AC 2012-3310: DESIGNING AND IMPLEMENTING AN ONLINE OFFERING OF A NUCLEAR ENGINEERING CURRICULUM

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Designing and Implementing an Online Offering of a Nuclear Engineering Curriculum

Abstract

Virginia Tech restarted its nuclear engineering program in the Fall of 2007. The program has grown from a class enrollment of 60 students to about 200 students in 2009. When we restarted our program, we took the opportunity to be innovative and find ways to differentiate our program from other programs nationwide. In addition, we targeted the nuclear industry within our state by offering the majority of our graduate nuclear engineering curriculum via distance learning. We initially started with live video teleconferencing to remote sites and recorded lectures for future playback. However, feedback from students indicated that students with extensive travel schedule or a heavy work load during the week have been unable to take these classes. In addition, we received many frequent requests to transmit classes to sites that cannot support high resolution live video teleconferencing. To address these requests, we decided to move the graduate certificate courses online. This paper presents the development and implementation of our online graduate nuclear engineering courses using asynchronous and synchronous technologies with the education grant from Nuclear Regulatory Commission (NRC). Discussion focuses on the instructional design employed, which is informed by theories, principles, and practices that have been validated for adult education by cognitive science and/or empirical educational research[1, 2 & 3] and processes used by the distance learning institute at Virginia Tech that relies on a structured life cycle methodology for online course development. End of course survey indicated that the online offering is welcomed by students.

1. Introduction

There is an increasing interest in nuclear power due to growing energy needs[4] with the projected increase in electricity demand in the United States as well as the world[5] in the recent years has led to a nuclear renaissance. One of the challenges of this nuclear renaissance is the workforce crisis. There is significant need for educating nuclear engineers who can engage in research in designing newer, safer, better, and advanced reactors as well as in designing and optimizing nondestructive detection systems and monitoring systems for nuclear security and safeguards.

Virginia Tech responded to the nuclear engineering industry's immediate needs by restarting its nuclear engineering (NE) program in August 2007 and offering undergraduate and graduate nuclear engineering courses. Enrollment in these courses for the 2009-2010 academic year was 217 students, consisting of 161 undergraduate students and 56 graduate students. The majority of the graduate students were located off-campus and employed in the nuclear industry at various sites within the state. Given our enrollment population, our graduate nuclear engineering courses have been offered via live video teleconferencing to remote sites from the onset. While the classes are offered at a distance, this type of delivery format as distributed by our university requires that students are able to attend the classes at particular sites as scheduled.

The classes are recorded for later viewing, however, students who have an extensive travel schedule or a heavy work load during the week are unable to take these classes. This has limited some employees from taking any kind of graduate course. Even for those who can attend classes, there is significant stress in balancing classroom and homework deadlines with family and work obligations. In addition, we receive frequent requests to transmit the classes to sites that cannot support high resolution live video teleconferencing or to sites out of the state. Thus, there have been needs to create an asynchronous online option for the nuclear engineering graduate certificate.

One of the appeals of asynchronous technologies is that learners can access materials, complete assignments, participate in discussions, and take exams according to schedules that they largely determine themselves. The hypermedia learning environment offers particular advantages to adult learners who are inherently self-directed[6]. In order to be inclusive of the diverse educational needs of the off-campus students as well as accommodate and enhance our on-campus nuclear engineering program, we proposed to incorporate innovative educational approaches derived from current adult learning theory, cognitive principles, and effective practices.

This paper presents the development and implementation of our online graduate nuclear engineering courses with the education grants from NRC. The courses in this program consist of Nuclear Engineering Fundamentals, Nuclear Fuel Cycle, Radiation Detection and Shielding, and Nuclear Power Plant Operations and Systems. In the following sections, we present the main factors influencing our design decisions as well as the iterative approach employed to design, deploy, and assess the effectiveness of our graduate nuclear courses. The focus of our approach has hinged on balancing the pedagogical techniques and best practices with fundamentals of how learning occurs and participants' personal experiences to respond to the needs of industry personnel as well as increasing enrollment and interest in NE.

