Introducing Building Energy Simulation Classes on the Web

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This paper reports the background, status and current outcome of a collaborative European Union sponsored international project which aims to promote computer modelling and simulation of energy in buildings by creating hypertext based self-learning course material and publishing it on the World Wide Web.

Key words: education, computer simulation, energy

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INTRODUCTION

Computer modelling and simulation has become a very important technology for assisting engineers with their non-trivial task of designing/analysing buildings and associated environmental systems such that the result is low energy consumption, good indoor conditions and minimal impact on the environment in general.
This fact is recognised by many engineering schools and in several cases the technology has been fully integrated in the curriculum; see for example Clarke (1994).

The World Wide Web is emerging as a powerful medium for dispersing and acquiring all kinds of information.
For various reasons - such as graphical attractiveness, low accessibility threshold level and flat learning curve - it seems to appeal to students, and therefore it might prove to become an efficient platform for educational purposes.

This paper describes the results of a project (see also Hensen et al. 1997) which aims to widely introduce building energy modelling and simulation classes by making hypertext courseware available on the Web.

BACKGROUND

The new democracies in Central and Eastern Europe (CEE) are characterized by an ongoing process of overall transition towards a market economy. This restructuring process involves rapidly changing needs of the labour market. The areas, where lack of skills and knowledge is enhanced by the previous centralized policy, are certainly quality control in engineering and global environmental management.

In the current context we can see an increasing need for graduates who are fluent in the professional language and who are familiar with technical and economical approaches to these problems in CEE countries.

Furthermore, the global effort for integration of CEE countries into European structures underline the emphasis on compatibility and equivalence with EU universities.

This paper stems from a project which aims to address these needs by restructuring curricula of four higher education institutions in Slovakia and three higher education institutions in Bulgaria by introduction of energy modelling and simulation courses using information technology.

The project (funded as Structural Joint European Projects by the European Union TEMPUS programme, a trans-European cooperation scheme for higher education) attempts to reach two major target groups. Firstly, final year (or MSc) students in building or mechanical engineering, in order to equip these students with required skills and knowledge, before entering the competitive labour market. Secondly, a structure will be created, which enables provision of continuing education for industry (in collaboration with industrial partners).

This three year project (1995 - 1998) comprises two main components: provision of necessary hardware for the CEE partners, and development, implementation and integration of courseware. This paper focusses on the courseware component.

COURSEWARE

The goal to create integrated and interdisciplinary classes and the aim to emphasize compatibility and equivalence with EU universities, led to the conclusion that the classes need an international dimension, and are therefore in the English language.

The courseware is organized as (relatively) compact modular texts with emphasis on graphical representations. The classes are prepared in hyper-text (HTML, Hypertext Markup Language) and include Computer Aided Learning features such as built-in excercises, assignments and sample answers. This enables the material to be used in self-learning mode.

The compact and modular courseware structure allows for a significant portion of interdisciplinary material to be easily integrated. Furthermore, the courseware can easily be reorganized in order to suit additional purposes and target groups (i.e. continuing education for industry) or later to incorporate new developments in the field.

