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DEVELOPING A WEB-BASED LEARNING ENVIRONMENT FOR BUILDING ENERGY EFFICIENCY AND SOLAR DESIGN IN HONG KONG

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Abstract—With the growing importance of renewable energy and energy efficient technologies, there is an urgent need to integrate the new knowledge in these fields into our education system. The Internet and World Wide Web (WWW) can be an effective medium for the delivery of good quality education and training for these subjects, because of its flexibility, timeliness, and breadth of access. This paper investigates an approach for developing a web-based learning environment for building energy efficiency and solar design. The use of the WWW as a delivery system for educational materials and information resources is discussed. Some of the technical and pedagogical issues associated with the web-based techniques are identified. The experience from a pilot study at the University of Hong Kong is evaluated and the major considerations for the design of web-based learning are presented. It is hoped that the present study could stimulate more discussions and innovative ideas for exploiting the educational potential of the WWW for energy education.

1. INTRODUCTION

Energy crises and environmental concerns have raised much global interest in energy efficiency and renewable energy. In both developed and developing countries these subjects are emerging as an important interdisciplinary area of professional and general education. The need to improve solar or renewable energy education has been raised and discussed by many people (Charters, 1996; Elliott, 1996; Garg and Kandpal, 1996a; Berkovski and Gottschalk, 1997; Hasnain *et al*., 1998). Programmes to develop global education and training for these subjects have also been endorsed at major international summits (World Solar Commission, 1997). With the growing importance of renewable energy and energy efficient technologies, there is an urgent need to integrate the new knowledge in these fields into the curricula of universities and professional education (Bhattacharya, 1996; Charters, 1996; Elliott, 1996; Pitts, 1996).

As people are the key factor in the equation of a successful energy efficiency programme, adequately skilled and motivated personnel are critical for promotion, acceptance and implementation of energy conservation projects and practices. It is becoming more and more important to incorporate energy efficiency and solar design concepts into education and training courses for building design and management skills (Hasnain *et al*., 1995; Todd and Harries, 1996; Schiller and Evans, 1997; Hui, 1999). To improve these activities, modern computing and communication technology has a significant role to play.

The Internet and World Wide Web (WWW) can be an effective medium for the delivery of good quality education and training for energy efficiency and renewable energy subjects, because of its flexibility, timeliness, and breadth of access. This paper investigates an approach for developing a web-based learning environment for building energy efficiency and solar design. The use of the WWW as a delivery system for educational materials and information resources is discussed. Some of the technical and pedagogical issues associated with the web-based techniques are identified. The experience from a pilot study at the University of Hong Kong is evaluated and the major considerations for the design of web-based learning are presented. It is hoped that the present study could stimulate more discussions and innovative ideas for exploiting the educational

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potential of the WWW for energy education and sustainable building design.

2. IMPORTANCE OF THE EDUCATION

Education is a key factor for the promotion of building energy efficiency and solar energy applications since development of these technologies depends very much on the people's understanding and awareness, adequate information for design and analysis, and sufficient manpower with technical and management skills. The learning process, in broad sense, covers all levels of education including primary and secondary school education, technical and vocational training, university education, short courses and workshops, and continuing professional development.

2.1. Needs for information and knowledge

Newborough and Probert (1994) pointed out that at present few people have acquired an adequate knowledge with respect to energy use and its environmental consequences. To overcome this problem, relevant and purposeful energy education needs to be promulgated in a more comprehensive and coherent manner throughout our education system.

Nowadays, the related information and technologies about energy efficiency and renewable energy are growing very fast and getting more and more complex. To effectively disseminate the information and provide appropriate training for engineers, technicians and users of the technologies as well as policy and decision makers, businessmen and industrialists, development of an efficient learning environment is very important. Not only the current university students have to learn actively on new technologies and methods, the existing practitioners also have to update or refresh themselves through continuing education or professional development.

2.2. Needs for trained personnel

Training is essential for strengthening human resources for energy efficient and renewable energy technologies (Berkovski and Gottschalk, 1997). Availability of educated and trained manpower at all levels is crucial for successful implementation of any sustainable energy programmes. However, the training programmes and materials are currently lacking in many countries and they are sometimes not taken seriously in energy conservation planning and policy making.