2. Course Design

Several factors guided the course design. One factor was the profile of the students who might enroll in the course. Additional factors included the approach used by Virginia Tech for online course design. Next, considerations of students' math skills led to the design of a refresher module on math to help those who needed additional help with these concepts. Finally, the technology available guided our course design.

A. Profile of Students' interested in online offering of Graduate Nuclear Certificate Program

Research revealed that the majority of engineers hired by the nuclear industry are not nuclear engineers. They are mechanical engineers, electrical engineers, structural engineers, chemical engineers, etc. However, they must apply their specialized engineering field toward nuclear power plant applications. Thus, having a solid foundation in nuclear engineering basics will provide significant gains for those engineers who were hired without ever having any knowledge about nuclear power. A graduate certificate in nuclear engineering will provide this foundation. In fact, about half of our industry distance-learning students are interested in only obtaining a graduate certificate and not continuing on to a Master's degree of any kind. In addition, we have had a large demand for these classes in just the short period since we started the program. Thus, this is our motivation to provide the certificate program in asynchronous online format.

B. Life-Cycle Model

While the classical approach to design and delivery of online courses is a linear model relegating assessment of teaching and learning to the end, the method employed for course development at the Research I university serving as the host institution for this study emphasizes a parallel model by integrating consideration of the various factors influencing the learning environment into the initial phases of the online course development. This systems-based approach is designed to allow for more effective integration of course objectives with online strategies, pedagogies, and best practices (Royce 1970). We worked with our distance learning institute and using their process that follows a life-cycle model with seven phases: (a) Planning Phase; (b) Analysis Phase; (c) Design Phase; (d) Development Phase; (e) Testing Phase; (f) Implementation Phase; and (g) Evaluation, Support, and Maintenance Phase. Each phase is distinguished by activities, techniques, best practices and procedures that combine to construct viable, sustainable, efficient, and useful online courses. The design choices are driven primarily by the learning objectives associated with a given course. This methodology for eLearning course development leads to reduced errors associated with haphazard instructional design and development and fewer technical support issues. These benefits are coupled with quality standards that are designed to create sustainable and efficacious eLearning systems that result in higher levels of learning and eLearner satisfaction, and improved understanding of instructional design and online teaching among faculty.

B. 1. Planning Phase of Online courses: role of self-regulation

The design of our nuclear courses was associated with mapping the current face-to-face or video conferencing lecture course into an online format to ensure alignment across the associated course objectives, activities, technology used, feedback mechanisms, assessments, and other key components. During this effort, we examined what the instructor and student each currently do to support or meet course objectives in the traditional format, and then considered the different ways needed to accomplish these in the online format. Both students and instructors face many challenges when making transition from the face-to-face courses to an online format where (a) in the computer-mediated learning social presence consisting of vocal tones and/or facial expression may be reduced, therefore, the instructors have to rely on students to communicate his/her challenge in learning the material, and (b) online learning requires students to exhibit higher level of self-regulated learning (SRL) behavior than the students in a traditional classroom setting.

Schunk[7] defined SRL as "learning that results from students' self-generated thoughts and behaviors that are systematically oriented toward the attainment of their learning goals" (p. 125). Pintrich and Schunk[8] have shown that successful self-regulated learners possess higher levels of motivation (personal influences), apply more effective learning strategies (behavioral influences) and respond more appropriately to situational demands (environmental influences).

The level of self-regulated learning required of students in the online paradigm represents a paradigm shift for many students as the study habits that have brought them success in traditional learning environments are not always effective in the new settings[9]. To facilitate self-regulated learning in students, the assessment therefore has to be formative and promote continued improvement in student performance in addition to assisting students to reflect on their own learning during the assessment exercises.