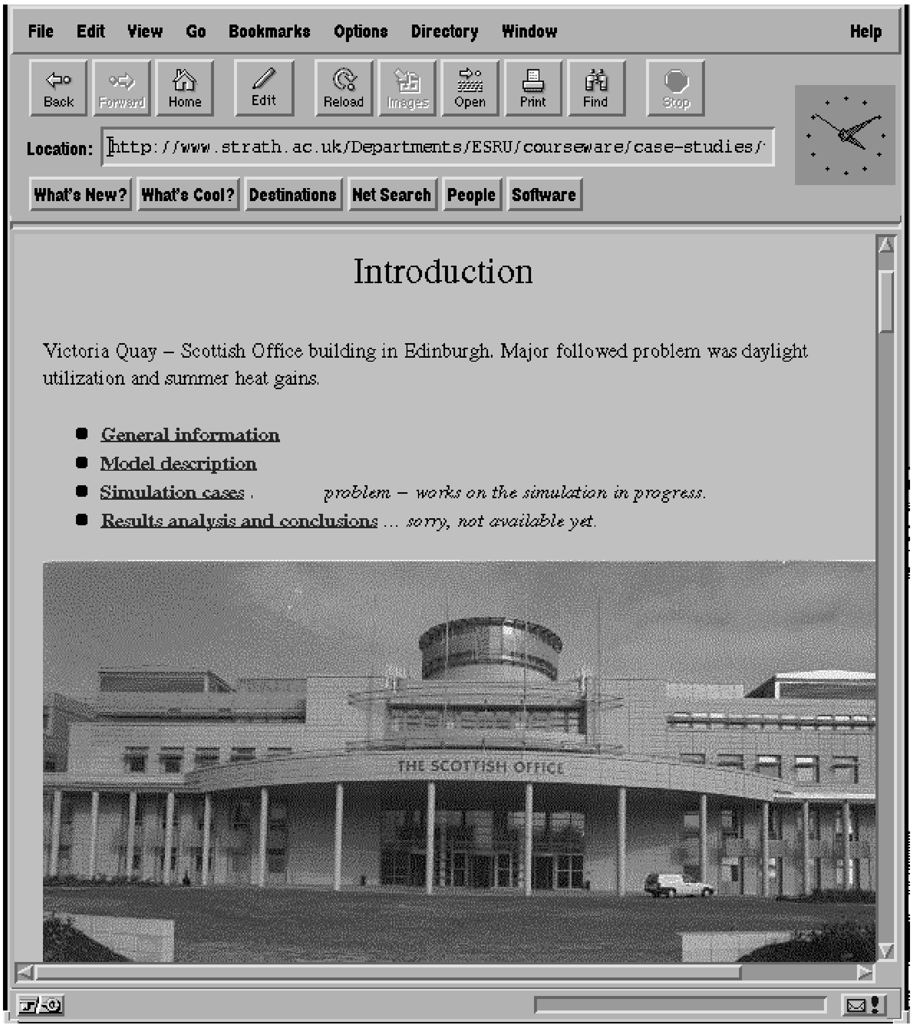

Figure 1 Introduction to the case study regarding daylight utilization and summer heat gains in a prestigious Scottish office development

The courseware currently constitutes three common "international" classes. The idea is that eventually about 95% of the material will be identical in the partner institutes, and about 5% will be specific to allow for special needs such as national codes, local practices and materials. In this way by the end of the project there will be set of fully EU compatible and equivalent classes.

Currently the courseware comprises the following three classes which are designed to be taken in chronological order:

Why should you use modelling and simulation for the design of buildings and environmental control systems?

This is a short introductory class which aims to generate interest and motivation for using the technology of computer modelling and simulation of energy in buildings.

Using a range of real case studies, students are given an overview of the main tasks involved in a simulation study:

* problem analysis and model creation;
* setting up and performing simulations;
* analysing results and generating "design knowledge".

