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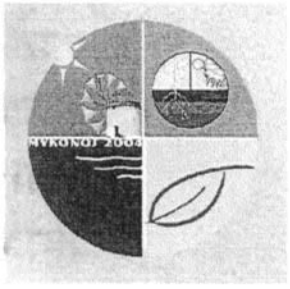

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Mykonos, Greece

June 28 –July 1, 2004

SMART ENERGY MANAGEMENT IN THE BUILT ENVIRONMENT

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ABSTRACT

This paper presents an e-learning tool on smart indoor environment and energy management in the built environment. The methodology for the syllabus development is presented and justified. Questionnaires are developed and sent to potential trainees as well as to relevant companies to collect information regarding their training needs. Furthermore, the relevant courses offered by universities or professional bodies around the world are investigated. The syllabus is developed according to the results obtained through these two studies. The training tool consists of seven modules covering introduction, the control systems for smart buildings, the communication protocols, sensors and actuators, economic issues and contracting energy management.

ΕΞΥΠΝΗ ΔΙΑΧΕΙΡΙΣΗ ΕΝΕΡΓΕΙΑΣ ΣΤΟ ΔΟΜΗΜΕΝΟ ΠΕΡΙΒΑΛΛΟΝ

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ΠΕΡΙΛΗΨΗ

Η παρούσα εργασία παρουσιάζει ένα εργαλείο e-learning σε έξυπνη διαχείριση εσωτερικού περιβάλλοντος και ενέργειας στο δομημένο περιβάλλον. Η μεθοδολογία για την ανάπτυξη του περιεχόμενου παρουσιάζεται και αιτιολογείται. Αναπτύσσονται ερωτηματολόγια και αποστελλονται σε πιθανούς εκπαιδευόμενους, όπως επίσης και σε σχετικές εταιρίες για να συλλεγούν πληροφορίες σε σχέση με τις ανάγκες κατάρτισής τους. Το περιεχόμενο αναπτυσσεται με βάση τα αποτελεσματα μέσω δύο μελετών. Το εκπαιδευτικό εργαλείο αποτελείται από επτά μέρη που καλύπτουν την εισαγωγή, τα συστήματα ελέγχου για έξυπνα κτίρια, τα πρωτόκολλα επικοινωνίας, τους αισθητήρες και μηχανισμούς κίνησης, οικονομικά θέματα και θέματα διαχείρισης συμβολαίων.

1. INTRODUCTION

The Building Energy Management and Control sector is now passing its phase of maturity overcoming the barriers that had confined its applications to only new buildings incorporating the Building Energy Management System (BEMS) in the construction phase. Nowadays, recent developments in the sector have lead to open protocols and the integration of artificial intelligence aiming to minimise the energy use and to simultaneously optimise the indoor comfort, which determines the productivity or well-being of occupants [1]. Therefore, the sector is a challenging field for vocational training targeting the following groups of people:

- Young engineers that want to enhance their employability in the developing energy market and to improve the quality of their initial education and qualifications;
- Young students who intend to leave their initial education with higher skills;
- Managers and skilled engineers oriented to energy management sector, for lifelong skill acquisition in order to increase their competency with the latest technological developments;
- BEMS manufacturers and services providers who need to improve the effectiveness of training customers and to maintain a strong connection with training providers;
- Trainers who want to improve their competence by approaching innovative Internet based tools for education and training;
- The unemployed, young engineers, female engineers, the disabled, etc. who need access to courses via Internet;
- Energy efficiency auditor who investigate and assess the energy efficiency of buildings.

This paper describes an e-learning tool on the intelligent energy management in the built environment. Providing training through the Internet increases the accessibility to a more diverse audience and decreases the cost. As a result the take-up of vocational training can be improved and awareness of energy issues and solutions can be raised.