Research suggests that there is a connection between motivation and SRL. Students must have motivation to use the SRL strategies and regulate their learning efforts. The instructional strategy in a recent study by Shih et al.[10]addressed three motivational components from Pintrich's[11] model for promoting use of SRL. Shih et al. delivered these motivational strategies to students through lecture that consisted of enhancing self-efficacy, increasing task value, and goal orientation (instruction help students to shift their focus from comparing their performance with peers to self-comparison toward intrinsic goal orientation). To enhance students' awareness of their learning process, for example, students were asked to report the number of hours they had studied, how many points they would have to achieve to be satisfied with their performance (satisfaction goal), and how confident they were about achieving their satisfaction goal.

The results of Shih et al.'s[10] study showed that students' performance was better when the instructor explicitly supported their use of self-regulated learning strategies. In the design and deployment of the online course, we attempted to operationalize these principles (self-efficacy, task value, goal orientation) using personal, behavioral, and environmental aspects of SRL strategies. In addition, formative assessment was used to facilitate self-regulation learning in students. One example of promoting SRL in our instructional approach was that we asked students in the first week what they expected to get from the course. We used their responses in the design of the discussion forums topics. Another example is our approach in providing timely corrective feedbacks that was positive and motivating.

B.2. Adult Learner: Theoretical Foundation

Previous research shows that students' motivation to learn impacts the effectiveness of teaching adults[1, 2 & 3]. Quiñones[12] draws the same conclusion in the context of corporate training that improving the participants' motivation to learn the content would increase the program's effectiveness. We mapped our instructional design to the five attributes of a learning environment that according to Wlodkowski[2] have motivational effects on adults as shown in Table 1.

TABLE 1: Factors that Motivate Adult Learning[2]

Factor	Rationale
1. *Expertise* of presenters	Adults expect their teachers to be experts in the material being taught, well-prepared to teach it, and knowledgeable about the interests, needs, and problems of their audience.
2. *Relevance* of content	Adults may quickly become impatient with material they cannot easily relate to their personal interests or professional needs.
3. *Choice* in application	Adults respond well when given options about whether, when, and how to apply recommended methods, and are skeptical of "one size fits all" prescriptions.
4. *Praxis* (action plus reflection)	Adults appreciate opportunities to see implementations of methods being taught and to try the methods themselves, and then to reflect on and generalize the outcomes.
5. *Groupwork*	Adults enjoy and benefit from sharing their knowledge and experiences with their colleagues.

Felder, Brent & Prince[13] show that "*How people Learn* (HPL)" criteria is compatible with Wlodkowski's motivational factors. HPL, a cognitive-based framework for effective instruction, is proven to provide a good basis for the design of engineering instruction[14, 15]. HPL criteria is based on a learner-centered approach and take into account the learners' knowledge, skills, and attitudes. This approach promotes relating the materials to learners' knowledge and providing freedom to make choices in learning tasks. HPL is also knowledge-centered which gives prime importance to most important principles of the subject. The instruction in HPL is designed to enhance skills. It is assessment oriented with timely feedback to learners to help them gauge their attainment of the program objectives. Lastly, HPL is community-centered and is based on a supportive environment among learners deemphasizing competition. Our instructional design approach was informed by HPL criteria and Wlodkowski's motivational factors.

B. 3. Implications to Instructional Development: Students' Data

The profile of students participating in our Graduate Nuclear Certificate program was discussed in section 2A and consists of industry personnel and/or graduate students who typically have significant experience and knowledge about the nuclear industry and are interested in building a solid understanding of nuclear engineering basics. The online version was developed using Wlodkowski's[2] five principles along with HPL criteria to accommodate these learner characteristics. In addition, course design took into account students' survey responses from those who took the previous video teleconferencing version of the Nuclear Engineering Fundamentals course. Some of these responses included the following,
"I have to say that it is an extremely valuable resource to be able to view the recorded lectures. Repeating sections really helps the concepts sink in."

"The annotated class notes and video are great. These features are new to me and I am very happy with the notes and videos. An improvement would be to somehow make those two media available to the students via a long term library. I would very much like to be able to depend on access to these files (notes and video) as a long-term reinforcement to the learning that took place this semester."

"I really enjoyed the class, it has helped me in my job more then you can imagine!"

