. (2009) highlighted how students can develop research skills in the module by compiling a literature survey to solve an engineering problem. The most recent developments have been the introduction of an online weekly project journal for each student and the involvement of biosystems engineering graduate students as mentors.

In Year 2, students must compile a state-of-the-art literature survey in the 5-credit module BSEN20040 Biosystems Engineering Research Trends. As with all projects from Years 2 to 4, the project topic is selected from a list suggested by academic staff, which is based on their expertise (food, energy or environment). An example of a survey topic might be the application of nanotechnology in food packaging. An oral presentation is also required from each student carrying out a project in each year.

In Year 3, students must undertake a year-long 10-credit module BSEN30250 Biosystems Engineering Design Project. The objective is to design a system, process or object. It was decided that each student should undertake a similar project in the current year, using a fermentation process as the core of the design. It was felt that graduates should have an understanding of how to design a bioreactor because this knowledge can be applied across the specializations within biosystems engineering (food, energy and environment).

In Year 4, students must take a year-long 15-credit module BSEN30270 Biosystems Engineering Major Project. The students can focus on experimentation, systems analysis and/or design. Sometimes, students decide to follow a common thread or specialization from earlier projects in food, energy or environment. Over the past few years, there has been a slight preference towards energy projects. However, it may be necessary to reduce the choice for students in order to balance the project supervision workload for academic staff.

The most recent thinking is that the design project should be moved to Year 4 so that it would be more similar to a capstone project, integrating knowledge and skills from earlier years. The transition from the current system is planned to take place over the next couple of years. Another aspect open for discussion is whether to have more group or individual projects as problem-solving and teamwork are important criteria for accreditation by Engineers Ireland. Critically, it is also necessary to examine the appropriate use of scarce resources while maintaining and enhancing the learning experience for students.

### ***Universidad Politecnica de Madrid (UPM)***

The degree course in Agricultural Engineering and Science is organized into four parts, which are distributed to 240 ECTS, equivalent to 6480 hours of student dedication, considering that each ECTS corresponds to 27 hours of work.

The curriculum has a semester structure (each year, two semesters of 20 working weeks each, including exams). Each semester can deliver a maximum of 6 subjects with a total of 30 ECTS credits and 810 hours of student work, equivalent to 40.5 h / week.

The subjects in the degree sequence have adequate training for optimum student learning. They have either 4 or 6 ECTS except the Final Year Project (12 ECTS) that the

The degree in Agricultural Engineering and Science qualifies students in the profession of Agricultural Engineer specializing in the field of Mechanisation and Rural Construction. Emphasis can be placed on Plant Production, Animal Production, Agricultural Economics and Rural Engineering

A module is made up of electives (20 ECTS) the student must choose one of four directions and choose at least three of the chosen subjects (12 ECTS). The rest of the optional credits (8 ECTS) can be chosen from among those offered in the same discipline, other specializations of the block cross-validated by business practices or participation in University cultural, sports, student representation, solidarity and cooperation.

To obtain a degree in Agricultural Engineering and Science, it is mandatory to defend a Final Project of 12 ECTS credits, consisting of a project or individual student work, professional in nature, in the field of Agricultural Engineering, which synthesizes and integrates the skills acquired throughout the course.

There is also a 60 ECTS Masters course available. The Master's Degree in Agroingeniería (Agricultural Engineering) is designed to train experts in any of the various areas: agricultural engineering projects, environmental impact, construction, energy supply, water management, mechanization, or automatic control. Masters graduates should have developed skills in design, project management, research, development, innovation, teaching and outreach in agriculture, livestock, food and rural environment, in their chosen specialization.

Among the most important collaborative experiences the ETSIA-UPM offers there is the Student Conference (already four editions, <http://congresodeestudiante.blogspot.com/>), and the International contest on Applied Robotics in Agriculture (third edition in 2011).

The purpose of the Student Conference is to provide additional training activities, along with all the new methodologies of educational innovation, to adapt to the European Higher Education, since all students must eventually produce a report to present or defend an experimental Work Project or Master Thesis. This exercise involves the learning of generic skills common to different subjects and disciplines.

Meanwhile the AGROTECH provides a multicultural and multidisciplinary challenging learning experience for those who are tired of learning theory but never see it put into practice, or bored of writing down notes instead of touching the technology with their own hands. It gathers students from about 30 universities among more than 15 countries in Europe. This competition is organized as a consortium by 2 innovation groups (TECNA and LPF\_TAGRALIA, together with the student association BEST).

The exercise for the Robotics contest based on Lego NXT is always set on the very first day of competition (<http://www.youtube.com/watch?v=zTpIT3XobuU>). This year the activity was entitled "The Energy Harvester", since the robots were required to gather energy in a variety of forms such as wind and solar.

