AC 2010-2155: HANDS-ON NUCLEAR ENGINEERING EDUCATION – A BLENDED APPROACH

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Hands-On Nuclear Engineering Education – A Blended Approach

Abstract

Blended instruction has become a powerful delivery mode whose power lies in the merging of traditional, face-to-face instruction and web-based instruction. It also lies in the significant transfer of responsibility for learning from the instructor to the student, a significant – and often challenging – culture change for both students and faculty. In this paper, we share the process, facilitated by an education grant from the U.S. Nuclear Regulatory Commission (NRC) that we followed to redesign Hands-on Nuclear Education to allow for a blended delivery format.

Introduction

Traditionally, engineering education has been content-centered, design-oriented, and permeated by the development of problem solving skills. More recently, team building and collaborative problem-based learning have been added. The amount of content deemed necessary for graduates of engineering degree programs has steadily increased over the last half century[1] .

Lectures are frequently used in engineering education to transmit information to students. In an online learning environment, lectures can be captured and replayed anywhere, anytime, thus providing enhanced flexibility for learning. Experts can be easily brought into the online classroom, enabling learning experiences that are not as readily acquired in a traditional on-campus classroom [1].

One of the distinguishing elements of engineering education is the lab requirements [1]. The current ABET [2] engineering criteria states that all engineering programs must demonstrate that their graduates have an ability to design and conduct experiments, as well as to analyze and interpret data; design a system, component, or process to meet desired needs; and use the techniques, skills, and modern engineering tools necessary for engineering practice. Successful and effective learning is always related to the degree of implication of the learner in the learning process. With problem-oriented and explorative learning methods, learners are directly implied[3].

To serve engineering students effectively and efficiently in today's digital age, engineering educators need to integrate Web-based and technology rich components into their programs [4]. Web-based methods and approaches have become critical components of teaching and learning as both faculty and students have become aware of and utilize many facets of online education [1] such as the integration of a learning management system or of Web 2.0 technologies into the traditional classroom. The experiences of individuals who can do something with Web-based technology that they could not do before and the effective integration of technology are key to the revitalization of engineering pedagogy.

Ultimately, as a blended course, Hands-on Nuclear Education will offer a comprehensive instructional approach to reactor physics, radiation transport and dosimetery measurements through the integration of class lectures with practical application of the material using unique facilities, a low power nuclear reactor and a powerful linear accelerator at Rensselaer

Polytechnic Institute in a synchronous, off-site setting. Hands-on Nuclear Education integrates web-based technologies with distance laboratory course delivery. This approach allows extension of hands-on activity to universities and other organizations that do not have the facilities currently available at Rensselaer Polytechnic Institute.

Blended learning, the quiet revolution

Blended courses have become part of a quiet revolution as they have changed the face of "traditional" higher education. Over the past decade, their numbers have grown dramatically [5] so that now, over 80 percent of all higher education institutions offer blended courses [6]. This move toward a new kind of education has been quieter than much-hyped efforts to create completely virtual programs [7].

Blended courses integrate online with face-to-face time in a planned, pedagogically valuable manner [8] , offering some of the convenience of fully-online courses without the complete loss of face-to-face contact [7]. From the "traditional" classroom, it takes the teacher driven presentation and selection of relevant content and the dialogue between student and teacher. From the Web-based world, it borrows the advantages of self-paced, self-regulated learning [3]. These courses seem to offer the best of both worlds, preserving face-to-face contact in a reduced seat time format, while allowing faculty to creatively use Web resources in instruction [9].

Blended learning approaches and design can significantly enhance the students' learning experience [10-11] by reducing "sage-on-the-stage" lecture time and shifting some of the teaching components to the online environment. More time can then be spent in the face-to-face class applying course materials, often with real-world example problems [12].

Levels of blend

The first critical decision was be to choose the level of "blend" to be used in the course. At Rensselaer Polytechnic Institute we use a modified version of Jones, Harmon, and Lowther's levels of Web use [13] to define the level of blend used in a specific course (Table 1).