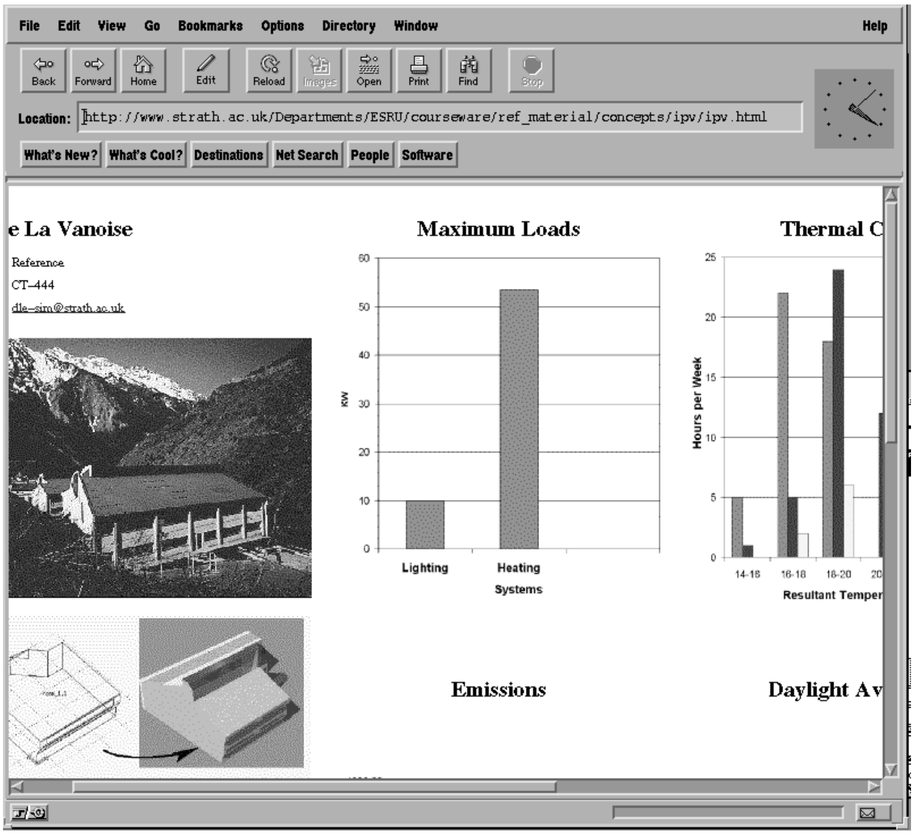

Figure 2 Some results of the case study regarding daylight usage in a French school

Figure 1 and Figure 2 are taken from two different case studies and illustrate the introduction and some simulation results respectively. Currently (June 1997) the list of case studies comprises:

Case studies originating from ESRU:

Daylight in a school in Modane, France;

Daylight in a prestigious office in Edinburgh, Scotland;
Summer overheating in offices in Glasgow, Scotland;
Sunprotective or thermochromic glazing for a klinik in Germany;
Wet central heating system modelling.

Case studies provided by others:
Natural ventilation in a unversity building in Leicester, England;
Retrofitting multifamily housing in Dolny Smokovec, Slovakia;
Summer overheating of a conservatory in Stupava, Slovakia;
Thermal bridges in panel system T06B constructions in Slovakia.

The various case studies aim to illustrate that simulation can be used to predict and assess energy consumption, load distributions, air and fluid flow rates, thermal and visual comfort, daylight distribution and much more. Obviously only a tiny fraction of the building performance characteristics which can possibly be predicted using modelling and simulation are illustrated in the case studies regarding design aspects of offices, hospitals, multi-family housing, conservatories, HVAC systems, etc.

The case study material (in each case comprising: background, introduction, model and climate, simulation results, and conclusions) stems from various sources and covers a range of countries and a variety of modelling and simulation programmes.

How can you practically use a real building energy modelling and simulation environment?

Once students are interested in the technology in general, they (hopefully) want to learn and use a real modelling and simulation system.

Since you cannot learn how to use software unless you are specific about the programme, this class is a pratical training course for a particular software environment: the ESP-r system for building and plant energy simulation (ESRU 1996).
ESP-r is a dynamic thermal simulation environment for the analysis of energy and mass flows and environmental control systems within the built environment. ESP-r allows designers to assess the manner in which actual weather patterns, occupant interactions, design parameter changes and control systems affect energy requirements and environmental states.
The "r" relates to the research and EU reference version. ESP-r is developed and distributed by a consortium which is principally based at a university in Scotland, UK. This university

