NUCLEAR EDUCATION AND TRAINING IN THE INTERNET AGE

George Bereznai
Chulalongkorn University
Bangkok, Thailand
bereznaig@aecl.ca

William Garland
McMaster University
Hamilton, Ontario, Canada, L8S 4L7
garlandw@mcmaster.ca

ABSTRACT

Student enrolment in nuclear engineering programs offered by Canadian universities has been declining, and at some universities has fallen below the minimum level needed to sustain the program. At the same time, a significant number of engineers working in the nuclear industry have retired and many more will be reaching retirement age in the next few years. The operation and maintenance of the 14 in-service CANDU units, the refurbishment of the four Pickering 'A' units and of the four Bruce 'A' units will require a significant level of new engineers and scientists. Service support for the CANDU units operating overseas, the construction of two units in China, the completion of Cernavoda 2, and the market for several more CANDU units in Asia, will also require significant numbers of new graduates.

The vast amount of information that the future practitioners of the nuclear power industry need to be aware of will be increasingly difficult to disseminate with the traditional classroom-based education and training methods. Almost all of the documents required for the design, analysis, procurement and operation of a nuclear unit are now generated by computer, and increasingly such information is accessible where and when needed via the company Intranet. The authors have developed an Internet/Intranet compatible self-paced interactive multimedia approach to deliver a course on CANDU Systems and Operations. The course has been offered at ten universities in six countries, including Thailand, China, Indonesia, Vietnam, the Philippines, as well as Canada.

INTRODUCTION

Nuclear engineering is a highly specialized discipline. It is only offered at a few universities globally, and most of the programs are at the graduate level. With only a few nuclear power plants having been ordered in the last 20 years, the enrolment in nuclear power plant engineering in particular has decreased to such a low level that many university programs have been discontinued. However, demand for nuclear engineers will continue, and is expected to increase, as many of the practicing nuclear engineers are reaching retirement age, the operating power plants require more maintenance and upgrades, particularly as the economic and environmental benefits of extending the operating lives of these power plants becomes apparent, and as initiatives for plants with new technologies are pursued. The resultant mismatch between the supply and demand for the next generation of nuclear power plant engineers is only now being recognized, by both industry and the universities, as approaching crisis dimensions.

For Canada, the operation and maintenance of the 14 in-service CANDU units, the refurbishment of the four Pickering 'A' units and of the four Bruce 'A' units will require a significant level of new engineers and scientists. Service support for the CANDU units operating overseas, the construction of two units in China, the completion of Cernavoda 2, and the market for CANDU units in Asia, will also require significant numbers of new graduates.

Developing countries wanting to benefit from the use of nuclear power as part of their long-term energy mix, as demand for electricity increases with the increasing economic activity and improving living standards, face a unique problem. They have to develop a sufficient number of experts to staff the regulatory agencies, the research and development institutes, the utility departments and key industries needed to establish the infrastructure that will enable each country to make its own evaluation of the applicability of nuclear power.

Thailand faced such a scenario in the mid 1990s when the use of nuclear energy, to meet the rapidly increasing demand for electricity, was considered. Atomic Energy of Canada Limited (AECL) and the Canadian International Development Agency (CIDA) reached agreement with the Thai government, the Electricity Generating Authority of Thailand (EGAT), Chulalongkorn University, the Organization of Atomic Energy for Peace (OAEP) and several Canadian universities to conduct a Nuclear Human Resources Development (HRD) Project [1]. The CIDA funded portion of the Project operated from 1995 to 1998, during which time 35 courses were developed and delivered by Canadian experts, and over 400 Thai engineers, scientists, educators and administrators participated in the program.

DISTANCE LEARNING

One of the key requirements of the Thai-Canadian HRD Project was to investigate how distance learning techniques could be used to deliver courses, and how the use of such technology could contribute to the long term sustainability of nuclear education and training in both Canada and Thailand. The use of video conferencing via satellites was initially considered, but the cost of equipment, communication charges and the 12 hour time difference between Thailand and Eastern Canada was shown to make this technology impractical. However, video taping of all lectures delivered in Thailand by the Canadian experts was considered to be useful in order to produce a permanent record of the lectures.