Level	Name	Description
1	Administrative/ Web-enhanced	• No course content • Administrative information (syllabus, schedule, contact info., ...)
2	Supplemental/ Web-enhanced	• Some course content (course notes, handouts, …) • Available material as an additional point of reference
3	Essential/ Web-centered	• Majority of course content and materials • Student cannot be a productive member of the class without regular Web access • Use of asynchronous tools
4	Communal/ Web-centered	• Blended/hybrid course • Retains traditional classroom meeting but makes steady use of the Web course site. • Use of asynchronous and synchronous tools
5	Immersive/ Completely online	• "Distance education" or "distributed" courses. • Virtual learning community. • Extensive use of asynchronous and synchronous tools

Table 1: Adapted from "*The five levels of web use in education*"[13]

As described below, we chose to re-design the course at a level 4. This Communal/ Web-centered level is often considered the "real" blended course. It offers a true blend of face-to-face and Web-based instruction. 30 to 79% of the content is delivered online from video streams, to learning objects and simulations, with the use of asynchronous and synchronous tools becoming an integral component of the instruction [13].

Rationale

The primary employer of nuclear engineers has traditionally been the nuclear electric power generating sector of the economy, and this remains true today. While this may seem a narrow career path requiring a focused preparation, nuclear engineers are generally expected to be strongly cross-disciplinary. Thus, while other types of engineers often design, analyze, operate, and maintain components and processes in a nuclear system, a nuclear engineer is more often expected to see the "big picture" of the system. This is especially true for quality assurance, including system safety, reliability, and regulatory compliance. Thus, nuclear engineers are expected to be multidisciplinary: able to communicate with, work with, and manage other types of engineers and scientists and to learn aspects of these other engineering and science disciplines, as needed, throughout their careers.

This multidisciplinary systems approach is reflected in nuclear engineering education. Undergraduate nuclear engineering curricula typically include a much broader basic science, mathematics, and general engineering background than most other engineering majors.[14] This is even more relevant now as the nuclear industry continues to both mature and broaden, and nuclear engineering majors are in ever higher demand for more and more diverse and cross-disciplinary careers. It is important for this broad background and practical systems view to be reflected in upper-level nuclear-engineering-specific courses.

Specific to the nuclear engineering field, nuclear reactor physics and radiation transport are two important topics in nuclear engineering education which are required for work in fields such as nuclear reactor core design, nuclear criticality safety analysis, and radiation shielding analysis. In addition, aspects of health physics, radiation safety, and quality assurance are an integral part of the nuclear industry, and thus must be embedded in the curriculum. These should not just be theoretical concepts, but a part of a student's working knowledge through laboratory practice. Indeed, safety and quality are hallmarks of the nuclear culture which must be pervasive throughout education and practice. This is best achieved by seeing theoretical knowledge applied in hands-on experimentation, particularly at an operating nuclear facility.

Although it was once rare for a program in nuclear engineering not to have access to a research reactor, several reactors have been forced to shut down during the years of inattention to nuclear power, and any new nuclear engineering programs that arise are unlikely to be able to construct facilities of their own. The goal of this project is to develop a modular course that will provide not only a robust theoretical background but also the practical experience, the application of the learned material, and the pervasive nuclear culture using the unique facilities at Rensselaer

Polytechnic Institute. These facilities include a low power nuclear reactor and a powerful linear accelerator.

The course will consist of both local and distance learning components and is being designed as a blended course – a combination of the best of face-to-face and online learning [15]. The emphasis is on live participation during the reactor and accelerator laboratory sessions whenever possible, and on remote participation for other participants. This allows Rensselaer to offer the use of its unique learning assets to other universities and organizations that do not own or have access to such facilities.

The impact of this new comprehensive instructional approach to reactor physics, radiation transport, and radiation dosimetry measurements will be the integration of class lectures with practical application of the material in a Web-based environment. This will enhance student learning, and offers a unique opportunity for other organizations such as the Nuclear Criticality Safety community, industry personnel, the U.S. Nuclear Regulatory Commission (NRC), and other universities to take the course and experience the laboratory component at Rensselaer or remotely.

One of the key objectives of the Web-based laboratory module is that remote participants would feel part of the experiment and have the ability to interactively participate and contribute so that their physical distance from the facility cannot remain a barrier to their connection with the nuclear culture and practice. The use of an actual, existing facility rather than a simulation, combined with the interactive delivery, is expected to give the students a better feeling of reality and responsibility for actions performed in class.