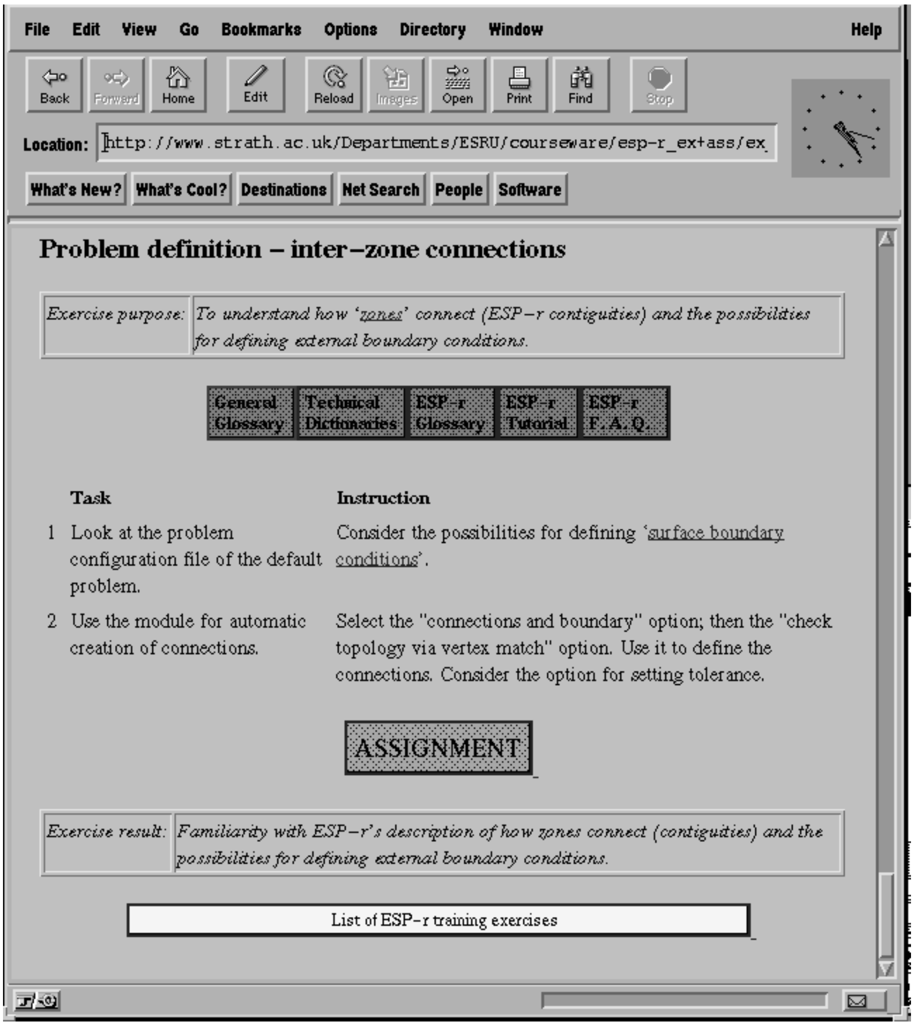

Figure 3 Typical example of a training exercise description

continues to develop ESP-r and to support the needs of several research, educational and commercial organisations in its application.

The practical training course is based on a series of hands-on exercises and assignments, which should be sent by e-mail to the supervisor. The purpose of the assignments is two-fold:

- in a training course or lecture/tutorial series, they enable the instructor to assess whether or not the training material is being absorbed effectively;
- for the student they form a series of "real world" consultancy sub-tasks enabling them to check whether the training material is understood, while at the same time placing the ESP-r simulation tool in a realistic context.

The exercises are designed to progress ESP-r users from the category of novice to specialist over a period of time which will depend on the individual's aptitude and stamina.

The sets of exercises make the student familiar with the main features of the system from the elementary level to comprehensive system simulation:

FOUNDATION LEVEL EXERCISES

Preparatory

* *Getting started on the workstation.*
* *Configuring the workstation for ESP-r use.*
* *Overview of ESP-r.*
* *Exploring the in-built training exemplars.*

Basics of ESP-r

* *Defining a problem to ESP-r - the basics*
* *Simulation - the basics*
* *Results analysis - the basics*

Problem definition

* *Problem definition - databases*
* *Problem definition - geometry*
* *Problem definition - constructions*
* *Problem description - operations*
* *Problem definition - inter-zone connections*

Simulation and analysis

* *Climate data and its analysis*
* *Control capabilities*
* *Simulation - advanced facilities*
* *Results analysis - additional facilities*

Review

* *Review of files and program modules*
* *Review of progress*

INTERMEDIATE LEVEL EXERCISES

Specific simulation facilities

* *Shading and insolation analysis*
* *Mass flow analysis*
* *Plant and control modelling*
* *Lighting analysis*

