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# Building Services Engineering Design and Management: An Innovative Undergraduate Course

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*This paper describes the philosophy and structure of an innovative undergraduate building services engineering design and management course. The philosophy which has driven the innovation is based on a need to produce engineers who can design building services systems which are energy efficient, provide healthy internal environments and take account of the impact of buildings on the biosphere. There is also a need for a range of management and communication skills in an already truly international business. In order to satisfy these requirements the additional two strands of management and a modern European language have been incorporated in the course. The paper also describes the method of project-work used in the course in which partnership with industrial tutors allows students to work on real engineering problems in a commercial environment. The course has satisfied the requirements of the Joint Board of Moderators of the Engineering Council and successful graduates can proceed to Chartered Engineer status.*

## INTRODUCTION

THE ROLE of building services engineering is to ensure that optimum standards are met within a building so that it is always both pleasant and healthy for those who live and work there. Building services engineering covers all the environmental services (air-conditioning, ventilation, heating, lighting, and sound) and the utility services (electrical power, communications, fire protection, water, and lifts) which make a building function. As technology advances and the needs of building clients become more discerning and exacting, the costs and professional responsibilities of designing, installing, controlling and operating building services are increasing. Depending on the type of building, they cost 30% to 60% of the total building cost. Additionally, the internationalisation of engineering has brought a need to strengthen communication links within the engineering community. The innovative language element of the Building Services Engineering Design and Management (BSEDM) course at the University of Reading provides engineering undergraduates with skills in a modern European language (French, German or Italian).

The new course in building services engineering design and management is about systems which:

- produce healthy environments for people to work and live in;
- are economic in the use of energy;
- meet the challenge of reducing atmospheric pollution;
- include ways to reduce the impact of buildings on the biosphere.

The interrelationship between climate, people and buildings is an integral part of the course. This is reinforced by means of an innovative approach to the formulation and application of integrated engineering projects. The role of thorough curriculum planning and the commitment of industrial tutors from sponsoring companies is identified as crucial for their success.

## COURSE PHILOSOPHY

The essence of building services engineering is the design and management of energy resources and environments for people. It is this fundamental belief that led a group of international electrical and mechanical contractors to sponsor a new Building Services Engineering Design and Management (BSEDM) degree course at Reading University. In the words of a world-famous German firm of design contractors, and more recently by the Design Council:

> People are the focal point of our thoughts and actions. Plants are designed, planned and constructed for people. Ecologically compatible systems are constructed to the latest, most advanced technical standards to comply fully with

* Paper accepted 3 March 1993.

> customer requirements. At the base of all our activities stands the principle: Technology for People and Environment.
>
> (Rudolf Otto Meyer, 1990)

> Engineering is more than applied science. It has a demanding intellectual, creative, philosophical, and human content, the serious study of which has frequently been neglected. It also has essentially pragmatic aspects, since its ultimate measure of success is the satisfaction of practical human needs. In this Report, engineering should be taken to include those design activities described above where functional safety, reliability, quality, efficiency, and economy must be assured, no matter how they are realized.
>
> 'Attaining Competence in Engineering Design'
> (The Design Council and the Engineering Council, 1991)

It is important that graduates acquire not only advanced engineering skills, but expertise in management and business operation. As technology advances, and the needs of clients become more discerning, the cost and professional responsibilities of designing, installing, controlling and operating building services are increasing. Buildings are no longer designed by one person, they are designed and constructed by teams of people. This new course in building services engineering emphasises the balance needed between design and management skills. Students learn about the importance of meeting the needs of clients and users; the development and implications of using advanced technology in buildings; the use of alternative energy resources; and the management of the design and construction processes. In addition, students study a modern European language, thus recognising the expanding market potential for the construction industry in mainland Europe and other countries.

## THE NEED FOR LANGUAGE—THE CULTURAL LINK

> *Thought development is determined by language.*
>
> Vygotsky

English has now become the principal commercial and business language of the world. It has become the second language in Japan, China and Eastern Europe as well as most countries in Western Europe. Those cultures whose lifestyles, art or other forms of expression so many people appreciate, have their root, their essence, in the language they use to express themselves. The sharing of that foreign language thus provides a most intimate link with different countries and cultures.