The Course

The blended course contains several lecture modules selected with the target audience in mind. The framework developed for this course allows additional modules to be added in the future, or current modules to be selected and arranged for a particular audience. In order to facilitate access to the course material, we developed a content and interaction environment in our learning management system, Blackboard. We also selected Mediasite, a videostreaming software, and Adobe Connect, a web-conferencing tool, to allow interaction of a remote class with online experiments. The approach allows remote delivery of the theoretical modules, while the hands-on component requires real time participation either physically at the facility or through remote connection. The format allows nearly full participation of the remote location in the hands-on experiment with bidirectional participation. The instructor, the operations staff, and the on-site students will interact with the remote class and involve it in the hand-on activity.

A short description of the blended course topics and modules is given in Table 2. To allow for additional flexibility based on an audience's needs and expectations, the nominal delivery order was designed in such a fashion that it could be easily customized by the instructor, based on the target audience.

Module Topic	Modules	Hands-On Module
General Nuclear Engineering	• interaction of radiation with matter • Nuclear Data and neutron interactions	• Cross section measurement with the RPI LINAC
Reactor Physics	• Criticality calculations • Point kinetics	• approach to criticality (RCF) • Control rod worth, Fuel rod worth (RCF) • Rod drop experiment (RCF)
Dosimetery	• Definition and units • Detectors for dosimetery • Gamma spectroscopy	• Neutron dosimetery (RCF) • Reactor gamma spectroscopy (RCF)
Radiation Transport	• Radiation transport theory • Diffusion equation • Radiation transport codes (MCNP, CPM3, etc)	• Measurements of axial and radial neutron flux distributions (RCF)

Table 2 - Modules of the blended course

Figure 1 shows two possible examples of the modules arranged for separate Reactor Physics and Radiation Dosimetry courses. The examples show the theoretical units and the associated hands-on modules. A module may be a single class session or several class sessions. The modules were selected so that a course unit constructed with a combination of modules would provide both a solid theoretical background and a reinforcing hands-on experience. This ensures that the students will have the background to understand the theory behind the hands-on activity. This will also be required for the analysis of the experimental results that will be collected during the experiments.

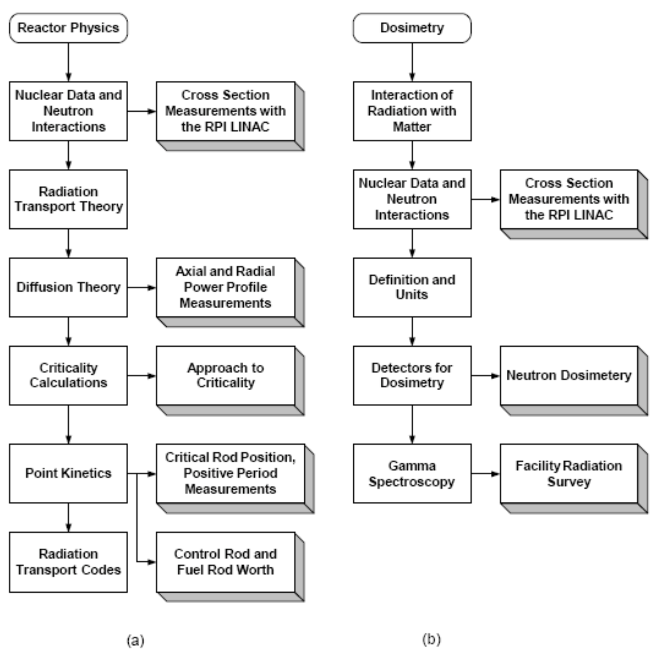

Figure 1 – Examples of the layout of two possible courses delivered by a different arrangement of the theoretical and hands-on modules.

Figure 2 illustrates the typical organization of a learning module, as it would be accessed from the learning management system. It shows the flow of learning from learning module to learning module, indicating which involve prerequisite knowledge and/or skills. As shown for Unit 4, there may be a variety of unit "materials", including reading materials, self-assessments, lecture materials, lab manuals, discussion forums, etc. These are materials available to the students. They also represent a repository of materials selected by instructors for students and for other instructors. This is especially useful when multiple instructors – on site and remote – may use the materials for different purposes and to integrate with different student backgrounds, learning styles, and their own teaching styles.