"Most of us talk and will help each other along the way. I am sure that you can tell by the emails when we have problems."

"It is fun when you believe you suddenly understand how to solve a problem!"

"I have all but decided to drop this course. My reasons for dropping are:
1) I am struggling with the calculus required for this course, primarily because I have not done any calculus since I completed engineering undergrad 18 years ago.
2) I have a wife and two young sons, a full time job, and other demands on my time (such as coaching a soccer team) that prevent me from devoting the amount of time that I believe I need to commit to re-learn calculus and study for this course.
3) Completing each of the two HW assignments for this course took me an inordinate amount of time. I estimate that I have about 15 hours in completing HW#1 and about 12 hours in completing HW#2. Though I received a grade of 100 on HW#1, I do not feel confident because a significant amount of collaboration with classmates was involved.
4) As a result of the above three issues, I am extremely concerned that I would not pass the up-coming mid-term exam."

As one can see from the above quotes there are many challenges that graduate students from the nuclear industry face while trying to also work and balance other personal demands. In our course re-design we attempted to address most of the identified issues in the redesign of the Nuclear Engineering Fundamentals course as well as the subsequent nuclear engineering certificate courses. Data collected from student survey responses indicated that the two key factors were providing an asynchronous self-paced course with just-in-time modules (such as needed mathematics) and providing a virtual collaborative environment among fellow students with multiple channels for communication.

C. Mathematics Review

The Nuclear Engineering Fundamentals course that was offered online in Spring 2011 requires some background knowledge of ordinary differential equations and atomic and nuclear physics. We provided review modules to accommodate these needs using online resources without taking time away from the course material. This was helpful to students who were not up-to-date in some of the prerequisites and these "just-in-time" modules would be used as needed for a refresher on the appropriate subject. This was found to be a particular issue for new students from industry who have not been in a classroom environment for over ten years. Even learning to use natural logarithms and exponentials for radioactive decay equations was difficult at first for some of the students. By incorporating some of the common mathematics skills in review modules with practice sets, this got those students who needed them up to speed much quicker while still allowed for a quick review for the more competent students. It allowed students to take the path through the course that is best for them. Given the success in relation to student learning we plan to incorporate this format into our online course offering.

D. Technology Use

The course management system at our institution is a local implementation of open source Sakai software, Scholar. Tools offered through Scholar are: Discussion Forums, Chat room, electronic assignments, calendar, announcements, lesson modules, Resources document folders, class listserv, electronic grade book, online quizzes, blogs, podcasts, and collaboration wiki. We also used Centra for synchronous virtual sessions including online tutoring and interactive virtual office hours. Centra is a powerful tool for online multiple-user interaction and course organization that includes real-time two-way audio, application sharing, web browsing, white boarding, and text chatting.

We used Camtesia to create course videos. These videos were coordinated with the class notes that were created in power point format and saved in the Resources folder in PDF format. These notes were annotated using tablet PC inking tool and also as an electronic white board. We used the Assignment features to outline the expectations for each week in terms of readings, corresponding videos, notes, home work, quizzes, forums postings, and other appropriate additional materials. We used as few navigation buttons as possible to avoid burdening students with locating the materials. The Home page and the syllabus provided straight forward directions how to access the materials and the expectations of the course. We had pilot tested these features with similar students in previous terms to ensure that the use of the tools and technology are undemanding and simple.

3. First Distance online offering of Nuclear Engineering Fundamentals

The faculty members teaching these courses are expert in the subject of nuclear engineering. For Nuclear Engineering Fundamentals we used the third edition of Introduction to Nuclear Engineering by Lamarsh and Baratta and other supplementary materials. The topics covered were: atomic and nuclear physics, Interaction of radiation with matter, Nuclear Reactors and Nuclear Power, Neutron Diffusion and Moderation, Nuclear Reactor Theory, and The Time-Dependent Reactor. However, we prepared course notes to be relevant and applicable to our students who have worked in industry for a number of years. The power point slides were posted online in advance and were annotated using the inking features provided by a Tablet PC. We prepared videos of the lectures with appropriate examples for solving problems in addition to discussion of additional interesting topics, e.g., a video about Chernobyl accident. Discussion board allowed students to ask questions about homework, quizzes, tests, or any other topics. In the first week, we asked students to tell us what they expected to get out of course.