From a more practical angle, a people's language gives valuable insights into its attitudes, approach and priorities. The delicate formality of French business correspondence, for example, provides clues to French work-practice, and initiates the British or American businessman, used to meetings where policy is decided, to the notion of the meeting as *debate*, wherein ideas are thrashed out, but not necessarily in order to lead to instant *decisions*.

## THE LANGUAGE OF THE POOR COMMUNICATORS

The need for a language dimension to vocational courses is now being recognised [1, 2]. This was not based on the academic merits of stretching science and engineering students into new areas where debate and interpretation were recognised as useful tools, but rather as a grudging recognition that some of the rest of the world either did not, or did not want to speak in English. Commercial pressure linked to international markets has probably focused minds onto the teaching of languages to engineers. This has been given new stimulus recently with the single European Act and the Maastricht summit. Although these points are generally true for all engineering disciplines they are particularly relevant for the building services engineering industry since its business is truly international.

There is a strong belief that engineers are very poor communicators, although this generally ignores the fact that engineers use the language of numbers in a universal way. The need for communication was recognised as sufficiently important to call for the introduction of communication skills, the structure of the industry, and the role of the engineer in society courses to be included in undergraduate engineering courses [3].

## THE INTERDISCIPLINARY VIEW

The home of the course is the Department of Construction Management & Engineering, which, since its inception in 1972, has provided the education in technology and management needed by the construction industry of the future [4, 5]. It has an interdisciplinary view of construction and engineering, and is contributing to the debate concerning the education of both professions [6]. Its staff are from many construction professions and relevant academic disciplines. The department, including within it the Centre for Strategic Studies in Construction, has an international reputation in research and teaching in the design and management of the built environment.

The course is taught in other departments including: Engineering, Meteorology, Cybernetics, Psychology, Economics and Languages. The course, which has been planned using the experience and insight of professional engineers and academics from several of the university departments, represents a significant development in course design in the UK. Equally, the highly

collaborative industry–university approach to project-work represents a major milestone. Building on the enthusiasm and commitment from industry, graduates of the course will be able to make a major contribution to meeting the increasing challenge of international competition and advancing technology with respect to the design, construction and management of healthy buildings.

The course is full-time, it occupies one of the three years duration, which includes an equivalent of one term in each of the second and third years spent on project-work jointly monitored and assessed by the university and industry.

## COLLABORATIVE UNIVERSITY–INDUSTRY PROJECT-WORK

The role of projects in engineering education pre-dates the requirement of the Finniston Report of 1980, since its contribution to theoretical courses was seen as providing the link with engineering practice and its contribution to practical courses was to provide academic depth and test communication and research skills. The formation of an engineer was attempted by placing the student into an environment where problems demanded engineering solutions. Projects of an essentially practical type (EA1) and those demanding theoretical and research skills (EA2) were seen as ways of achieving lower- and higher-order educational objectives as well as producing better engineers.

The Reading BSEDM students carry out a design-and-make project (EA1) involving mechanical and electrical components during the first year of their course.

From its conception the course has been strongly linked with the building services industry and in this way it brings together the qualities of academic leadership and industrial expertise. This co-ordinated approach is particularly well demonstrated in the integrated project-work. The overall plan for the course is shown in Fig. 1. The integrated project-work has been timed to arrive at a point where students have foundation engineering knowledge of sufficient breadth and depth to permit the synthesis, analysis and evaluation of new knowledge.

## EXPERIENTIAL LEARNING

Experiential learning theory offers a different view of the learning process from that which underlies traditional educational methods. The term 'experiential' is used for two reasons: The first, refers to its intellectual origins in the works of Dewey, Lewin and Piaget; the second and the principal one as far as we are concerned is to emphasise the central role that experience plays in the learning process. Traditional learning theories give emphasis to acquisition, manipulation and recall of information, whereas the behavioural learning attempts to introduce some experience into the process by project-work, for example. Experiential learning combines experience, perception, cognition and behaviour.

