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# Environmental Engineering at the University of Strathclyde in Glasgow

*J A Clarke, J L M Hensen, C Johnstone, R C McLean*

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**Abstract**

This paper describes the recently revised curriculum for the Environmental Engineering course at the University of Strathclyde in Glasgow. This is done in relation to course content and scope, design and research projects, the role of experimentation and the deployment of advanced computing in terms of problem simulation and learning assistance.

## Introduction

The Environmental Engineering course at the University of Strathclyde [1] was instituted in 1965 and is one of four undergraduate courses offered by the Department of Mechanical Engineering. Essentially, the course is concerned with the design, manufacture, installation and operation of the engineering systems that control the environments in which people live and work. Since its inception, the course has evolved to reflect society's growing awareness that the quality of life must be balanced by the need for conservation of world resources, especially energy, **and** the protection of the environment. The principal aim is to produce professionals who understand this balance and who seek to harness and utilise energy resources in an environmentally benign manner. At the present time two degree options are available, with a third MEng (Honours) in the planning stage.

| Course | Duration | Mode |
|---|---|---|
| BEng (Honours) in Environmental Engineering | 4 years | full-time |
| BEngDiplEng (Honours) in Environmental Engineering | 5 years | full-time |

There are three premises underlying the course:

i) *That an understanding of fundamental engineering principles is vital and will lead to more creative and applicable design solutions.* The course aims to provide a thorough grounding in, and understanding of, basic engineering principles, with the emphasis on such subjects as fluid mechanics, thermodynamics, energy conversion systems, heat and mass transfer, control and energy/ environmental simulation.

ii) *That industry relevant, team-based design projects will engender an appreciation of the issues and limitations relating to good and best practice.* The aim is to provide, through the study of realistic design cases, the knowledge base necessary for the specification of engineering systems which can meet the requirements of an increasingly stringent legislature and an environmentally aware public.

iii) *That skills in the application of IT and computer modelling will allow the effective appraisal of options at the design stage.* The aim is to provide skills in the application of computer technology at the different design stages, from inception to completion and post occupancy.

It is against these premises that the course curriculum has been revised as described in the following section.

**Curriculum**

The course adheres to a credit based structure in which students take classes amounting to no less than 12 credits in the 1st, 3rd and 4th years and 13 in 2nd year (where *Engineering Applications I* is compulsory). A credit represents the learning load of approximately 24 hours of formal lectures plus associated tutorials and laboratory classes totaling an equivalent period of time. This credit-based structure offers flexibility in terms of student choice and the exporting of classes to other courses.

In the 1st and 2nd years, elective classes are offered from a wide menu available within the University. These are intended to increase the breadth of the educational programme but can also be used to give greater technical depth (for example, via the *proctoring* system as outlined later). In 3rd year, students have the opportunity of spending a semester at a European University under the ERASMUS exchange programme and/or attending the Outward Bound Centre at Loch Eil where the aim is to integrate management and leadership skills, team working and personal challenge. In the final year, which comprises a mix of compulsory and elective classes, students must pursue a major research project (4 credits) and individually prepare a thesis and technical paper, the latter for presentation at a one day 'conference' with published proceedings.

In 1991-2 a *proctoring* system was arranged whereby 2nd year students could take a one credit elective class which formed part of a final year student's research project. In this way the final year student gains experience in project management and supervision, while the 2nd year student learns about the final year project requirements.

Tables 1 through 4 list the classes by year and give a brief indication of the purpose of each class.

| Class | Credits | Comment |
|---|---|---|
| Engineering Mathematics | 2.0 | Essential prerequisite to study of all engineering subjects. |
| Dynamics | 1.0 | A sound understanding of Newton's laws provides the basis for virtually all aspects of engineering endeavour. |
| Structural Mechanics | 1.0 | Force analysis, equilibrium and the prediction of the effect of forces is the creative design function of engineering. |
| Engineering Materials | 1.0 | To engender an understanding of the hygrothermal properties of materials. |
| Thermodynamics and Fluid Mechanics | 1.0 | Prerequisite knowledge for all energy systems. |
| Engineering Analysis 1 | 1.0 | Introduction to computing concepts and systems in an engineering context. |
| Energy and the Environment | 1.0 | Introduction to basic concepts and terminology underpinning conventional and renewable energy sources, conversion techniques and related environmental issues. |
| Electrical Engineering | 1.0 | Introduction to basic concepts involved in DC, AC and amplifier analogue circuits. |
| Total Design | 1.0 | Introduction to the design process, team working and performance quantification approaches. |
| Elective Classes | 2.0 | Choice from a comprehensive list of University-wide classes including languages to support ERASMUS exchange in 3rd Year. |
| Total | 12.0 | |