### ***University of Bari***

A Bachelor Degree in Biosystems Engineering is not available at University of Bari, but several courses concerning Biosystems Engineering are present in the bachelor degree programmes,

i.e. Agricultural Science and Technology degree, Forest and Environmental Science degree and Food Science and Technology degree. Typical courses concerning Biosystems Engineering are “Structures and equipment for protected cultivation”, “Agricultural hydraulics”, “Machines for pesticides distribution”, “Agricultural buildings”, “Forest buildings and land surveying”, etc.

The Bachelor phase lasts three years, each student takes 180 credits, 60 credits each year, which is divided in two semesters; The maximum number of courses and exams in each degree is 20, the number of credits for each course ranges from 6 to 12, one credit requires 25 hours of work. The course can be composed of two or three different modules, each having a minimum number of three credits.

Project-based courses or modules are not available at University of Bari. Design concepts are taught within the “Agricultural buildings” course, “Forest buildings and land surveying” course, and the “Forest hydraulics and hydrology”, usually held in year 2.

In the “Agricultural buildings” course, the student develops the design of a building, typically a barn for livestock, the student learns the fundamentals principles used in developing plans, selecting materials, and choosing energy efficient solutions.

In the course “Forest buildings and land surveying”, the student develops the design of a building suitable for the forest environment such as a guest quarter.

Watershed management and torrent control are the objectives of the design developed by the student attending the course of “Forest hydraulics and hydrology”; the students study solutions and apply the design techniques to a real case.

The project topic is selected by the student together with the academic staff that supervise the design development. The work required for the development of the design ranges from 25 to 50 hours of work.

### ***Virginia Polytechnic Institute and State University (VT)***

The Biological Systems Engineering (BSE) program at Virginia Tech (VT) focuses on the two areas of Bioprocess Engineering and Land and Water Resources Engineering.

The emphasis of Bioprocess Engineering is on the design and development of processes for environmentally responsible manufacturing of food and industrial products from biological materials. Land and Water Resources Engineering focuses on environmental protection and natural resources management.

The module ENGE1024 (Sustainable Energy Design Project) requires students to work in teams of 4-5 on a ten week long design project. Successful completion of this project should demonstrate ability to:

- i) Apply the principles of sustainability to the design of a product, system or process.
- ii) Apply the design process to solve an engineering problem as part of a team.
- iii) Effectively describe the team’s product and convey the challenges, solutions and reasoning both orally and in writing.

The module combines individual and teamwork assignments along with assessment of the performance of team members.

In the module BSE 2105 (Introduction to Biological Systems Engineering), the goal of a laboratory exercise is to use engineering design methods to design a sedimentation chamber to remove suspended kaolinite by settling and to minimize process time and cost.

The combination of the modules BSE 4125 & BSE 4126 (Comprehensive Design Project) course is the capstone design project for students in Biological Systems Engineering and can focus on either land and water resource engineering or bioprocess engineering. Having successfully completed both modules, the student will be able to: 1) perform detailed design analysis; 2) develop and update a project schedule; 3) maintain a comprehensive design logbook; 4) design and complete an engineering design project; 5) write a technical design report; and 6) give a technical presentation in a confident and professional manner.

### ***University of Illinois at Urbana-Champaign (UIUC)***

The Agricultural & Biological Engineering (ABE) program in University of Illinois at Urbana-Champaign (UIUC) offers two different undergraduate degree paths: a 4-year program administered by the College of Engineering, and a 5-year program that combines agricultural and biological engineering and agricultural science. The 4-year program of study provides a bachelor of science in agricultural & biological engineering from the College of Engineering. Coursework includes basic and advanced engineering principles, agricultural engineering, biological and related agricultural sciences and other technical subjects. The 5-year program of study provides dual bachelor of science degrees from the College of Engineering and the College of ACES. Coursework covers the same comprehensive education as the 4-year program and includes an additional year of related agricultural, physical, and biological science courses.

A recent change has meant that ABE students must first select either Agricultural Engineering or Biological Engineering as their concentration and then are required to choose a set of coherent courses that constitutes a specialization in their area of career interest either from the following lists or a customized area chosen in consultation with an advisor:

#### Agricultural Engineering Concentration

- Renewable Energy Systems
- Off-Road Equipment Engineering
- Soil and Water Resources Engineering

#### Biological Engineering Concentration:

- Bioenvironmental Engineering
- Ecological Engineering
- Food and Bioprocess Engineering
- Nanoscale Biological Engineering

The key areas of design activities are in the modules ABE 100, ABE & TSM 430, and ABE 469.