'Here and now' concrete experience is used to validate and test abstract concepts. Immediate personal experience is the focal point of learning, giving life, texture and subjective personal meaning to theoretical concepts and at the same time providing a concrete publicly-shared reference point for testing the implications of the validity of ideas. By a feedback process, learning transforms initial ideas, feelings and concrete experience into higher-order purposeful action. This involves observation of surrounding conditions, knowledge of what has happened in similar situations in the past, and judgement which puts together what is observed and what is recalled to see what pathway to take next. Piaget describes the dimensions of experience and concept, reflection and action as forming the basic continua for the development of adult thought. Ideas are not seen as fixed and immutable elements of thought, but rather as things that are formed and reformed through experience.

Kolb [7] suggests that learning is by its very nature a tension- and conflict-filled process. New knowledge, skills, or attitudes are achieved by four

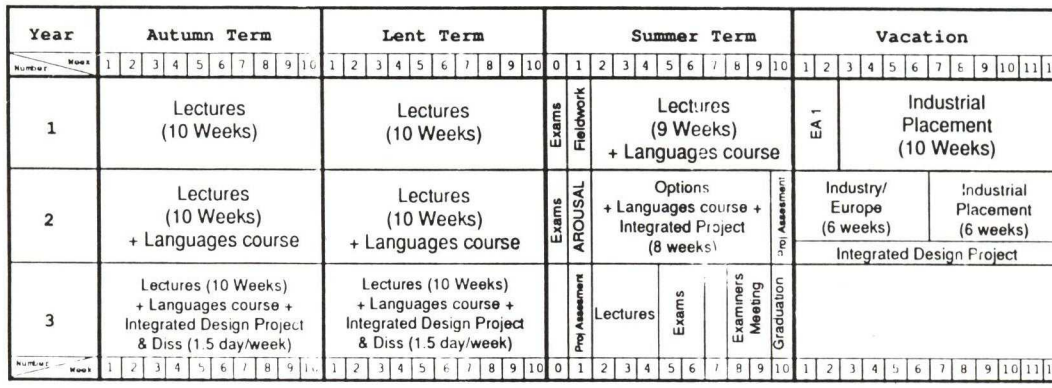


Fig. 1. Structure of the BSEDM course.

principal modes of experiential learning which involve concrete experience, reflective observation, abstract conceptualisation and active experimentation abilities. People need to be able to create concepts that integrate their observations into logically sound theories and they must be able to use these theories to make decisions and solve problems. Thus experiential learning is a holistic concept describing the central process of human adaptation to the social and physical environment, whereby knowledge is created through the transformation of experience.

## THE PROJECT MODEL

Although there is a continuing debate [4, 5, 6, 8] there appears to be a need for a different approach to the education of engineers compared to surveyors and construction managers. Engineers must be able to apply principles to the solution of engineering problems within a management framework.

The new BSEDM project model has been designed to meet the requirements of systems engineers who require design and management skills. In this regard it takes account of the design model proposed by SEED [9]. It is single-student-based and integrative in approach through a binary tutoring system. The use of industrial tutors from the sponsoring companies gives the course a unique dimension. They bring with them engineering expertise and provide realistic project material. This departure from the fictional documentation normally provided is another significant difference between the BSEDM projects and projects undertaken elsewhere.

The BSEDM engineering projects take place in one term of the second year and throughout the third year. The BSEDM students work on four projects during the sixth term (Integrated Projects), they then concentrate on an integrated building project (Integrated Design Project) which continues through the seventh and eighth terms with assessment in the ninth term. This final project is subject to regular review panels which include external as well as internal assessors in a similar way as in Schools of Architecture.

The aims of the Integrated Projects are:

- to allow the student to integrate the different bodies of knowledge which are important to practising engineers and are essential for rigorous decision-making;
- to expose the student to the practice of building services engineering through projects with an academic breadth and depth using real engineering problems;
- to improve the students' skills in visual, written and oral communication;
- to improve the decision-making skills of the student.