2. THE TRAINING METHODOLOGY

Of fundamental importance in developing a successful Internet-based course on energy management and control in the built environment is that both the market needs and existing education sources are well understood. Based on this the gap between the market need and the existing education sources is identified and a suitable CPD course can be accordingly developed. Two activities are undertaken to fulfill this goal:

- A market survey study through questionnaires oriented at: (i) individuals (architects, mechanical & electrical engineers, control engineers, facilities managers, etc) about the issues related to their needs for training that can improve their productivity and effectiveness; (ii) relevant companies with major business focus on the area about the issues related to their current practice of staff training and their expectation for a CPD course such as the one to be developed in this study.
- A literature study on the existing education sources offered at different levels, including undergraduate, postgraduate, and CPD. Relevant universities and professional organizations around the world are approached for the information about the courses they offer.

Key findings obtained from the market survey are briefly summarized as below:

- Major knowledge gap between the graduates from universities and a skill engineer who can effectively carry out the work covers the following aspects: Application of theory, such as control engineering, building services engineering, and energy conservation in the built environment; familiarity with commercial BEMS; communication protocols and standards; best practice of design, commissioning and maintenance of BEMS.
- Given the following four choices of training focuses, most individuals and companies consider that the best practice of both control and building services engineering are of the highest

priority: fundamentals of control engineering in the built environment; best practice of control engineering in the built environment; fundamentals of building services engineering; best practice of building services engineering

- Regarding to the current practice of staff training, very small proportion is carried out through CPD (Figure 1).
- Regarding the training methods desired by individuals exists a significant discrepancy between the desired one and the current practice; more training through CPD is desired (Figure 2)
- Regarding to the length of training (Figure 3), individuals want to have more hours of training per year than companies think they should be offered.
- Regarding the suitability of CPD courses for improving effectiveness of working in the BEM industry (Figure 4), almost all responding surveyed regard CPD as a suitable courses for them, with 97.1% giving a score of above 3 (5 refers to most suitable).

Key findings obtained from the literature study of existing education sources are:

- Courses offered in universities lack practical contents. As a result, most graduates are found to need training to enhance their ability of employing theory in their practice.
- Courses offered by professional organizations are normally not comprehensive. Most of these courses are focused on a very particular problem and fail to provide a clear overview about the BEM industry, which was found through the survey mentioned above to be critical for individuals to develop their skills.
- Courses offered by system vendors are designed for their existing and potential clients. Consequently these courses are biased and normally fail to release completely accurate information.

Based on these findings, a CPD course is developed, which:

- Covers the most important aspect of energy management and system control in the built environment (see the following section for details).
- Contents are organized in seven modules that can be flexibly offered to individuals of different background and capability.
- Length is 50 hours so that it can be finished within one year.
- Is delivered to end-users through either the Internet or CD-ROM.

Module 1: Energy in the Built Environment

This module covers the following topics [2,3,4]:

- Definition of BEMS with focuse on "intelligent building".
- The need for BEMS: Definition of sustainability in buildings, global warming and energy consumption in buildings, the importance of the building sector in terms of energy efficiency and productivity and the role of intelligent buildings in sustainability.
- What is a BEMS: The basic structure of a BEMS is described in this section.
- Historical overview of Energy Management in buildings.
- Indoor comfort requirements: the definition of thermal comfort and thermal comfort indices, visual comfort and the parameters that influence the visual quality, indoor air quality and indoor air pollutants and occupants' response to control systems are included.
- Fundamentals of Building automation: feedback control, HVAC control, lighting control.
- Life cycle assessment: definition of life cycle costs, the primary uses of life cycle costs, and a short description of Life Cycle Analysis.

Module 2: Control systems oriented to smart buildings and building services [5-11].

- Single Input - Single Output Systems.
- Multivariable systems
- Intelligent control: fundamentals and design of fuzzy logic control systems, an example of a fuzzy logic controller for thermal, visual comfort and indoor air quality for buildings. Moreover the section incorporates neural networks technology.