Table 1: First Year Curriculum

| Class | Credits | Comment |
|---|---|---|
| Engineering Mathematics | 1.0 | All energy systems are dynamic in nature, requiring PDEs for their mathematical representation. |
| Dynamics | 1.0 | Understanding of concepts relating to dynamic behaviour and transient response. |
| Structural Mechanics | 1.0 | Introduction to elementary stress and structural analysis. |

| Class | Credits | Comment |
|---|---|---|
| Thermodynamics | 1.0 | Appreciation of energy in terms of its forms and transformations. |
| Fluid Mechanics | 1.0 | The dominant mechanism in most energy/ environmental systems. |
| Engineering Analysis 2 | 1.0 | Training in engineering applications such as CAD, simulation and data processing. |
| Electrical Engineering | 1.0 | Develops theory underlying electrical power applications and the representation, by analogy, of heat transfer. |
| Environmental Engineering Science 1 | 1.0 | Introduction to basic principles underlying the interaction of humans with their thermal, visual and acoustic environments. |
| Energy Systems 1 | 1.0 | Introduction to systems used to provide heating, cooling and power within the built environment. |
| Design | 1.0 | Team-based, with focus on the use of computer applications to evaluate options. |
| Elective Classes | 2.0 | Selected from a University-wide menu. |
| Engineering Applications 1 | 1.0 | Workshop skills as required by the Engineering Institutions. |
| Total | 13.0 | |

Table 2: Second Year Curriculum

| Class | Credits | Comment |
|---|---|---|
| Dynamics | 1.0 | Covers principles involved in dynamic analysis of systems. |
| Measurement, Microprocessors and Control | 1.0 | Uses an integrated approach to study dynamic behaviour and control of engineering systems, including fluid and electro-mechanical systems. |
| Energy/ Environmental Simulation | 2.0 | Training in the use of simulation within the design process and design stage performance modelling appraisal. |
| Thermodynamics and Heat Transfer | 1.0 | Advanced concepts as required to design the heat transfer components of real engineering plant. |
| Fluid Mechanics | 1.0 | Advanced concepts as required to design the fluid flow components of real engineering plant. |
| Energy Resources and Conversion | 1.0 | Energy resource availability and the efficient conversion of these resources into useful forms is of considerable importance for the future. |
| Environmental Engineering Science 2 | 1.0 | Advanced concepts in relation the objective functions of building design. |
| Energy Systems 2 | 1.0 | Advanced concepts in relation the systems and processes form within buildings. |
| Environmental Engineering Design | 2.0 | Group based design projects, addressing fundamental design issues (e.g. air quality) within a contemporary design problem (e.g. natural ventilation). |
| Strategic Analysis of Engineering Business Case Studies | 1.0 | Introduction to the concept of engineering as a wealth creating activity. |
| Total | 12.0 | |

Table 3: Third Year Curriculum

| Class | Credits | Comment |
|---|---|---|
| Energy Conscious Building Design | 2.0 | Focus on new technologies such as TIM, PV, CHP, etc. to develop an appreciation of the multi-disciplinary, multi-variate nature of the design process. |
| Engineering Applications 2 | 4.0 | Major research project involving a significant quantitative component (experimentation, simulation of case study). |
| 2 classes in *Computer Aided Engineering* selected from | | |
| Heat Transfer and Fluid Dynamics | 1.0 | Modern computer aided design methods applied to a range of thermo-fluids problems including heat transfer applications. |
| Dynamic Modelling and Simulation | 1.0 | Modern computer aided design methods applied to control and vibration problems. |
| Building Thermal Engineering | 1.0 | Introduction to methods available for analysis of thermal performance of building structures and systems. |