With a view to the expanding role of the Internet that was becoming evident in 1995, it was also decided to have all the course material produced in electronic form. This would, as a minimum, allow students and industry practitioners to access the course material in hard copy and electronic form, sustaining the program beyond the three years during which CIDA funded the travel of the Canadian lecturers to Thailand. Whether the materials were to be self-studied or courses were to be delivered by Thai lecturers, e-mail could be used to maintain fast and inexpensive communication between Thai and Canadian subject matter experts.

More recently the need for distance learning has become apparent beyond the original scope of the Thai HRD Project.

Considering the widely scattered locations of the existing CANDU plants in Canada, as well as the export markets that range from Europe, to Asia and South America, the need for education and training in CANDU technology is global. To meet this need, the use of learning technology that was not campus-based has become a strategically important component of supporting the use of CANDU power plants. Since the lecturers and other CANDU subject matter experts are also widely scattered and could not be relocated to any one campus, “distributed education” is the term that, in our opinion, best describes the type of learning environment that should be used to meet the industry’s needs to develop, maintain and upgrade the knowledge of personnel in the nuclear industry.

INTERACTIVE MULTIMEDIA

The rapid growth in using computers and the Internet in information processing and communication is well known. Since education and training are essentially about the sharing of knowledge, one would expect a similar growth and wide acceptance of IT by the learning institutions. Although there are an increasing number of courses and programs that may be studied via computers and the Internet, the vast majority of education and training world wide still takes place in the conventional classroom setting. Apart from the resistance to change by the tradition-bound educational institutions, the high cost of developing interactive course material has been used as the main reason for not embracing IT-based education. Production efforts of several hundred hours per one hour of finished lecture content have been quoted for good quality multimedia course material.

In order to minimize development costs, we needed to find a technique that made good use of the course material already developed for the Thai-Canadian HRD Project. Since the lectures were delivered with the help of overhead projectors, the authors decided to implement an IT-based learning system that retained as much of this format as practicable. Having obtained good educational results with the use of a power plant simulator running on a PC [2], a technique that simulated classroom course delivery was developed.

LECTURE SIMULATOR

The typical classroom lecture is essentially a “show and tell” presentation: the lecturer displays the main points of the lecture using text and illustrations written and drawn from a sequence of transparencies placed on an overhead projector, and points out the key features while giving a verbal explanation. Figure 1 is an example of such a display: an illustration showing two views of a CANDU fuel bundle with the main components identified on the diagram, and the text of the key points that the lecturer wants to make when presenting this part of the lecture.

In a distance learning environment the students should be able to replicate the delivery of the lecture content that would be experienced in the classroom. We have found that playing back a videotape is not a satisfactory approach: the usual classroom environment does not lend itself to a quality production, stopping and replaying parts of the lecture that were not well understood was rather time consuming. It is our view that the passive watching of a videotape does not provide an acceptable learning environment.

To allow an individual student to experience via his/her computer the actions taken by the lecturer in making a presentation using overhead displays, the following elements need to be allowed for:

- select for display any of the pages used in the lecture
- select any of the key points on a given display page and observe the features that the lecturer wants to highlight
- listen to what the lecturer says for each key point.

Figure 2 shows the interactive features that were added to the page in Figure 1 to realize the above functions:

- buttons at the top and bottom margins of the display provide the means to navigate between pages
- selection of the "arrow icon" next to each key point shows the highlights for that item (item 1 in Figure 2, as indicated by the arrow icon being dark)
- selection of the "speaker icon" plays the sound recording for that particular item (speaker icon turns dark and sound controller displayed at the top of the page).