Further simulation capabilities

* *Other ESP-r facilities*
* *Upcoming ESP-r features*

EXPERT LEVEL EXERCISES

Advanced topics

* *Making Models: CAD and Attribution*
* *Making Models: Fluid Flow, Plant and Control Networks*
* *Making Models: Enhanced Resolution*
* *Integrated Performance Appraisal*

Practical ESP-r model development
** Edit/ compile/ link test cycle*

In addition to the above mentioned general case studies, there are also specific ESP-r training exemplars which are designed to illustrate selected features of modelling and simulation using ESP-r.

In order to be able to use and appreciate ESP-r, it is assumed that the student has access to a Unix workstation and that a copy of the ESP-r software has been installed by the system manager.
For research and educational purposes the university is normally able to offer a free system licence. The restrictions imposed by the licence agreement are primarily that it is not allowed to undertake commercial work or pass copies to a third party.

How does building energy modelling and simulation actually work?

Some of the students may want to know more and will be interested in how modelling and simulation actually works.
The material in this module aims to give an understanding of the theoretical and operational principles underlying this new technology. In a series of elements as outlined below, the class introduces the assumptions and limitations which underlie the methods currently used to appraise the energy performance of buildings and their associated environmental control systems. Particular attention is given to methods for representing and integrating building energy and mass transfer processes. The subjects are developed from basic principles assuming limited knowledge of computers and application software. The associated exemplars are designed to demonstrate theoretical concepts introduced in the tutorial material, and to gain practical experience in using this new technology.

This class addresses the following subjects:
Part 1: Introduction
Problem domain and scope
Energy modelling techniques

Part 2: Modelling Building Energy Processes
Heat and mass transfer through solids
Heat and mass transfer by convection