The integrated projects, although of relatively short duration, place the aspiring engineer in a model of the design process similar to those of Gregory and Hamilton [10]. The projects are jointly planned by university and industrial tutors in a way which enables each student to integrate their theoretical engineering knowledge with vocational and industrial experience. In this way they realise the objectives of (EA2) in a real world context. This form of experiential learning offers the student an insight into engineering, with additional resources, and insights beyond those offered in a purely academic setting. The subject matter and content of all of the projects is developed as the result of the stimulus of ideas generated by a series of meetings of a joint committee of university and industrial tutors. In this way content is considered against the background of the overall course structure and its objectives. This is not a straightforward exercise for the industrial tutors who are not experienced in the educational process.

Due to the rich array of practical engineering experience of the joint committee a wide range of project titles is developed. The joint committee each year establishes a range of topics which will test and extend the students' knowledge. The content of the integrated projects is considered in relation to the content of the total course. It is weighted to give 75% engineering and 25% management of engineering content.

The apportionment of projects to students is carried out by the university tutors and is generally based on the projects supplied by the sponsoring company. However in order to offer a challenging range of projects to each student, the university tutor may choose from the complete range of projects.

## MENTORS AND ADVISERS

Each student has an industrial mentor, as well as a tutor in the university. The course thus exploits the advantages of experiential learning [7], by using the industrial and academic workplaces. There is also an Advisory Committee for the course which meets approximately three times per year and includes two Consultants as well as six Contractors. In planning the course a wide interpretation of design has been adopted to cover concept design, installation and construction, commissioning, maintenance and facilities management. Thus, the course aims to familiarise students with analytical, synthesis and evaluative skills. Students completing the course are being educated to cope with the increasing rate of change in technology.

## ECONOMIC AND SOCIAL BLEND

Most major decisions in the building industry require a blend of economic and social as well as technical understanding and it is appreciated that

however brilliant the original design this will not be successfully achieved unless management processes are equally as good. Thus, the spirit of the course reflects the view expressed by the Engineering Council in its publication entitled, *Raising the Standard*:

> Engineers of tommorrow must be technically competent, market conscious, commercially adept, environmentally sensitive and responsive to human needs.

This is nowhere more true than in the building services engineering sector where the services costs of a building can be as much as 60% of the total building cost. The impact of modern technology is having a profound affect on building services, not only with regard to electronics, microprocessors and communication systems, but also with respect to materials, energy and the environment. In the next decade it can be expected that the architect will need to rely increasingly on the skills of the building services engineer. In turn, the engineer will have to develop a wider understanding of building design including passive as well as active solutions. Climate changes are now directing a new impetus to saving energy so that equipment has to be designed to operate with very high efficiencies over the heating and cooling seasons. Even more fundamentally, engineers and architects have to rationalise with the client the need for effective energy use. Health in buildings is another aspect that emphasises the need to understand the holistic nature of environmental design.

## EFFECTIVE COMMUNICATION

However good the base of knowledge, it is less effective unless there is good communication. Throughout the course the need for good communication is emphasised. The opportunity to add a language element into an engineering course would always involve some reappraisal of the traditional course structure, if realistic student hours and course content are to be balanced. The Engineering Council specifies the responsibilities of a Chartered Engineer and this includes having an international outlook. Courses are at present undergoing many changes to try and attract school-leavers but more importantly introducing a language course can achieve enhanced education [11].

In practice the time squeeze on all engineering courses makes them intensive due to their vocational nature and the increasing rate of technological change. This is more marked in the BSEDM course at Reading since it contains a core of engineering interwoven with the two distinct strands of management and a modern European language.

At Reading we offer a choice of French, German and Italian which is studied during Part II (three terms) and Part III (three terms) for a total of *c.*170 hours. The Part II course is designed to consolidate and improve conversational, reading and basic writing skills, aiming to provide a solid foundation on which to develop a grasp of the more technical vocabulary relevant to the main degree discipline. In the summer following Part II the student spends six weeks in the relevant country working for a company in the building services engineering industry. This differs from those courses which involve study periods in Europe [12], but offers many of the educational advantages.