The software used to produce the interactive displays is Adobe Acrobat Exchange; it allows the creation of "buttons", labels and other highlights, as well as all the interactions that we found necessary to simulate the lecture environment. The methodology used requires only minor format changes to the original illustrations that were prepared for overhead projections, then each page was converted into a portable document format (pdf) document by the Adobe Acrobat Writer. Each page was subsequently combined with a pdf template that contains the interactive buttons and icons. While each page required some customization, in most cases these were not time consuming. The preparation of the scrip and the recording of the sound files was the main additional effort that was required to convert a static page of text and diagram to an interactive multimedia display.

The resultant course material allows each student to proceed at his/her own pace, selecting each element of the lecture for as long as needed, and repeating it as often as necessary. The sound recordings are also made available in text form, so students have the option of reading and/or listening to the lecturer's words, making their owns notes and highlights on the hard copy, and being able to search for key words and expressions. All of these elements, including the student's interaction with the computer, listening, reading, and making notes, contribute to better learning as the student uses more of his senses and is able to progress at a speed and sequence that is best suited to his individual learning needs.

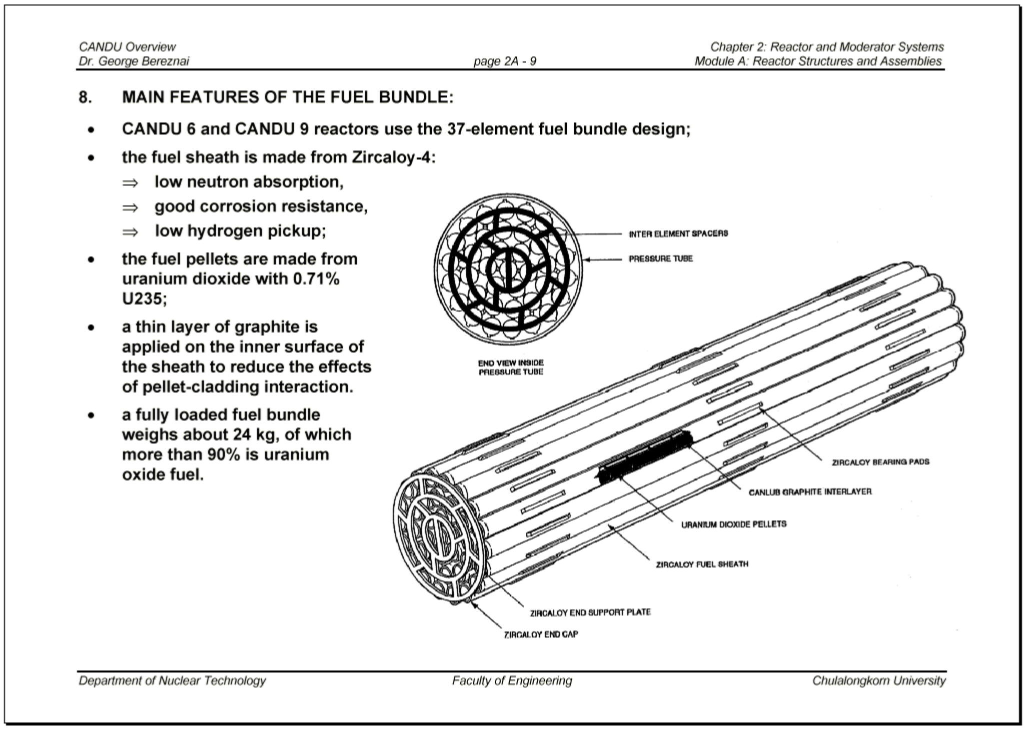

Figure 1. Typical lecture illustration used with overhead projector.

