Environmental Engineering Curriculum at the Technical University of Crete, Greece

Dionissios Mantzavinos, Evan Diamadopoulos, Nikolaos P. Nikolaidis
Department of Environmental Engineering Technical University of Crete, GR-73100 Chania, Greece
mantzavi@mred.tuc.gr; diamad@dssl.tuc.gr; nnikolai@mred.tuc.gr

Abstract - **Environmental engineering at the Technical University of Crete is a five year programme leading to the Diploma of Environmental Engineering. The minimum number of courses required is 60. The students must also submit an undergraduate thesis. The environmental engineering subjects are covered both from a civil engineering approach (hydrology, hydraulics, water resources management) and a chemical engineering approach (unit operations, processes) and, therefore, are supported by academic staff who predominantly come from the respective engineering background. During their final year (9^{th} and 10^{th} semesters) the students must take a capstone design course. A different design theme is examined every year, such as municipal wastewater treatment for specific areas using different treatment methods or designing recycling systems for various materials in a specific area. The course is being supervised by non-academic qualified engineers holding doctorates (consultants, environmental authorities). Lectures on environmental impact assessment and engineering economics, as well as seminars delivered by design engineers on the specific subject are also part of the course. In addition to the undergraduate curriculum, the Department offers two postgraduate programmes leading to MSc and doctoral degrees.**

Index Terms – Environmental engineering, Curriculum, Design project.

INTRODUCTION

Environmental engineering education at Universities is a rapidly changing field globally. Traditionally, it has resided in the civil engineering programme addressing water and wastewater quality, treatment, design and regulatory issues. In recent years, environmental engineering has become a much broader field encompassing water, wastewater, soil pollution, air pollution, risk assessment, ecosystems, human health, toxicology, sustainable development, regulatory aspects and much more [1].

In this perspective, the environmental engineering profession of the future will need to address problems of enormous complexity due to an increasing global population and associated stresses. The problems of the future are not known and cannot be foreseen. The environmental engineers must acquire skills that can serve them a lifetime. They should be capable of understanding a problem, restoring the natural environment to a desired state and maintaining it in a way compatible with the demands of modern society. Environmental problems are global in nature. They also require extensive integration of many disciplines. Students need to integrate scientific principles and apply them to natural and engineered systems. Field investigation, laboratory testing and synthesis through mathematical modelling provide an integrated approach to solving environmental problems and preserving human health and the environment. The emphasis of environmental engineering programmes should be interdisciplinary and problem-solving.

The industrial model of higher education has served society very well in preparing scientists and engineers that could advance its ever increasing technological needs. It created professionals that had been highly specialised and could continuously advance their field. This over-specialisation and single-discipline approach of education does not serve well several disciplines, especially environmental engineering because it is interdisciplinary in nature. Environmental engineering systems are "open" systems whose understanding requires integration of all physical sciences (chemistry, geology, biology, plant science, physics, mathematics, etc.), as well as social sciences (social, political, economic).

The market needs related to environment are high. On a global scale, environmental companies and industries have annual sales of $525 billion dollars (2001) that will grow at an annual rate of 2,5-3% [2]. In the US, the financial influence of the "environmental bussinesses" from the point of view of gross sales is at the same level as the petroleum refining, paper and related products, and the airspace industry according to the US Department of Commerce. Thirty percent of the total sales are taking place in the European Union (EU). In Greece, the environmental engineering labour market depends primarily on EU legislation. The Water Framework Directive (WFD) drives the environmental market of Europe. The implementation of WFD will employ environmental engineering students at least until 2012, the year when it should be fully implemented by every Member-State.

In Greece, environmental engineering education at undergraduate level has begun since mid 1990s and is offered by the respective Departments of Democritus University of Thrace (DUTh) and the Technical University of Crete (TUC). The latter has been offering the programme for the past decade aiming at balancing the interdisciplinary nature of the field with current and future market needs, thus ensuring the employment of its graduates, while creating students with technical competence, communication skills and global awareness to assume a leadership role in environmental management. This aim is achieved through regular programme evaluation and updating according to the recommendations of internationally renown expert academics and professionals in the field.