It is important to promote training and information to the possible users of energy efficient and solar energy technologies, such as architects and engineers. Information and tools for the planning, design and operation of the energy systems need to be established; resources and management skills for financial supports and incentives of the energy projects need to be developed and disseminated.

For developing countries which have limited technologies and experience, providing and promoting energy education and training is a great challenge for their governments (Garg and Kandpal, 1996b; Schiller and Evans, 1997; Othman and Sopian, 1999). International cooperation and networking may help create an environment that is conducive to technology transfer and human resource development.

2.3. Public awareness

When examining the education for alternative technologies in UK, Elliott (1996) has considered the need for a general public awareness of the nature and implications of renewable energy systems. During the last few years, a new vision of the role of education and public awareness in achieving sustainability has emerged. Education is no longer seen as an objective in and of itself but as a means to bring about changes in behaviour and lifestyles, to disseminate knowledge and develop skills, and to prepare the public to support changes towards sustainability emanating from other sectors of society.

The establishment of a culture of maintenance and the early involvement of individuals and community organisations in the design and implementation of energy efficiency projects are essential elements for their success. It is very important to provide the necessary information, both to the decision-maker and to the public at large, in order to 'sensitise' them on the potential of renewable energy and to develop familiarity and positive attitudes towards it. Teaching and educating such a wide range of audience for energy awareness requires careful consideration of the approach and pedagogy.

3. WEB-BASED LEARNING APPROACH

Totten and Anderson (1997) pointed out that the Internet is now a critical tool for renewable energy professionals. There are already a number of systems on the WWW designed for the information management, education and networking for energy efficiency and renewable energy, such as CREST (1999), ISES (1999) and USDOE (1999). The WWW is becoming increasingly used

as an information bank and a method of transmitting knowledge to students, including the built environment sector (Hui, 1999).

3.1. Internet technology basics

The Internet, sometimes called simply 'the Net', is a worldwide system of computer networks – a network of networks in which users at any one computer can, if they have permission, get information from any other computer (and sometimes talk directly to users at other computers). Today, the Internet is a public, cooperative, and self-sustaining facility accessible to hundreds of millions of people worldwide. Physically, the Internet uses a portion of the total resources of the currently existing public telecommunication networks. Technically, what distinguishes the Internet is its use of a set of protocols called TCP/IP (Transmission Control Protocol/Internet Protocol).

Nowadays, the most widely used part of the Internet is the World Wide Web, also known as 'WWW', 'Web' or 'W3'. The WWW is the universe of network-accessible information, the embodiment of human knowledge (W3C, 1997). Through the use of hypertext and multimedia techniques (including graphics, video clips and sound) for cross-referencing and presentation, the web is easy for anyone to roam, browse, and contribute to. Using the web, people have access to millions of pages of information and web 'surfing' is done with a web browser, such as Netscape Navigator or Microsoft Internet Explorer.

The WWW is based on two standards for exchanging files: Hyper Text Transfer Protocol (HTTP) and Hyper Text Mark-up Language (HTML). HTTP describes the way that hyper text documents are fetched over the Internet; HTML specifies the layout and linking commands present in the hypertext documents. Resources on the web are specified with a Uniform Resource Locator (URL). A URL indicates the protocol used to fetch a document as well as its location.

3.2. Advantages and potential

The WWW as a network infrastructure has the great advantage of flexibility and low cost (Duchastel and Spahn, 1996). The fact that WWW information is readily updatable and that users always access the latest version provides tremendous flexibility by eliminating the outdatedness of printed materials. The multimedia nature of the WWW can also provides an environment richer and more interactive than traditional paper-based alternatives.

With the benefit of platform independence and global accessibility, a web-based system is ideal for distance or open learning courses. Using web-based learning, students can proceed at their own pace, and work from anywhere, at home or in school. Extensive hard-copy printing is not required; the pages can be linked to external sources of information. With the aid of a projection device, the pages can be used to support lectures or hands-on lab sessions. The teaching materials and student work may be exposed to a broad audience, and since the pages are accessible around the world, collaborative work is also possible, such as virtual design methods which involve participants from different regions to form a working team.

More and more studies are now being done to exploit the potential of using computers and the WWW to support architectural and engineering education. For example, Beckman (1996) has experimented with the teaching of solar energy technology with computers; Jain *et al.* (1998) has designed a web interface for teaching solar concepts. Christopher Gronbeck has developed an interesting web site for providing solar design and analysis tools (http://www.susdesign.com/), which are essential for designing climatically responsive and energy saving buildings.