The Part III course aims to introduce a more technical vocabulary, building on the students work-experience and using manuals designed for the relevant country's HNC/D-equivalent students. Two technical journals in the relevant language, chosen after consultation with the Building Services Research and Information Association are subscribed to, and multilingual specialist dictionaries are available in the library.

Communication is also developed in other ways. For example, students present a minor study during Part I, and present one of the Integrated Projects to an invited audience of practitioners and academics. In the final year the students have to present their major project-work to a review panel.

## UK AND EUROPEAN INDUSTRIAL PLACEMENT

The students are placed in industry in the UK for the first summer of the course. During the summer of Part III all of the students are placed with European building services engineering companies. In 1992 and 1993, five were placed in Germany. Six were placed in France in 1991 and five in Italy in 1992. Details of the placements are given in Table 1. Some German companies were selected through an established link between Reading and the University of Kassel which has a specialised department that can place students into the workplace both during courses and following graduation. Although Kassel does not run a building services engineering course it has links with many engineering companies. This short period of six week contrasts sharply with other examples of engineering courses with a language component [13].

Most of the French companies were selected with the help of UK consultants and engineers.

Accommodation was generally provided by a family from the placement company who were requested to speak the foreign language only, except in a case of emergency. This provided the student with a considerable amount of time to develop the foreign conversational skills. During working hours it was expected that some English would be spoken. The students were expected to keep a detailed diary and produce a 2000-word technical report in English and a smaller 500-word report in the foreign language. In this way duplication of the contents of the reports is minimised

Table 1. Details of European Industrial Placements Summer 1991 and 1992

| Country | Town | Company | Activity |
|---|---|---|---|
| Germany | Kassel | Rudolf Otto Meyer | Building Services Engineering Design and Construction (one student) |
| Germany | Betzdorf | Heinrich Nickel GmbH | Building Services Engineering Research and Development (one student) |
| Germany | Thuringia | Energietechnik GmbH | Building Services Engineering Design and Construction (two students) |
| Germany | Rodermark | JEWA Industrieplan GmbH | Building Services Engineering and Construction (one student) |
| France | Paris (Chatillon) | CGC Entreprise | Building Services Engineering Design and Maintenance (two students) |
| France | Courbevoie | Sulzer | Building Services Engineering Equipment Design/Installation (one student) |
| France | Nanterre | CEGELEC | Building Services Engineering Plant/System Design (one student) |
| France | St.Jean de la Ruelle | Herve Thermique | Building Services Engineering Site Installation (one student) |
| France | Cergy Pontoise | Spie Batignolles | Building Services and Electrical Engineers (one student) |
| Italy | Milan | Progettisti Associati S.r.l. | Consultants (one student) |
| Italy | Milan | Impianti Tecnologici | Building Services Consultants & Contractors (four students) |

Table 2. BSEDM course syllabus

| Part | Subjects |
|---|---|
| I (two terms) | The Construction Industry |
| | Building Construction |
| | Building Engineering Science |
| | Economics for Managers |
| | Electrical and Mechanical |
| | Engineering Science |
| | Management I |
| | Management and Engineering Applications $ |
| | Engineering Mathematics I |
| | Atmosphere and Climate |

| | |
|---|---|
| II (three terms) | Environmental Engineering Systems § |
| | Electrical Engineering Systems and Control I § |
| | Lighting Acoustics and Noise Control § |
| | Management II |
| | Construction Economics |
| | Human Factors |
| | Engineering Applications (EA1) $ |
| | Modern European Language |
| | Computer Aided Design $ |
| | Atmosphere and Climate |
| | Engineering Mathematics II |
| III (four terms) | Environmental Engineering Systems and Architecture § |
| | Utility and Space Engineering Services § |
| | Electrical Engineering Systems and Control II § |
| | Modern European Language |
| | Business Management Exercise (Arousal) $ |
| | Integrated Projects * |
| | Integrated Design Project and Dissertation * |
| | Management Options (choice of two from: Innovative Technology, International Construction, Site Management and Practice, Construction Project Management, Facilities Management, Business Organisation and Planning, Finance for Managers). |

Note:

$ 100% weighting on coursework and/or laboratory work.