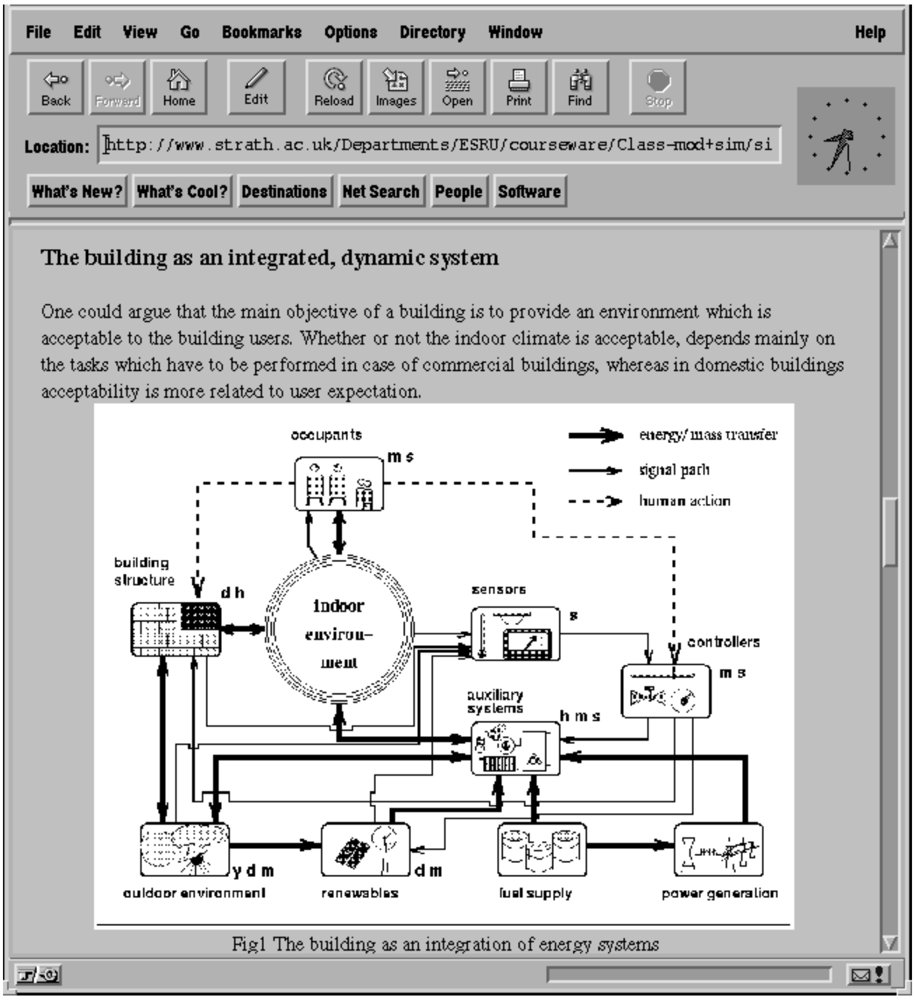

Figure 4 Typical example from theory section showing the building as an integration of energy systems

Heat and light transfer by radiation
Energy transfer by electricity

Part 3: Modelling Building Energy Systems
Building structure
Auxiliary systems
Control systems
Occupants
Outdoor environment
Integration

Part 4: Simulation for Environmental Engineering
Quality control
Methodology
Case studies

Part 5: Close
Modelling and simulation context
Conclusions

In total the class has 17 sub-modules each comprising a list of key concepts, an outline of the lecture structure, a summary, course material for studying by the student, and often links to further reading material.

Each module ends with an assignment (plus some sample answers) which aims to link the theory to practice. As an example, the assignment following the sub-module on quality control reads:

As a member of the design team you are using modelling and simulation to assess the relative performance of various fenestration options for a new multi-purpose building. The design is still in an early phase, and detailed information is not yet available.

Discuss which error sources (internal or external) are likely to be more dominant in this situation, and suggest a procedure or approach which will reduce the impact of the error sources on your advise to the other team members in terms of which fenestration option will be best.

Both the Introduction class and the Theory class are very general in terms of modelling and simulation software. For reasons indicated above only the Practical class is specific in terms of a software product.

In developing the hypertext material we started from existing material such as existing course notes, papers, articles etc. This material was then transformed into HTML format, cross-links were established (for example from practical and theory sections to case studies) and where possible links to other Web sites were introduced (for example to a Unix training site and to various building energy related sites).

At various locations in the text, students have access to additional information under a variety of topics. For example:

- a general glossary of terms related to modelling and simulation for environmental engineering;
- technical dictionaries comprising terms commonly used in modelling and simulation of energy in buildings, currently in Bulgarian - English, Czech - English, Dutch - English, Slovak - English, and the inverse forms of these;

- a collection of links to other World Wide Web sites providing information in the area of energy in buildings;
- various ESP-r specific materials such as an ESP-r glossary of terms; an ESP-r tutorial; and an ESP-r "Frequently Asked Questions" collection.

In this way there exist a number of classes which form study material which is not "restricted" as is the case in a normal (flat) text book, but which will allow students to find more and more information by digging deeper into the Web material. Basically the assignments are designed and used to ensure a minimum level of studying.

On completion of the three classes students should appreciate the capabilities and limitations of the various methods for assessing the thermal behaviour of buildings, including energy efficiency and indoor comfort. They should also:

1 appreciate that environments result from complex interactions of many energy and mass transfer mechanisms;

2 have a basic knowledge of how to apply computer modelling and simulation to address this complexity;

3 understand the theoretical and operational principles of contemporary modelling programs;

4 appreciate the limitations of current design support and performance evaluation tools and the issues to be addresses to bring about their improvement;

5 possess practical skills in using the technology in an environmental engineering context.

IMPLEMENTATION

As indicated above, initial versions of the courseware has been developed. Currently this constitutes about 12 Mbyte of HTML and image files.
The courseware has been implemented on various Web servers for efficient access from the partner countries. (Access time and speed to and from CEE based universities tend to prohibit efficient student interaction.) The preferred Web location for global access is from the university in Scotland (ESRU 1997).

The information technology aspect of the courses allows self-learning, relatively easy maintenance of the course material, but - most importantly - it provides almost unlimited dissemination possibilities (anyone with INTERNET can access and use the course material).