3.3. Operational issues

One should be aware of the limitations and pitfalls inherent in the application of teaching and learning methods based on use of the WWW (Ausserhofer, 1999). There are several operational issues that need to be considered when planning to teach using the WWW (Polyson *et al*., 1996):

- Internet access: connection speed and availability of access;
- equipment and software: compatibility of computer hardware, web browser, plug-ins, and other software; and
- technical support: internet service providers and web-based resources; technical assistance to learners.

There are many different approaches to developing online course materials – some requiring sophisticated technology skills, some requiring only moderate or minimal skills. Selection and planning for the technology is important for cost effective management of the learning environment.

As web pages must be 'served' on a web server, it may be necessary to work with a

computing staff to move the web pages to the web server. Or, in some cases, one may opt to run their own personal or departmental web server. Another challenge could exist if it is necessary to restrict access to only students in a particular class. In this case the teacher will need to work with the web server administrator to create logins and passwords for each student or learner. Many of these technical and logistic challenges have been solved recently by some new software products designed to make it easier for non-technical instructors to create, serve and administer online courses. An example is WebCT (UBC, 1999).

3.4. Pedagogical issues

Allen (1998) has examined the themes of multimedia and interactivity in web-based education. He has found that the WWW can support the learning process in many more ways than its traditional information delivery role. The integration of web techniques into the curriculum might take many aspects of the learning process into account, from the delivery of information and references, through demonstration, example and practice, to learning by reflection and assessment. In general, the use of WWW will encourage self-paced and distance learning over the traditional directed teaching.

Polyson *et al.* (1996) has pointed out the importance of not losing sight of teaching goals when mastering the web technology for teaching, since those people who are using the materials in a self-study manner may be subject to waning or distraction in the web context. The directiveness of learning materials and the issue of learner control are essential for captivating the learner and keeping attention focused. The best advice with regard to pedagogy is to think beyond traditional classroom paradigms when creating on-line course materials, and integrate the unique features of the WWW into the teaching environment. The following web-based learning paradigms may be considered:

- personalised learning environment – by nature, the WWW lends itself to student-centred learning. Students can create individually tailored paths to master the desired goals, move at their own speed and retrieve additional information as needed;
- collaborative learning – many studies have indicated that learners will greatly benefit from environments which encourage shared learning. The WWW presents an effective environment for asynchronous collaboration in which students work together but not necessarily at the same time;
- multimedia presentation of content – the WWW is providing an increasingly rich variety of media through which to present learning materials. Text, graphics, audio and video can be used to accommodate different learning styles and provide approaches for both visual and auditory learners;
- reinforcing of content at different stages – feedback and monitoring are important to self-paced learning. By using HTML forms and client-side scripts, it is possible to provide structured automatic responses and generate recommendations for remedial work or more advanced study;
- up to date information obtained from the Internet – textbooks are static and tend to become out of date soon after publication. Web materials can be dynamic and allow for easy updating and fast dissemination. In the energy research fields access to recent research and data over the Internet is getting more and more important. The WWW is becoming indispensable in ensuring that the most recent data and discussions are consulted;
- global resources – by putting learning materials online and linking them to web sites from throughout the world, a rich environment can be created to combine both local and global resources. As the web sites are just a 'click' away, students can easily access valuable information contributed from experts or professional organisations;
- experiential learning – while discussion forums provide basic interactivity on the WWW, the interactive software at your desktop (such as Shockwave, Java and JavaScript) is a world of immersion into simulated experiences. These technologies allow people to create and visit virtual places, carry out simulations of science experiments, and interact with graphics, voice, and music. If used properly, the learning process can be enriched and extended widely; and
- new assessment models – to evaluate students partly or completely on the Internet is a challenge to designers and researchers of web-based learning environment. New assessment models and methods are needed to evaluate students' performance in virtual classroom or examination.