| Class | Credits | Comment |
|---|---|---|
| 4 classes from: | | |
| Heat Transfer | 1.0 | Develops material given in third year to cover multi-dimensional and transient problems. |
| Alternative Energy Systems | 1.0 | Examines current trends and the evaluation of emerging renewable energy technologies. |
| Nuclear Energy Systems | 1.0 | Theory and technology of nuclear power. |
| Signal Analysis and Condition Monitoring | 1.0 | Application of computer based systems to maintenance and protection of mechanical equipment. |
| Air Conditioning and Refrigeration | 1.0 | These systems play a prominent role in environmental control applications in commerce and industry. |
| Computational Fluid Dynamics | 1.0 | Covers principles of computational fluid dynamics involving heat and mass transfer. |
| Advanced Control Systems | 1.0 | Examines current trends and the evaluation of emerging technical developments in the area of control system design. |
| Acoustics | 1.0 | Acoustic analysis, measurement and legislation covering internal and external environment. |
| Total | 12.0 | |

Table 4: Fourth Year Curriculum

This curriculum effectively extends the scope of the traditional Environmental Engineering course in order to help students acquire knowledge of the various energy forms (renewable, fossil and nuclear) and their related engineering systems/ processes. Emphasis is placed on the impact these processes have on the environment and on the techniques by which this impact can be mitigated. In this way the course covers both the supply and demand sectors but with the emphasis on the built environment because this is where most energy is consumed, from where much of the avoidable environmental damage emanates and where most students will find employment after graduation.

In summary, Environmental Engineering education at the University of Strathclyde is seen as the process of

- understanding the physical world from a classical (e.g. thermodynamics() viewpoint
- acquiring knowledge of energy sources, conversion technologies and environmental impact mechanisms
- understanding the inter-relationship between the supply and demand sectors
- appreciating the objective functions - such as human comfort and fuel efficiency
- understanding the design process - its systemic nature, its uncertainties and its context uniqueness
- developing a working knowledge of options (scholarship) and a methodology to process these options
- acquiring skills in the new technologies - both IT and modelling
- developing personal skills in terms of strategy formulation, defence of ideas, team working and performance appraisal
- developing a balance between macro and micro issues - e.g. between community scale and component scale issues.

Essentially, the course has three complementary parts: *fundamentals* - aimed at imparting an understanding of the behaviour of the natural world - industrially relevant *design projects* - aimed at imparting skills in the design of environmental control systems - and *technology training* - aimed at providing students with the means to differentiate between the various context-specific, technically complex options.

Fundamentals

This part of the course emphasises the principles which govern energy and environmental systems. By adhering to the maxim *understanding is power*, the goal is to produce graduates who appreciate the complexity of the natural world and who are alert to the dangers of applying simplistic paradigms and practices.

Laboratory based experimentation is used throughout to reinforce the taught curriculum and engender a deeper understanding of the concepts. The Department operates seven laboratories and four workshops. Of these two laboratories are devoted to the needs of Environmental Engineering, with the following facilities available.

- wind tunnels for duct flow and model testing
- transparent chamber for flow visualisation
- air conditioning rig and environmental chamber
- sound level measurement and analysis equipment
- lighting laboratory with colour comparator and photometric bench
- extensive UNIX and PC-based computing equipment
- refrigeration and heat pump equipment
- test chamber for the calibration of leakage apparatus
- heat flux meters, laser anemometer, solarimeters, etc.
- fan pressurisation and tracer gas apparatus
- solar simulator
- data acquisition equipment
- site wind analysis equipment

Students also have access to the PASSYS outdoor test facility which is part of a specially equipped network of 40 test cells located across Europe. Four of these cells have been established in Scotland, firstly at the University of Strathclyde, with a recent relocation to BRE Scotlab. One of these cells has been designated the 'Strathclyde Teaching Cell'.