Module 3: Communication protocols and components in smart buildings energy management.
The module covers the following topics [12, 13]:

- Introduction to communication protocols and components and process of energy management programming.
- 'How much energy can be saved' by Energy Management practices and the breakdown of energy use in buildings.
- The architecture of the BEMS systems.
- Communication protocols features, and control systems network wiring structures. EIBUS Usage, Bus Line, Topology, Transmission Power Configuration and Suitability for rehabilitation. The basic properties, integration, usage, maintenance and applications of PROFIBUS. Overview, performance facts, applications, benefits and drawbacks of CANbus. Description of neurons, nodes, expandability and LonTalk protocol. Description of BACNET's characteristics, advantages and appropriateness. Advantages, disadvantages and applications of Bitbus. Finally a comparison of the communication protocols is integrated into the specific section.
- Advanced courses in EIBUS technology, PROFIBUS, CANbus, LonTalk, BACNET and Bitbus protocols.
- Case studies: implementation of the various protocols.
- Sensors: Climatic parameters and sensors used to measure them. Engineering parameters such as mass flow, heat flow and heat flux.
- Actuators and their interconnection with the communication protocols.

Module 4: Tools for development, monitoring and testing smart buildings
This module covers the simulation tools that incorporate control techniques into buildings. For example ESP-r, TRANSYS, etc. are some of the examples of simulation tools. Simulation tools are computational methods that are employed in architectural and HVAC design and research of building systems to determine: (i) design values; (ii) comfort conditions within the building; (iii) the thermal performance of the building envelopes; (iv) the performance of the mechanical systems; (v) power requirement and energy consumption;
Development kits for smart buildings are usually offered by the manufacturer of smart components (e.g LonWorks and the LonBuilder development kit, etc). The monitoring tools are plug and play solutions for the monitoring of smart buildings via Internet.
The application of simulation tools in the management of building systems are emphasised in this training tool. The course is not designated to be a tutorial of particular simulation tools. Therefore it only provides brief information of selected simulation tools. The tools to be introduced are selected among the most popular and reputable ones with the following criteria: (i)Reputation; (ii)Simplicity in use; (iii) Availability of needed resources; (iv) Applicability in the management of building systems.
These selected tools include: APACHE, BLAST, DOE 2.0, ENERGY 10, ENERGY PLUS, ESP-r, HVAC Sim+, TRNSYS [19].
Module 5: Economic issues. Demand side management.
Economic indices can be incorporated in this module indicating the turnover of such solutions, etc. Sustainability indices are included also in this module. There are two major chapters in this module:

- Tools for economic assessment (definitions, investment costs, operating costs, maintenance costs, payback period, life cycle costs, financing modes, energy cost rates, etc.).
- Criteria for the smart buildings energy management evaluation (assessment, criteria, sustainability, economic methods, cost-benefit assessment methodology).

Module 6: Smart buildings energy management contract.
There are three major chapters in this module:

- Process of BEMS installation: how to prepare and to perform an energy audit and survey, how to develop control strategy.
- Contract energy management.

- Presentation of case studies.

Module 7: Project

This module offers several projects related to the course syllabus.

3. THE STRUCTURE OF THE TRAINING TOOL

The tool has two parts: (i) the front end which is the part of the tool that the trainee uses; (ii) the back end which is the administrative part of the tool manipulated by the trainer. The main aspects defined are discussed in the following sections.

Tool Structure

The implementation of the tool requires storage of the modules of the educational content. Additionally, each module's pages are stored in a particular format:

- MODULES (Module ID, Title/Description of the module)
- PAGES (Page ID, Page Title, Page Short Description, Page Source, Module to which the page belongs, estimated learning time, next Page to be presented according to trainee's level of expertise).
- TRAINEE_PROFILE (User/Trainee ID, Full name, Contact Information and Expertise level for each module).

Internet Page Components

The Internet based course consists of a number of modules, and each module consists from a number of Pages. The relevant knowledge is presented in a Page through the following Internet Page Components:

- Title of content: The trainee is able to see the Page's position in the content in the whole course.
- Help on the Tool: Hints and Help on the use of the tool.
- Access to relevant other Pages.
- On-line Help: The on-help is provided to facilitate the use of the course contents by the trainee.
- Interactive Features: to perform interactive features, such as Quiz with immediate assessment.
- Calendar: to schedule the learning and mange the progress and events.
- Personal Briefcase: to manage the knowledge that is particularly of interest to a trainee and will be kept if the form of bookmark.
- Logos and Legends: relevant icons or legends are used to indicate the relevance to the contents being presented.
- Web-sites: to access a list of relevant web-sites when given by the material organizers.
- Glossary and Terms: to give a glossary with the specific terms used.
- Partners Info: to give information on the partners of the project.
- Authors Info: to give information on the background and CV of the authors/tutors.
- Module Structure: a visual graph representation of the prerequisites modules for each module.