A major problem with teaching energy at tertiary level is that it is a fundamentally comprehensive and deep subject which combines

technical issues with social and environmental issues (Newborough and Probert, 1994). When taught within engineering and science, some broadening of the student's mind is desirable with respect to environmental management, energy economics, legal and ethical responsibilities and the social-psychological aspects of energy use. Much research is required to identify the preferred means of integrating and coordinating energy education within tertiary education. The main problems are the separate educational paths of the professions, the relative lack of resources for multi-disciplinary research and teaching, the poor availability and quality of energy education resources as well as the attitudes of the people and institutions involved.

4. EVALUATION OF PILOT STUDY

A pilot study for developing the web-based learning environment has been carried out at the University of Hong Kong (HKU) in 1998–99. Initial findings of the study is presented and the use of Internet resources for energy education is discussed.

4.1. Pilot study at HKU

At present, there is no degree courses at HKU specific to the topics of energy efficiency or renewable energy. But these topics have been included in some parts of the syllabus of the undergraduate and postgraduate programmes of the engineering and architectural faculties. To support the education and training of building professionals, a web-based learning environment is being developed to promote '*integrated building technology*' for interdisciplinary education and research. Information about this initiative can be found at the web site 'http://arch.hku.hk/teaching/'. Various learning resource formats were being developed including descriptive concepts, design guides, case studies, references, software, and in-house information and external links.

To improve training and educational experience of the architectural students on energy issues, two key areas have been identified and web-based materials are being developed. The two areas are Building Energy Efficiency (BEE) and Solar Energy in Architecture (SEA). Fig. 1 shows an outline of the learning environment for these two areas.

Subtopics and their educational contents have been developed on the web server to augment the usual teaching methods and courseware. The web pages have also been used to support design studios, lectures, and seminars for the postgraduate and undergraduate students in the Department. With the development of the network

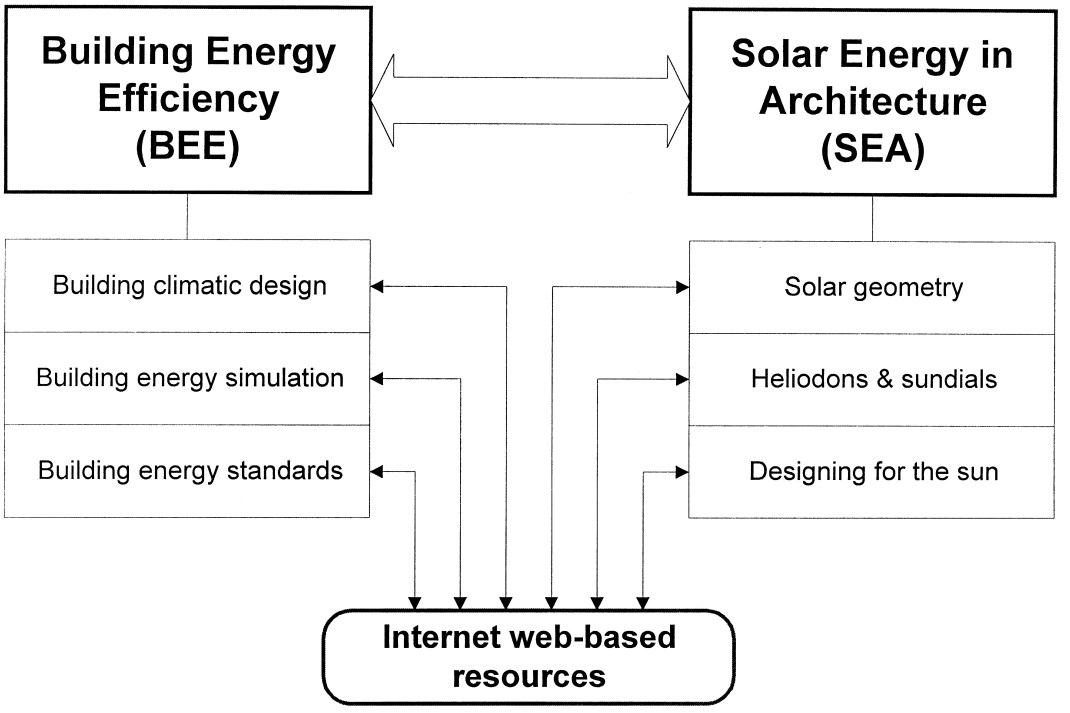

Fig. 1. Outline of the learning environment.

and Internet facilities at the campus of HKU in recent years, web-based teaching is becoming easier to achieve and operate.