§ 70% weighting on examination 30%, weighting on coursework/laboratory work.

* 85% weighting on project 15%, weighting on project presentation.

All other subjects have 100% weighting on the examination.

whilst the challenge of communicating technical aspects in a foreign language is not.

## BREADTH AND DEPTH: A FRAMEWORK

It is sometimes alleged that a broader course cannot import a depth of engineering knowledge. Building services engineering is, by its very nature, a wide discipline and one course cannot possibly cover all of the basic knowledge in every area. Increasingly it is being recognised that many traditional engineering courses have become over-stocked in factual knowledge, particularly with regard to analytical techniques. This course aims to provide a substantial framework to which the student can develop further understanding by self-learning and experience. The Engineering Council has suggested that the overloaded nature of some single subject syllabuses derives partly from an insistence on cramming students with excessive amounts of material in every subject. Such an approach is neither satisfactory for intended research workers nor for those entering the industrial and commercial worlds. Rather, it is the ability to solve problems and for self-learning which is very important.

## SUMMARY OF COURSE AIMS

The general aim of this course is to provide an educational foundation for a Chartered Building Services Engineer to pursue a career in the design and management of building services and environmental systems.

The specific aims of the course are:

- to provide a knowledge and an understanding of the engineering and management skills required in the building services industry;
- to provide a substantial framework to which the student can develop further knowledge by self-learning, continuing professional education and work experience;
- to enable the graduate of this course to undertake decisions in industry which are based on sound engineering, management, economic, and social knowledge using analysis, synthesis and evaluative skills;
- to foster communication skills and the ability to be an effective member of a design and management team;
- the ability to communicate with other professionals in a second European language.

The structure of the BSEDM course is shown on Fig. 1 and the syllabus for the course is shown on Table 2. The course has received accreditation by the Chartered Institution of Building Services Engineers.

## REFERENCES

1. D. Lloyd, Department of Combined Engineering, Coventry Polytechnic, personal communication (1992).
2. R. J. Saunders, Department of Mechanical and Process Engineering, University of Sheffield, personal communication (1992).
3. G. Ellison, The future pattern of first degree courses in engineering, Report of the Engineering Professors Conference Working Party, Prof. G. Ellison (Chairman), EPC Secretariat, University of Surrey (1991).
4. D. J. Croome, Educational futures for the construction industry, *Ind. High Ed.*, **5** (1), 34–46 (1991).
5. D. J. Croome, Education for the built environment, *Proc. Ove Arup Conf. Ed. Built Env.*, Cambridge (1991).
6. G. K. Cook, Foundations built on science, *Chartered Builder*, **3** (9), 14–15 (1991).
7. D. A. Kolb, *Experiential learning*, Prentice-Hall (1984).
8. F. C. Harris, Some views on education and training in the construction industry, *Chartered Institute of Building Technical Information Service*, No. 140 (1991).
9. P. J. Hicks, Engineering design education—a unique facility, *Proc. 3rd World Conf. on Engng Ed.* (ed. T. V. Duggan), **3**, 199–204 (1992).
10. R. D. Gregory and P. H. Hamilton, Interdisciplinary design project, *Proc. Nat. Conf. Innovative Teaching in Engng* (ed. R. A. Smith), Ellis Horwood, London, 409–14 (1991).
11. R. J. Saunders, The European dimension in engineering education, *Proc. Nat. Conf. Innovative Teaching in Engng* (ed. R. A. Smith), Ellis Horwood, London, 65–9 (1991).
12. D. Lloyd and S. J. Harvey, An engineering student exchange programme between Britain and Germany, *Proc. Nat. Conf. Innovative Teaching in Engng* (ed. R. A. Smith), Ellis Horwood, London, 47–52 (1991).
13. B. E. Mulhall, Engineering degrees and foreign languages, *Proc. of 3rd World Conference on Engng Ed.* (ed. T. V. Duggan), **1**, 279–83 (1992).

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