On-line Help

Some of the course contents may be presented as on-line help but it has to be specified by the material organizers.

Interactive Features

The main interactive features of the Web based tool for Smart Buildings Energy Management are:

Login – Trainee Profile

The trainee acquires a username and a password during the first login or registration process. Some additional information concerning the trainee's profile are also asked. The trainee has the ability to change his/her contact information, at a later time.

Story Board

Training for every module is structured according to the expertise of the trainee on the module's specific subject. The trainee is asked to define the level of expertise on the specific subject upon entering the module for the first time. The Web tool then automatically suggests the syllabus that the trainee should follow according to his/her expertise. The expertise levels are the following:

- Novice

- Medium expertise
- Good expertise
- Expert

The personalized syllabus is defined by the administrator/trainer and can be changed. Although specific pages are suggested, the trainee has access to all the pages that belong to each module. With the story board the trainee saves training time.

Quiz

There are a set of questions for each module. Each question is associated to a number of alternative answers, multiple choices.

A scoring mechanism is developed to calculate the trainee's score by simply summing up the correct answers and thereby deducing the percentage of correct answers. The outcome of the scoring mechanism is compared to a predefined score-assessing table defined by the administrator/trainer. Only the trainee that has passed the quiz is able to view the score and the answers and explanations on each question. The trainee who failed are not allowed to view any information and has to study the module longer and re-take the quiz. Each time the trainees take the quiz the questions are randomly selected from a questions database. Therefore the trainees do not answer to the same set of questions over and over.

Table 1: The trainee's calendar for each module

Module Title: INTRODUCTION	**Time required to complete the module (hours): 35**	**Time period required to complete the module (days): 14**
Page Title	***Estimated Learning Time (hours)***	***Time Spent up to date (hours)***
Page 1 title	1	2
Page 2 title	2	2
Page 3 title	2	3
Page 4 title	5	4
Total Hours	35 hour	*37 hours*
Quiz Date	***Pass/Fail***	***Grade***
15/6/02	Fail	-
20/6/02	Pass	*73%*
Starting Date	***Completion Date***	***Duration (in days)***
5/6/02	20/6/02	*16 days*

Calendar

The training procedure is scheduled on the basis of the information about the trainee's expertise and is managed by the Calendar. The Calendar closely monitors the training progress and assesses the progress against a specific schedule defined by the trainer. However, flexibility is given to the trainees.

The calendar is a progress checking-table which records and presents data by module. The table for each module and for each trainee is tabulated in Table 1.

Assessment is done in the following way: Each time the quiz is taken, it is recorded at the calendar. Also the time is kept in two ways. Time in hours spent visiting the pages of the module, and time period in days to complete the module.

The starting date for each module is considered to be the date on which the module is entered and the level of expertise is defined by the trainee on the specific subject the module is concerned with. The completion date for each module is considered to be the date on which the quiz was passed for the given module.

The estimated learning time for each page (in hours) is determined by the trainers as well as the time period required to complete the module (in days), and do not vary with the degree of expertise of the trainee. The total estimated time (in hours) for the module, is the sum of the estimated time of

each page that form the syllabus, according to the trainee's expertise. The system keeps track of the time up to date that the trainee spent on each page as well as the total time spent on the module.

Personal Briefcase

The personal briefcase consists from a set of pages the trainee has added in (i.e. favorites or bookmarks). On each page, a link exists that adds the specific page automatically to the briefcase if selected. Another link moves to the trainee's contents of the briefcase.

4. DISCUSSION AND CONCLUSIONS

The Internet based training tool is still in development phase (http://ape.chania.teicrete.gr/smart-be). The tool offers training to building services engineers, facility managers and architects. The syllabus is personalized according to the level of expertise of each trainee such that the trainee can more effectively gather information about intelligence in buildings.