UNDERGRADUATE PROGRAMME OVERVIEW

I. The Undergraduate Curriculum

The undergraduate curriculum offers 76 courses spanning across nine semesters. Of these, students need to qualify to at least 60 courses (183 credit units) as well as carry out a diploma project and produce a thesis (during the tenth semester) to graduate with a Diploma in Environmental Engineering. Table I summarises the courses offered at TUC.

TABLE I
COURSES OFFERED IN ENVIRONMENTAL ENGINEERING AT TUC

Course area	Number	Breakdown, %
Natural Sciences	11	14
Humanities/Social Sciences	12	16
Environmental Science	5	7
General Engineering	20	26
Environmental Engineering	28	37
Total	76	100

In general, the courses offered can be summarised in five major areas, namely (i) natural sciences (including, amongst others, mathematics, statistics, general chemistry and programming), (ii) social sciences (sociology, political economy, philosophy and foreign languages), (iii) environmental sciences (including, amongst others, environmental microbiology, aquatic chemistry and ecology), (iv) general engineering subjects (including, amongst others, statics, geodesy, physical chemistry, soil mechanics, GIS, fluid mechanics, chemical and biochemical reaction engineering, thermodynamics and transport phenomena) and (v) environmental engineering subjects that expectedly constitute the core of the environmental engineering programme. These subjects are primarily design-based and cover topics such as water and wastewater treatment, air, water and soil pollution monitoring and control, management and treatment of hazardous wastes, groundwater flow and contaminant transport, environmental modelling and optimization, hydrology, hydraulics and many more.

The above programme is supported by (i) permanent academic staff and part-time lecturers of the Department of Environmental Engineering and (ii) academic staff from other Departments of TUC.

TABLE II
ACADEMIC STAFF IN ENVIRONMENTAL ENGINEERING AT TUC

First Degree in	Number	PhD from
Chemical Engineering	8 (P=4, AP=1, ASP=2, L=1)	Canada: 3; UK: 1; Sweden: 1; Greece: 3
Civil Engineering	4 (P=3, AP=1)	Canada: 1; US: 3
Rural & Surveying Engineering	1 (L=1)	Greece: 1
Physics	2 (AP=2)	Germany: 1; Finland: 1
Chemistry	1 (ASP=1)	UK: 1
Forestry	1 (P=1)	US: 1
Agriculture	1 (L=1)	Greece: 1
Total	18 (P=8, AP=4, ASP=3, L=3)	North America: 8; Europe: 5; Greece: 5

The interdisciplinary and multidisciplinary nature of the programme is also reflected to the academic background and professional experience of the departmental permanent staff which currently consists of 18 members as seen in Table II. Numbers in brackets show the respective academic ranking, i.e. professors (P), associate professors (AP), assistant professors (ASP) and lecturers (L). It is also notable that although most of the staff have obtained their first degrees from a Greek University (14 out of 18), they have pursued doctoral and/or postgraduate studies in various North American and European institutions. The Department (which is only 10 years old) is rapidly growing and 10 more staff members are expected to be recruited within the next 5 years in the areas of applied hydraulics, water resources management, environmental microbiology and toxicology, public health engineering and many more.

Over the past few years, the Department has been funded by the Hellenic Ministry of National Education & Religious Affairs to implement changes that would strengthen its undergraduate curriculum. The underlining principle behind this is to balance the interdisciplinary nature of the field with current and future market needs. The philosophy behind this effort is congruent with the notion that Universities should be centres of excellence that are conducive to developing “strategic analysts” [3]. To develop “strategic analysts” the University must promote teaching and research that refines four basic skills: capacity for abstraction, systems thinking, experimentation, and collaboration. Graduating students with such skills would ensure their employment, while developing their technical competence, communication skills and global awareness and preparing them to assume a leadership role in environmental management.

In this perspective and based on (i) the recommendations of expert panelists from European and North American Engineering Departments who were invited to assess the undergraduate and postgraduate environmental engineering curricula (three assessments took place over the past five years), (ii) the background of the departmental academic staff (which is continuously enriched due to new recruitments) and (iii) the EU objectives of the 6^{th} Environment Action Programme (European Commission, 2001) that focuses on four themes (i.e. climate change; protection of nature and wildlife; environmental and health issues and preservation of natural resources; management of wastes) that the Commission will take strong action over the following 10 years, it was decided to develop three areas of excellence as follows:

- **Environmental management** aiming at the protection and improvement of water quality (both surface and groundwaters) at the watershed scale and coastal zone, protection of air quality, rational management of solid and toxic wastes at local and regional levels, protection of ecological quality and sustainable development. This area includes all pollution sources like the interface between agricultural production and the environment (sustainable/biological agriculture, study of the trophic chain, agrochemical pollution).
- **Treatment of wastes** with emphasis on life cycle analysis, recycling technologies and assessment of

environmental impacts. This area includes the design and optimisation of treatment technologies for wastes from several sources (domestic and industrial wastewater, air pollution, hazardous wastes).