To ensure that the web-based materials are relevant to the local conditions and current international trends, a significant portion of the teaching/learning materials comes from the key results and findings of relevant, on-going research in the Department. It is believed that integration between research and teaching is essential for keeping the educational context fresh and updated. Evaluation of the pilot study indicated that initial implementation of the web-based learning environment would require much effort and time in coordinating the computing equipment, preparing the teaching materials, and converting them into suitable web formats. Once the setting has been established, the running and maintenance efforts can be greatly reduced.

4.2. Students' response

Feedback of students is important for evaluating and improving the web-based system. The effects of using web-based teaching have been investigated through discussion with the students and assessment of the assignments and case study projects they submitted. As some features of the system were not yet completed in the first year, a combination of both web-based and traditional approaches has been used for the elective course. Other students not taking the course have been encouraged to read the materials by themselves in order to integrate the knowledge into their design studio projects. It is found that students were stimulated by the WWW and many of them have used the web materials to support their assignments and design projects.

As compared with the traditional classroom- and textbook-based approach, the web-based learning environment has greater flexibility and many advantages in presentation. Multimedia and interactive methods can be used to enhance and enrich the learning process. This is especially useful for architectural students who are stronger in visual comprehension and graphical representation. On the other hand, the web-based delivery system is helpful for problem solving tasks wherein ready access to additional information and tools are given to students and a flexible and universal means of presenting all aspects of the problem solving process is provided.

One of the drawbacks to this form of web-based teaching is that students may get lost in a maze of external references (hyperlinks) – it is also known as hypertext-related disorientation and cognitive overload. The web-based approach also presumes basic computer literacy on student's part. It is essential to check to make sure that all the students have sufficient Internet and computing skills and they are clear about the educational instructions and objectives.

4.3. Use of Internet resources

Internet resources on energy topics could be extremely useful for web-based learning and research. In recent years, the WWW resources on solar energy and energy efficiency around the world (from energy, engineering and physical science fields) has grown significantly and this has opened up a new area for managing the web-based information (Hui, 1999) – it may be called energy 'informatics'. The information from web sites around the world could be integrated into the web-based learning environment to supplement and strengthen its contents. Although the connection speed, quality, reliability, and cultural differences are still common barriers to the use of overseas or non-local web materials, this method of utilising global information has the potential to enhance itself as the WWW proliferates and the web technology advances.

Although there is an enormous amount of information on the Internet, it is often quite difficult for one to search for required information, for example, using the Internet search engines (such as Altavista and Excite). The tools and systems that exist to filter the specific information that one requires are not currently able to match the amount and complexity of the information. There is much dross as well as good information on the Internet and this is largely due in part to the largely unregulated nature of the Internet. Locating web sites of quality information is sometimes more a case of good fortune than good planning in the selection of search key words and phrases; keeping track of all the relevant 'links' is not easy since documents on the WWW are ephemeral and dynamic in nature.

To integrate web-based techniques effectively into our education system, it is important to understand the characteristics of web-based teaching and the criteria for designing good web sites that can support growth, management, navigation, and ease of use. Some key factors and suggestions are presented in the next section.

5. DESIGN FOR WEB-BASED LEARNING

Sachs and Stair (1997) have suggested seven keys to effective web sites as follows:

- key 1 – visually appealing;
- key 2 – valuable, useful, or fun;
- key 3 – current and timely;
- key 4 – easy to find and use;
- key 5 – intuitive on-page navigation;
- key 6 – involve the visitor; and
- key 7 – responsive to its users.

It is important to organise the site's hierarchy in ways that are meaningful to the users, and to create navigation systems so that users can move through the site without getting lost and frustrated. It is also constructive to label the site's content in the language of its users and to configure searching systems so that users' queries actually retrieve meaningful results.

5.1. Informal learning and interests

Duchastel and Spahn (1996) has pointed out that the greatest use of the WWW is informal learning through browsing. People access and learn from information made available by a whole host of organisations and individuals within a non credit-granting structure. This way of learning is quite common for energy-related professionals. The on-line informal learning may augment more formal off-line educational efforts, but it more typically takes place simply out of the sheer enjoyment of learning.