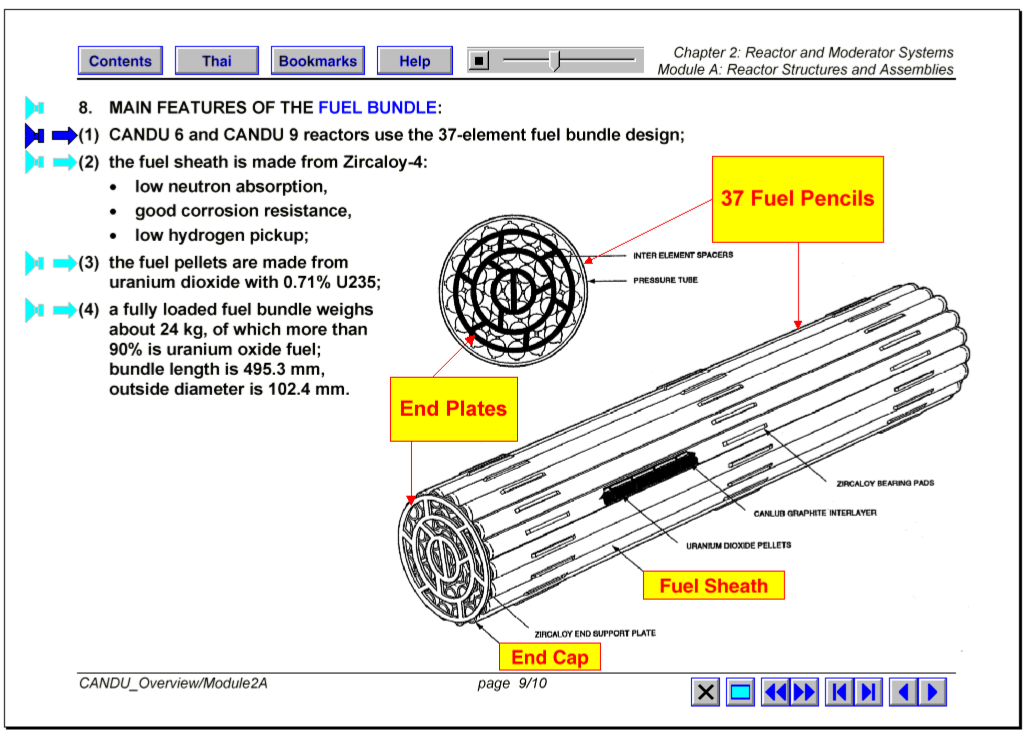

Figure 2. Interactive multimedia display page adapted from Figure 1

The authors have converted a course from the classroom lecture delivery format to interactive multimedia using the above methodology. The original pages containing text and diagrams were prepared in Microsoft Word and converted to pdf files. Other illustrations, whether originally drawn by a graphics or word processor program, or scanned, were also converted to pdf. The individual sound recordings were typically of one minute duration, with the longest requiring about two minutes. The production effort for the course was in the order of 800 person hours, i.e. a 20:1 ratio of producing an interactive multimedia version of a typical 40 hour one-semester course.

The complete software for the course requires about 600 megabytes, and therefore can be placed on a single CD-ROM. The Adobe file format is also compatible with the Internet, but because of the size of the sound files and the limited speed and accessibility of the Internet in Thailand and in many of the other countries in Asia where the course is delivered, we are using CD-ROMs, for the time being, as the medium of distribution to our students.

COURSE DELIVERY

Although the distance learning format allows great flexibility over the timing of the course, our target was to meet the needs of a semester-based curriculum. Because we believe that the self-paced interactive nature of the course design provides a superior learning environment over the classroom setting for the majority of the students, we offer the course in the self-paced format both at our own campuses and at locations away from our campuses.

At Chulalongkorn University, the department's computer room is reserved for the three hour period identified for our course on the time table. It is optional for the students to study the course material at that time and place, but most of them take advantage of knowing that the lecturer is available at that time to answer questions and to provide assistance. At other times, the students are encouraged to use e-mail to ask questions and to submit the weekly assignments, and the lecturers' answers and feedback on the assignments are also provided via e-mail. Typically once a month we meet in a classroom to discuss common problems and provide remedial material as needed.

At McMaster University, this course is offered as a regular course at the graduate student level in the Department of Engineering Physics on a self-paced basis, augmented by one-on-one, email, and ad-hoc discussion groups as required. It can be used for credit as a Continuing Education course, for the Nuclear Technology Diploma, for the Master's of Engineering Degree and the Ph. D. degree. Since the Faculty of Engineering at McMaster has reciprocal agreements with a number of other Canadian Universities, the course can be used for credit in engineering degrees at those universities. A number of professionals from industry have taken this CD-ROM based course as well as classroom-based courses offered by McMaster.