This ensures that the project deliverables will be "automatically" dispersed to other universities and schools within and outwith the countries involved, as well as to practitioners in the construction industry and elsewhere.

As part of the Tempus project the material is currently being introduced in new and existing classes. Due to its modularity the material can be incorporated into the curriculum either as complete classes or in bits and pieces e.g. case studies, parts of theory, etc. The modules can be used for self-study or may be used as additional reading in other classes.

In the University of Strathclyde the courseware has already been fully integrated in two under-graduate classes and in one post-graduate module. The courseware is also used for continuing education purposes.

In order to assure successful implementation, for the other partners target groups with appropriate time schedules were defined, for instance in the case of the Slovak Technical University:

First year:

> Post-graduate students were the first target group in order to test the prepared newly introduced course content. The post-graduates form an integral part of the project, because they are considered as staff members and their updating and retraining will have a significant impact during second and third year of the project.
>
> Integrated interdisciplinary courses were developed by restructuring existing MSc classes in Building Engineering and introduction of three new courses by implementing them within the existing MSc degree curriculum.

Second year:

> A limited group of final year students has been selected as the target group in this stage of the project in order to enable a final check before introducing the new courses in the normal educational curriculum.
>
> Two existing final year classes (15 weeks each) on Energy Efficient Building Design and on Special Building Construction have been upgraded by introduction of simulation and modelling into the tutorial part of these existing courses.

Third year:

> All final year students of the MSc in Building Engineering degree course in the normal curriculum. In this stage, also continuing education courses for industry will be made available to enterprises and practice.

RESULTS

Successful completion of the project will provide the following results:

CEE participants:

necessary hardware infrastructure for education (teaching/computer laboratories), software for education, updated and trained staff, training capacities for continuing education to be offered to industry, restructured existing courses, and introduced three new classes.

All participants:

three EU compatible and equivalent courses, international links with other universities, and the courseware as above.

It is too early to report on results in terms of increased/decreased learning efficiency.

Current feed-back from students suggest that they appreciate the medium in which the material is presented. Early observations and experience suggests that on average students learn quicker and more independent; ie putting less demand on the supervisor/ teacher.
Although some students report ‘to get lost’, most students are positive, especially regarding the appearance andrichness of the material, which actually encourages students to dig deeper at the click of a (mouse) button.

CONCLUSIONS AND FUTURE WORK

One of the major outcomes of the project can be characterized as unlimited global dissemination potential of the courseware which is being developed within the project.

As indicated above, the project is not finished yet, and indeed it is our intention to continue development and improvement of the hypertext courseware once this Tempus project is completed. In a sense, development of this type of courseware is just starting. Many aspects need to be explored further. We therefore invite feed-back and will obviously very much appreciate any contributions.

Future work will certainly involve comparison of this hypertext courseware to more traditional course notes and text books in terms of educational efficiency.

Acknowledgements

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References

J.A. Clarke, J.L.M. Hensen, C. Johnstone, and R.C. McLean 1994. ‘‘Environmental engineering at the University of Strathclyde in Glasgow,’’ in *Proc. 1st Conference of the Forum for Environmental Engineering Education, 7-9 Sept 1994*, University of Abertay Dundee, Dundee (UK).

J.L.M. Hensen, M. Janak, N.G. Kaloyanov, and P.G.S. Rutten 1997. ‘‘Introducing IT based energy simulation courses in Central/Eastern Europe,’’ in *Proc. 5th IBPSA World Congress "Building Simulation ’97", Prague, Sep 1997,* vol. II, pp. 31-37, Int. Building Performance Simulation Association, Prague.

ESRU 1996. ‘‘ESP-r A Building Energy Simulation Environment; User Guide Version 9 Series,’’ ESRU Manual U96/1, University of Strathclyde, Energy Systems Research Unit, Glasgow.

ESRU 1997. *Building energy modelling and simulation self-learning modules,* University of Strathclyde, Enery Systems Research Unit, Glasgow. URL: **http://www.strath.ac.uk/Departments/ESRU/courseware/Class-mod+sim/Intro.html**