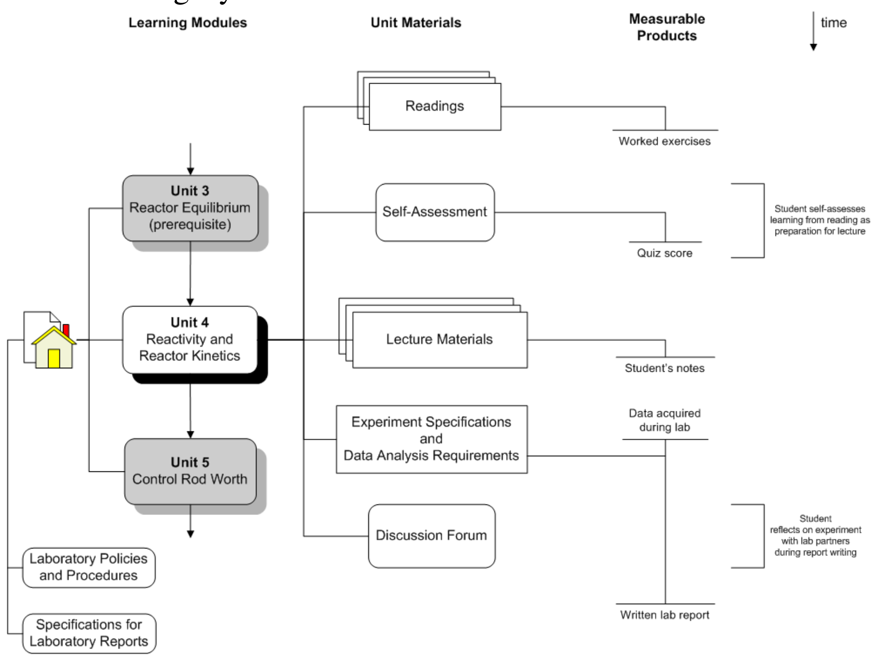

Figure 2 – Example of a typical web site map for a learning module

To utilize the unit materials, students only need an internet connection and access to a Web browser. The videostreaming software, MediaSite, allows for both the live streaming and recording for postponed delivery of lectures and experiments. This software automatically synchronizes the video and slide presentation such that if the student clicks on a specific slide the video will be forwarded to the appropriate location and the student can view the associated content. The streams can be linked to and accessed from the Blackboard site.

Also shown in Figure 2 are the measureable components produced in each unit. These can be used by individual instructors – on-site and remote – according to their teaching style, their objectives for their students, and how they want to assess student outcomes. On-line spaces, such as discussion boards, can also be used by students to interact with each other; for example, to discuss a completed experiment when later trying to write a lab report based on their fuzzy recollections of the experimental details. Instructors can also direct students to use these interaction tools to facilitate peer review and/or assessment of the measureable products.

Blended format

The course material was designed to be delivered both locally and to remote classes. In this project, Rensselaer Polytechnic Institute collaborated with the United States Military Academy at

West Point (USMA), which recently received ABET accreditation for their nuclear engineering program. The USMA does not have local access to a critical facility or a linear accelerator, so their perspective on the module development was critical. Because of the proximity of USMA to Rensselaer (~2.5 hours drive), students will be able to participate both by physically attending the hands-on course at the facilities and via remote connection. This will allow the two modes of participation to be compared and contrasted by on-site and remote instructors and students.

Walthausen Reactor Critical Facility (RCF)

Rensselaer's RCF is a unique low power (<100 Watt maximum, <1 Watt typical) open pool reactor and uses low enrichment (4.8%) SPERT fuel pins (see Figure 3). This configuration allows students to perform a variety of experiments which are usually not possible in higher power university reactors; it also allows handling the fuel with no special protection. The facility includes an adjacent classroom and has some capability to deliver video to a remote location via the web. A current lab course includes the following experiments: Source Range Detector Calibration, Core Loading By Subcritical Multiplication, Determination of Critical Rod Position and Core Excess Reactivity, Differential and Integral Control Rod Reactivity Worth, Fuel Pin Reactivity Worth, Moderator Temperature Coefficient of Reactivity, Void Coefficient of Reactivity, Boron Coefficient of Reactivity, Facility Radiation Survey, Axial and Radial Power Mapping, and Absolute Power Measurement with Gold Foil Activation.