ABE 100 is an introduction to the engineering profession with career opportunities in the agricultural and biological engineering discipline. Interactive class activities include concepts necessary for becoming a successful engineer including time management, design concepts, ethics, and team building. Students become familiar with laboratories, computer facilities,

internships, and other opportunities that are available to agricultural and biological engineering students. A team design experience is included. Class emphasis is on problem-solving skills, technical communication, and career planning.

Students are highly encouraged to participate in student organizations, such as ASABE Illinois Student Chapter, Illini Pullers, Engineers Without Borders, Solar Decathlon, etc. Students are asked to attend at least three student club meetings through the semester and, for each meeting, submit a 250-word report/reflection on what transpired at the meeting.

Microsteam cars are also constructed from supplied car kits and materials. The design projects are intended to promote peer-learning and practice problem-solving and technical communication skills. Project options are presented during class and each student is assigned a team based on their interest. Each team has a mentor specific to their project. At the end of the semester, students present a poster based on their project to the class and ABE Department.

ABE & TSM 430 (Engineering Project Management & Product Innovation) provides a defined framework of nine Project Management Knowledge Areas for understanding and analyzing project management activities. This framework serves as a checklist that should be considered by a project manager.

Students are assigned project teams to learn about and work on real-world projects related to a specific company, with company background information provided and a specific industry contact person selected. Each student team is expected to apply Project Management principles to learn about the company's competitive strengths and strategies and to work as if they were employees of that company. Teams explore the new product development process, similar to how that company approaches product development. They must develop a comprehensive "Product Development Plan" and present a final written and oral report.

The aim of ABE 469 (Industry Linked Design Projects) is for students to experience modern engineering design practice and the product development process with team oriented, industry sponsored design projects. There is an emphasis on written and oral communication skills, technical presentations, development of interpersonal skills, economic justification of designs and product development processes and teamwork.

A key element of ABE 469 is industry involvement. Engineers from industry visit campus the first week of the semester to present "real life" design problems. The students select the projects of greatest interest and form four person teams. After the teams form, they visit the industry sponsor to gather data, evaluate manufacturing capabilities, and work with their engineering sponsor to finalize project parameters. Teams maintain contact with the sponsors by phone, fax and email. Weekly project reports and monthly project reviews are developed for the sponsors. A formal project review is conducted at the sponsor's site at the end of the semester and they receive an industry quality written project report complete with budgets, schedule, bills of material, photos, experiment data, conclusions and recommendations.

Student design teams have full responsibility for research, design, fabrication, test, and evaluation of an optimum design solution. Teams develop and "track" their project schedules and budgets. The course is mentored by an engineer with over 30 years of product development experience in industry. This experience helps the students make a transition from an individually based classroom situation to a team based collaborative industry environment. Faculty and visiting engineers from industry teach the course modules in ABE 469.

The industry "partners" pay a flat fee and furnish parts, expertise and components. For \$4000 the sponsor receives an optimum design solution, working prototype and over 400 hours of engineering resources.



ABE 469 is considered to be a “Win/Win/Win” situation. The students win by making the transition to an industry environment by working as a team on a “real life” engineering problem. They learn to integrate past experiences and training into optimum engineering solutions. The University gains by providing an outstanding educational experience for the students and a closer tie to industry. The sponsor wins by deriving an engineering solution at nominal cost, while having an opportunity to network with the university and to evaluate potential engineering talent for their organizations.

## **Discussion**

It is clear that there are differences in the course structures and content across the partner institutions in the EU and US. The move in Europe towards a 5-year Masters degree program also has implications as to how design activities are managed throughout the courses. There is a definite trend across the TABE.NET partners of problem-based learning in real-life type projects, particularly towards the end of the degree program. There is a big emphasis on teamwork and some modules incorporate peer assessment. There are also opportunities for student teams to compete against other teams in internal and external competitions.

The US partners appear to have more of a focus on capstone design projects which integrate knowledge. The UIUC module ABE 469 (Industry Linked Design Projects) highlights close collaboration between industry and academia. There are major advantages for the students, University and participating companies. There is no doubt that these project-based modules require much work in initiating and developing them, but the enhancement of the student learning experience is rewarding.

There is clearly potential to develop an international collaborative design project for undergraduate students in the participating institutions due to the rich diversity of experience among the partners. Further work is required to examine how this could be achieved.

## **Conclusion**

There are many differences in course structures and content across the TABE.NET partners. There is a trend towards problem-based learning in real-life type projects in team environments. There is potential for a collaborative undergraduate design activity across the network but further discussion and analysis is required.

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