When the course is offered at a campus other than Chulalongkorn University or McMaster University, one of the course authors travels to that campus at the start of the semester in order to meet the designated local teaching partner(s) and the students, and to ensure that the students gain the necessary familiarity with the interactive learning technology. In most cases the students will submit the weekly assignments to their local lecturer, who keeps in e-mail contact with the course authors, but there are also provisions for the students to contact the course authors directly. At the end of the semester one of the course authors returns to the host campus to resolve any outstanding problems and to participate in the conduct of the final examination.

An important aspect of engineering education is to ensure that the students gain the practical experience necessary for the full mastery of a particular subject. In the case of nuclear power plants such practical experience is commonly gained with the use of simulators that replicate the behaviour of the power plant under normal as well as abnormal conditions. Such a simulator is used as part of the course the authors teach on Nuclear Power Plant Systems and Operation. The course has been delivered at the following institutions:

- Chulalongkorn University, Bangkok, Thailand
- Prince of Sonkhla University, Sonkhla, Thailand
- Gadjah Mada University, Yogyakarta, Indonesia
- Bandung Institute of Technology, Bandung, Indonesia
- University of the Philippines, Manila, the Philippines
- Shanghai Jiatong Technical University, Shanghai, China
- Xian Jiatong Technical University, Xian, China
- Tsinghua University, Beijing, China
- Hanoi National University, Hanoi, Vietnam
- McMaster University, Hamilton, Canada.

DOES IT WORK?

As discussed, this self-paced CD-ROM course methodology is well suited to the task of information delivery and provides a higher degree of student involvement that traditional lecture style courses. Engagement of the learner's mind in integrative tasks is key to learning, so, in this regard, the format is a demonstrated success. It is also appropriate that the instructor's time is freed from the 'content delivery' task and can now be better spent on tasks that are more hands-on and interactive, such as individual mentoring, group discussions, material development and augmentation, and student monitoring and assessment.

As might be expected, some students report that they feel more disconnected from the rest of the class than is the case with a traditional lecture-based course. It is apparent that the more high-tech the format is, the more high-touch [3] the course as a whole needs to be. Regular discussion groups are recommended as a means of compensation. Email and electronic forums have also proven to be effective in providing asynchronous and synchronous discussion platforms. The class dynamic is different with these platforms and can lead to more thoughtful exchanges than might be possible otherwise.

This CD-ROM format is not suitable for student assessment, nor was it intended to be. Traditional methods (assignments, plus invigilated tests and exams) continue to be used to ensure that the course meets the university accredited course standard. There is no reason, however, that testing cannot be conducted at remote testing centres as long as they are recognized by the host universities.

Yes, it works! The knowledge of subject matter experts is brought to the learner, instructors are effectively utilized and learning is taking place that is on par or better than traditional methods. Coupled with electronic communication (email, conferencing, etc.) and discussion groups, it has proven to be an effective learning tool for universities and for industry.

CONCLUSIONS

The global economy will increasingly demand that education and training be delivered where and when required by the subject matter experts best able to provide the information and the learning experience. The vast amount of information that the future practitioners of the nuclear power industry need to be aware of will be increasingly difficult to disseminate with the traditional classroom-based education and training methods. Almost all of the documents required for the design, analysis, procurement and operation of a nuclear unit are now generated by computer, and increasingly such information is accessible where and when needed via the company Intranet or Internet.

The authors have developed and implemented a method of multimedia interactive learning methodology which they believe is well suited to facilitate the transition from classroom-based to distributed education. The Adobe portable document format has been found to be a suitable software package into which course material produced by any word processor, graphics, spread-sheet and similar programs, as well as scanned documents, can be converted. Adobe Acrobat Exchange has the tools to add the necessary interactive features to the pdf files. The course the authors produced in this format has been delivered at ten universities in six countries.

A sample of the course can be found at http://epic.mcmaster.ca/~garlandw/ under the link for course EP704.

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