- **Remediation of contaminated soils** with emphasis on the development and use of advanced technologies for soil cleanup and assessment of environmental impacts. This area includes landfill design, long term impacts of solid waste disposal, remediation technologies and risk assessment.

Each area of excellence has at least 5 staff members actively involved in it. A few staff are actually involved in more than one area. The creation of the areas of excellence is complemented with the development of "course clusters" within each area. Each course cluster consists of several compulsory and elective courses, thus providing a coherent specialisation in the area. Table III shows representative courses forming the respective clusters. Courses marked with an asterisk are electives, while the rest are compulsory.

TABLE III
COURSE CLUSTERS WITHIN AREAS OF EXCELLENCE

Environmental Management	Waste Treatment	Soil Remediation
Hydrology	Unit operations in water & wastewater treatment	Toxic and hazardous waste treatment & management
Coastal hydraulics	Chemical processes in water & wastewater treatment	Aquatic chemistry
Groundwater flow & contaminant transport	Biological processes in wastewater treatment	*Bioremediation
Air pollution monitoring & control	Design of sanitary landfills	*Soil & groundwater remediation technologies
Environmental meteorology	Air pollution abatement technologies	
*Surface water quality models	*Thermal treatment technologies	
Renewable energy sources	*Decentralised systems for wastewater treatment	
*Agricultural engineering systems		
*Sustainable development		

The courses are coordinated with emphasis on laboratory application, fieldwork and the holistic design of environmental systems. The expected outcome from such coordination is the development of the basic skills of the students, their introduction to research and the interdisciplinary approach to solving problems. An example on how the coordination of courses within a cluster can achieve the above goals is as follows: a watershed can be adopted by a series of courses as an area for application. In meteorology, the students can obtain meteorological data for the area, in hydrology, they can study the rainfall-runoff processes using the meteorological data obtained previously, and in the surface water quality models they can apply a mathematical model to assess the impact on water quality. In other words, by working in the same area for a period of time, the students can obtain a better knowledge and appreciation of its problems, have the opportunity to examine them in depth, and thus be introduced easily into the concepts of environmental research.

In addition to forming course clusters aiming at rationalising specialisation, the development of students' basic skills (i.e. capacity for abstraction, systems thinking, experimentation and collaboration) is also achieved through the integration of laboratory work, field trips, industrial placements, diploma thesis and the final year design project in the curriculum. For a typical core course, the weekly contact time consists of 2-3 hours of lectures, 1 hour of tutorials and 2 hours of laboratory practice. The latter comprises the more traditional "wet" and "computational" lab exercises as well as the so-called "virtual" labs. A series of software that model environmental problems are developed by Departmental staff. The objective of the creation of virtual labs is to provide the opportunity to the students to gain experience through simulation as well as to examine scenarios with extreme environmental conditions. In both circumstances the student is able to visualise conditions that would be otherwise impossible under normal conditions. Table IV gives examples of such labs already operating in the three course clusters of the curriculum.

The students also participate in two field trips (6^{th} and 8^{th} semesters) visiting premises of the public and private sectors that have a clear environmental focus (e.g. municipal wastewater treatment plants, landfills, power plants etc), while they are also advised to spend summer time in industry through a University-Industry placement scheme (about 50 students participate every year). A mandatory component of students' education is their diploma, semester-long dissertation during which they are asked to carry out an individual research project, write up a thesis and defend it in front of a panel committee.