Acknowledgements

The development of this tool is partially sponsored by the European Commission under the framework of Leonardo Programme through project SMART-BE (EL/2000/B/P/114146).

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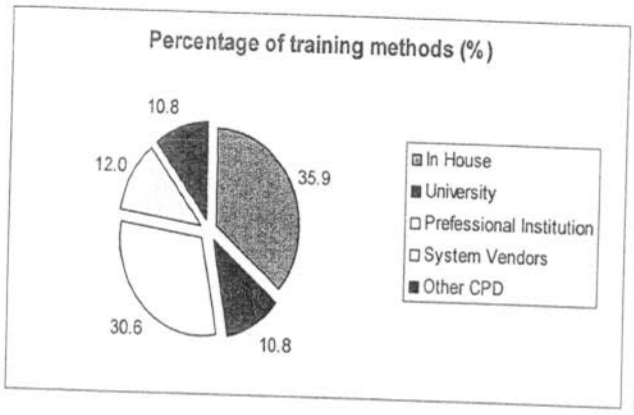

Fig. 1. Percentage of training methods in the current practice of staff training

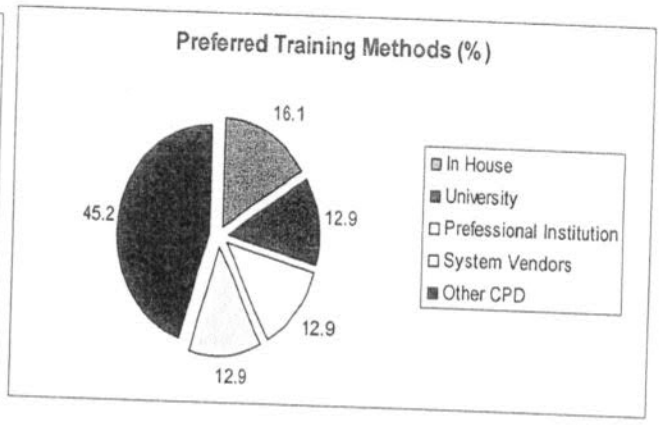

Fig. 2. Percentage of training methods desired by individuals

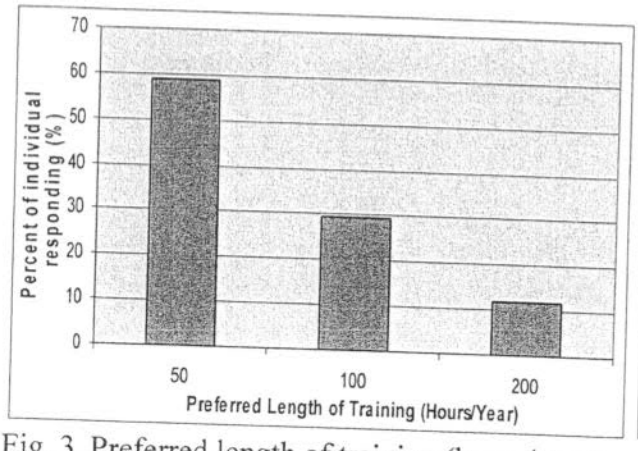

Fig. 3. Preferred length of training (hours/year)

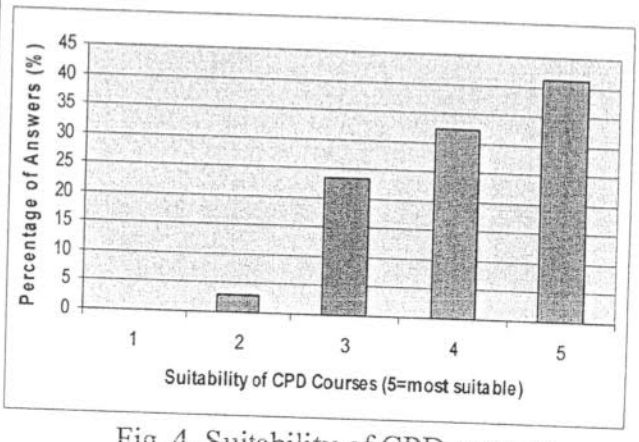

Fig. 4. Suitability of CPD courses