It is understood that the great majority of information made available on the WWW is not specifically prepared for learning purposes. Rather, it is more often developed with a view to interest and inform a general and varied audience. It is in this respect akin to public communication products and less aligned with instructional products, even though it often finds itself at the interface of both realms. To make the best use of the WWW resources, it is necessary to study how informal learning can be optimised for educational purposes.

Advanced educational use of the WWW can evolve along two major axes (Ibrahim and Franklin, 1995): (a) use of the technology on a closed corpus of educational material, for the hypermedia and distance delivery capabilities of the WWW, and (b) use of this technology on an organised structure of links for an open corpus of material that was not necessarily meant for educational use but which can be 'redirected' and exploited in guided educational explorations. These two axes can be complementarily exploited and they should be studied carefully for developing effective energy education. Some professional institutions have already started to make use of web materials for on-line training, self-directed learning and continuing education, such as 'www.aeecentre.org', 'www.ashrae.org' and 'www.aiaonline.com'. Formal instructional systems, which are rather didactic, will guide the learner to the achievement of very specific learning outcomes. On the other hand, there are forms of instruction that create a context for guided exploration for autonomous learners. Since instructional means are often weak or not present in a typical web context, greater cognitive demands are put on the user-learner to make the best use possible of the information resources available.

5.2. Information specification and representation

The procedure for building a web-based education system usually involved the following steps (McCormack and Jones, 1998):

- analysis;
- planning and design;
- content development;
- distributing information;
- enabling communication;
- online student assessment; and
- class management.

The development process of an educational web site will typically look like this. Each module is constructed in the same way, opening with a motivation page to introduce the topic and engage the user's interest. The next page or section lists the learning objectives of the module, any prerequisite modules the user should study first, any subsequent modules which follow on, and a list of the module's contents. The following pages then contain the teaching material, whilst the final page contains a summary of the material which draws out the salient points of the topic. Users navigate through the modules by clicking on arrows on a button bar at the bottom of the screen to progress page by page, either forwards or backwards. Alternatively, they can click on the 'module structure' button which enables the user to go directly to any page of their choice.

To support this learning environment, a glossary to explain the technical terms and a keyword index which lists modules containing material on a topic chosen by the user may be established. Facilities for one-to-one and one-to-many communication may also be included, such as email to subject experts, discussion groups and Internet relay chat areas. Polyson *et al.* (1996) have summarised the common features of a web-based learning environment as follows:

- online syllabus;
- assignments;

- announcements;
- personal home pages;
- interactivity;
- testing;
- course management; and
- content.

In general, the interface should be designed to be as simple as possible so that users could learn to use it as they went along. If a multilingual project is being considered, the interface should preferably be designed to be language-independent, such as by using icons or graphics, instead of texts.

5.3. Dynamic and interactive process

It is possible to use scripting languages, CGI (Common Gateway Interface), Java, ActiveX, Flash and Shockwave to add interactivity or animation to web pages. But great care should be taken so as not to over-use the technologies and distract readers from the main themes. If properly designed and implemented, these web technologies can be used to enhance the user interface and develop online tools for energy analysis and presentation of abstract energy concepts. For example, web interface can be used for energy modelling and simulation (Forowicz, 1999); annotated and manipulated digital images on the WWW can be used to teach energy efficiency and solar concepts in an interesting way. The WWW can also be used as a calculation tool that allows the user to input information and then simulates the behaviour of the system. This will create web-based tools which provide cross-platform collaboration services to groups using existing web technologies.

Usually, the learning effect and interest can be enhanced if the users are considered as a 'community' of learners, and web-based discussions are encouraged among them. For example, web forums, bulletin boards and chat rooms may be created to promote interactions among the learners. Some people have used the WWW as a community resource, where the students and the teachers can discuss projects and get feedback.

6. CONCLUSIONS

Education and training are essential components of any developmental effort for sustainable energy, especially in developing countries. The Internet and WWW has an important role as a method of learning in energy efficiency and renewable energy. If utilised effectively, it will contribute to developing of technical and human resources as well as information management for energy systems.

Improved tools for developing web-based teaching and learning materials, together with focused training by individuals, and institutions, have led to a greater confidence in network technologies by educators at many levels. It is hoped that the present study could stimulate more discussions and innovative ideas for exploiting the educational potential of the WWW for energy education. The deployment of energy efficient and renewable energy technologies in the future will depend heavily on the human resources and skills that we foster in the present days.

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