TABLE IV
EXAMPLES OF VIRTUAL LABS IN ENVIRONMENTAL ENGINEERING AT TUC

Virtual Lab Description	Affiliated Course
ED-WAVE software: this is an e-tool operating in Windows that consists of a reference library with animations of processes for water/wastewater treatment and a database with case studies on municipal and industrial effluent treatment	(1) Unit operation in water & wastewater treatment (2) Chemical processes in water & wastewater treatment
KARSTIC SPRING model: this is a MATLAB-based model simulating the combined flow and quality from a karst within a watershed	Surface water quality models
A MATLAB-based simulation package has been developed for organic pollutants degradation in slurry-phase bioreactors (*ex situ* bioremediation)	Bioremediation
This is a FORTRAN-based model operating in MATLAB environment for groundwater pollution in the saturated and unsaturated zones	Groundwater flow & contaminant transport
This a Gaussian FORTRAN-based model of air pollution dispersion from point and area sources	Air quality modelling

II. The Final Year Design Project

One of the most important recent changes in the undergraduate curriculum was the introduction of the final year capstone design project. The primary goal of this year-long project (spanning across the 9^{th} and 10^{th} semesters) is twofold, namely: (i) to help students recap and apply knowledge obtained throughout individual courses to "real life" projects in a coherent and systematic way and (ii) to "force" them act as team players, experiencing the benefits and drawbacks of team work. The initiative was originally proposed by staff members of a chemical engineering background who had experience from the respective capstone course typically offered in European and North American chemical engineering curricula.

The design project has now been running for two academic years (2005-06 and 2006-07) and is implemented through the following steps:

- **Selection of design theme**: each year the Department offers a different design project; for instance, the first one dealt with the design of municipal wastewater treatment plants to operate at different areas of Crete, while the second one with the recycle of various materials from a specific industrial site.
- **Assignment of course leader**: although several staff members would be qualified to teach this course, they usually lack the necessary practical, "non-academic" experience that people from industry possess to tackle engineering design problems. In view of this, the Department recruits a doctorate-holding expert to run the project; in the case of wastewater treatment design for example, a consultant from the Ministry of Environment, Planning & Public Works supervising the operation of Athens wastewater treatment plant was assigned as the course leader.
- **Course syllabus**: during the first half of the course, students attend weekly seminars on certain aspects of engineering design such as environmental impact assessment, technical and economic analysis, preparation of flowsheets, project management, current national and European legislation specific to the theme in question etc given by the course leader, staff members and other external consultants.
- **Team work**: the class (of about 60 students) is split into groups of four. Each team are assigned their own case study; in the case of wastewater treatment for instance, they are given different locations all over the island of Crete to design their plant. This essentially means that, although the concept is common to all teams, different treatment technologies (e.g. activated sludge, biofilters, constructed wetlands etc) and operating capacities have to be considered according to the particulars of each specific location.
- **Course requirements**: each team have to prepare and submit a mid-term preliminary report regarding the fundamentals of their case study (i.e. selection of exact location to build the plant based on e.g. meteorological data or geographical constraints, recommended technology, selection of operating conditions etc). They are then asked to proceed with the full engineering design and submit a final report.
- **Student evaluation**: students' performance is assessed based on the quality of (i) the preliminary and final reports and (ii) an oral presentation of their work in front of a panel committee. Each student is assessed for both their individual competence (as they are assigned certain pre-determined design tasks) and team work.

POSTGRADUATE PROGRAMME OVERVIEW

In addition to the undergraduate curriculum, the Department offers two postgraduate programmes in "Environmental & Public Health Engineering" and "Quality Control & Environmental Management" both leading to MSc and PhD degrees. The former programme is exclusively run by the Department and accepts students with an engineering background, while the latter is run in collaboration with other Departments of TUC and accepts students from various backgrounds (engineering, natural sciences, life sciences). Both MSc programmes last for a full academic year during which students must qualify in six courses and undertake a research dissertation.

CONCLUDING REMARKS

The environmental engineering profession of the twenty-first century needs to address whether to shift from the traditional physics-based "civil engineering" education to a more "chemical engineering" approach to educate engineers that can more fully embrace the new array of chemical and biological technologies. This shift is currently reflected to many North American environmental engineering curricula [4]. The Department of Environmental Engineering at TUC, Greece has adopted this move and this is reflected to both the undergraduate and postgraduate curricula offered and the background of the academic staff employed. As a result, students graduate with an educational background for employment in environment-related public works as well as for employment in environmental engineering related to the chemical industry or consulting or for further education at the postgraduate level.

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