Design and Research Projects

Projects play a central role within each year of the course in that they are used to encourage 'learning by doing' and to help the student develop communication skills. In years one and two, the goal of a project is to impart basic skills. For example, *Engineering Applications I* covers such topics as electronics, electrical systems, condition measurement, manufacturing, and standards. In the later years projects are used to foster an understanding of the experimental and modelling process and a full appreciation of best practice. As an example, the following table lists some of the projects pursued under Engineering Applications II.

| Project | Issues Addressed |
|---|---|
| Development of strategies for large scale energy management and environmental impact assessment. | Fuel and environmental monitoring, IT, socio-economic assessments, information processing, etc. |
| Investigation of the potential of passive solar technologies for heating/ cooling/ power applications in buildings. | Design options identification, laboratory experimentation, outdoor test cell use, computer simulation, etc. |
| Investigation of the accuracy and applicability of design tools for energy conscious building design. | Case studies, design process analysis, use of experimental data for model validation, etc. |

| Project | Issues Addressed |
|---|---|
| Investigation of the ability of micro-scale combined heat and power systems to cost-effectively satisfy the heating and power needs of single and grouped premises. | Case studies, technical and economic appraisal, load 'shaping' through design, environmental and social impact. |
| Investigation of thermal diffusion effects in building structures. | Theoretical analysis of moisture transmission in porous materials, design of suitable test apparatus for non-isothermal conditions. |
| Development of a model for the assessment of work patterns in high temperature environments. | Basic physiological responses to hot environments, theoretical analysis of body heat and mass transfer. |

Design projects are intended to encourage the student to develop an approach to design which highlights the following elements:

- understanding: effective conceptualisation of a design problem and its inherent causal relationships
- scholarship: elaboration of design options without attempts at quantification
- differentiation: application of modelling techniques (computer or laboratory based) so that quantification can take place at the time of decision-making
- decision-making: development of a methodology for design appraisal and options selection.

Design is treated as a core, enabling discipline within the course and is introduced progressively as the course evolves. In the first year the emphasis is on the design process and issues such as team working, options identification, performance appraisal and so on. In the second year the focus is on the 'instruments' of design in terms of CAD, related design tools and project management. In the third year the emphasis shifts to a multi-disciplinary context and entails the evolution of a design from inception to completion while undertaking a series of more focussed projects on issues such as ventilation systems, air quality, advanced glazing materials, BEMS and the like. Finally, in the fourth year, a project is undertaken which entails a high level of industrial involvement and encourages the students to address advanced concepts such as intelligent buildings, passive solar systems, use of photovoltaic technology and so on.

Technology

At each stage of the course students undergo training in the latest techniques in IT and the computer simulation of energy/ environmental systems. These are the essential technologies which increasingly are being used in practice to appraise alternative options at the design stage.

The Department's policy is to maintain state-of-the-art computational and experimental expertise and associated facilities which are utilised throughout teaching, research and industrial work. For example, by good timetabling, students can each have individual access to a SUN workstations which combine a powerful processor with a high resolution graphics display. In addition, Environmental Engineering enjoys a dedicated 'computational modelling laboratory' where an extensive range of building design software is maintained. Students in the early years of the course are exposed to these applications by means of structured demonstrations delivered in the context of their curriculum subjects. In the latter years full training in Unix and design tool application is given and the students are encouraged to apply the technology in the context of their design and research projects.

**Related Developments**

At the present time the Environmental Engineering course benefits from three related developments within the Department:.

i) The presence of a strong MSc course, *Energy Systems and the Environment*, which attracts approximately 30 students/ annum and provides an appropriate development path for those graduates who wish to specialise.

ii) The presence of a significant research activity in the energy/ environment area which serves to widen the scope of student projects and help to stimulate interest.

iii) The move towards Computer Aided Learning [2] as an effective response to rising student: staff ratios and the need to provide more flexibility in learning content and mode.

## Conclusions

This paper has described recent changes to the curriculum of the Environmental Engineering course at the University of Strathclyde. The rationale of the new curriculum was presented and its component parts explained.

By means of such improvements the Department aims to ensure that it lives up to the Faculty of Engineering's slogan: "First for Engineering".

## References

1. *Environmental Engineering Course Handbook*, Department of Mechanical Engineering, University of Strathclyde, Glasgow.

2. Clarke J A and Lindsay M 'Computer Aided Learning: The GCAL Authoring System' *ESRU Technical Report*, Department of Mechanical Engineering, University of Strathclyde, Glasgow.