Figure 3 – Top view of the reactor core (left), and the RCF control room (right)

The instrumentation in the facility was recently upgraded and includes digital recorders and computer displays (some shown in Figure 3 on the right). Recently, a grant was secured to instrument the facility with five remotely operable pan-tilt-zoom video cameras, as well as video recording and switching equipment. The layout of the facility and the locations of the cameras used for recording class session are illustrated in Figure 4. A new high bandwidth internet connection was installed to enable video conferencing. Thus, most of the equipment needed to enable distant learning with this facility was already in place. The second phase of this project is intended to enable full reactor operation from a remote location via the internet. This will include transmission of some of the instrumentation data to the remote operator (virtual control panel) and allowing some level of operator-mediated control of the control rods. This will, of course, be done with all the necessary safety and security precautions, just as on-site students can control the reactor under the supervision of a licensed operator. Initial discussions about this idea with the NRC indicated that there is no obvious licensing issue with this concept.

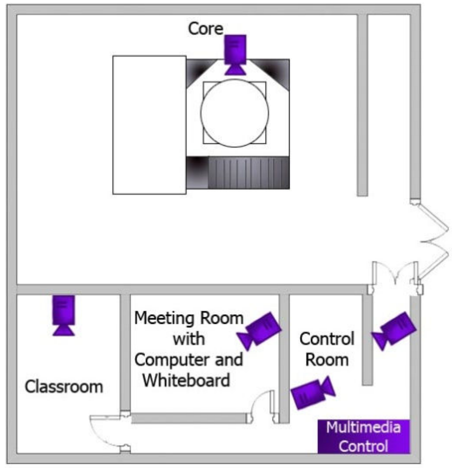

Figure 4 – Simplified layout of the RCF showing the location of the five cameras used for recording class sessions.

The Gaerttner LINAC Laboratory

Rensselaer's LINAC is a powerful 60 MeV linear electron accelerator (shown in Figure 5) which can be used with targets to act as an intense pulsed neutron source. The facility is used for research on neutron reaction cross sections relevant to nuclear power reactors. Reactions such as total, capture, scattering and fission cross sections are routinely measured. This is one of three facilities in the U.S. that still maintains the capability to perform nuclear data measurements in the resonance region of the neutron energy spectrum (~1 eV to 0.01 MeV in energy). Quality nuclear reaction data are vital for useful neutron transport calculations. Inexperienced nuclear engineers may take the nuclear data delivered with computer codes as granted and often do not consider its implication on the accuracy of the calculations. The LINAC lab facility is used to demonstrate how nuclear data are obtained and the students have the opportunity to perform a measurement of the energy dependent total cross section of several materials. This broadens the students' understanding of the importance of nuclear data, how such data are obtained, and the inherent uncertainties in data which can only be obtained experimentally. This is a unique capability at Rensselaer, and this blended course allows for sharing this facility with other institutions.

Figure 5 – The LINAC acceleration sections (left), a neutron producing target (right)

Conclusion

We developed a blended course integrating Web-based components and face-to-face interaction. This approach allowed for the extension of hands-on activities to other universities and other organizations that do not have the facilities available at Rensselaer. These facilities include the Walthausen Reactor Critical Facility (RCF) and the Gaerttner LINAC laboratory.

Combining theoretical modules and hands-on modules provides the flexibility to configure courses that address both reactor physics, criticality safety, and radiation dosimetry related topics. The development was done in collaboration with the United States Military Academy to help in the development and testing of some of the modules. New media instrumentation was recently installed at the RCF and includes five video cameras and the equipment to record the audio/video feed. Data streaming through the internet was added to allow high quality video conferencing and web conferencing. The course material is delivered through Blackboard, Adobe Connect, MediaSite, and video conferencing technologies. Future enhancements will include the possibility to stream some of the control panel instrumentation, and to allow operation of the reactor by remote students – under the supervision of a licensed operator, just as student operators are on-site.

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