The topics in the discussion board were designed parallel to topics discussed to allow opportunities for students to communicate and discuss the materials without the pressure of being graded. In addition, forums allowed students to communicate their conceptual understanding of the materials with application examples. As an example, in one of the forum discussion, we asked:

"If you were the Vice-President of Nuclear Operations for an electric utility company and were in charge of deciding whether to build a pressurized water reactor (PWR) or a boiling water reactor (BWR) for your next nuclear power plant, which type would you recommend? Please fully explain your decision. In doing so, state at least four reasons why."

Students' responses are included in the Appendix. All the students participated in the discussion and applied what they have learned to the case. However, responses from the students clearly differentiate those with nuclear industry experience from those without. Those with industry knowledge discussed the case couching the reasoning in their experiences and using conversational words and phrases common among engineers in the work place. The last response, although accurate, lacks of familiarity with industry verbiage and was from a graduate student. This is an example of experiential learning as well using interactive technology to facilitate peer learning and combining disciplinary knowledge with real-life situations.

We provided online office hours to allow students to ask questions and have a live discussion. These were recorded for further viewing. The assessment consisted of 2 to 3 online weekly quizzes depending on the materials covered. Students received feedback on these quizzes after the deadline. These feedbacks were available to students throughout the term for reflection and preparation for final exam.

There were homework problems in line with the topics covered. We provided additional online help for some of the home works. For example in the case of estimating the current lifespan of the world uranium, they used "Nuclear Fuel Supply Calculator" which is an online resource: http://www.wise-uranium.org/nfcs.html and they needed to make some assumptions about the input data. Assignments were graded using PDF annotator and re-uploaded to Scholar. We provided detailed feedback through these home works to help with deeper understanding of the materials. The final exam was a comprehensive take home exam. Students uploaded their solutions using feature of the assignment in Scholar.

4. Observations and Discussion

The first online offering was offered through the distance learning institute. Observational data reveals that distance students in an industry setting appear very comfortable in using all the tools. They took advantage of Forum questions and replay of recorded lectures with annotated lecture notes. Students were diligent in attending to course requirements. They took two to three quizzes weekly except for weeks there was a test. They asked frequent questions about homework and few would post responses to help those with questions along. However, the instructor monitored these questions and for most parts provided answers. We chose to provide feedback to students on their quizzes. However, in Scholar, there is no option to retract this feedback. This allowed students to review the correct responses and prepare for the midterm. Not all the students enrolled in this first online/distance offering worked for nuclear industry. Students' responses to open-ended question in forums reflected the influence of their work experience on their learning. This is considered a valuable experiential learning opportunity to those students who do not have nuclear work experience. In our first offering of the Nuclear Fundamentals, we did not provide a feedback rubric nor did we make posting to these discussion forums a graded item. However, our previous research[16]showed the value of rewards associated with these postings mostly for undergraduate population.

Below are students' responses to the survey at the completion of the course administered by the distance learning institute (Likert scale: 1= strongly disagree, 6= strongly agree),

The mean on the following items "The instructor was well prepared", "The instructor presented the subject matter clearly**"**, "The instructor provided feedback intended to improve my course performance", "The instructor fostered an atmosphere of mutual respect", and "My interest in the subject matter was stimulated by this course" were 6. On the open-ended question: "What did the instructor do that most helped in your learning?" one student wrote "Posting hints to some of the homework problems was quite helpful. Most of the time the huge time consumption came from first understanding and setting up the problem to be solved."

5. Conclusion

The first online offering was successful in meeting our expectations to provide a meaningful learning experience for our adult students. We had offered this course every term since 2007 using video conferencing. However, we designed the online version as outlined in section 2 based on proven theory and empirical results. We made many adjustments during the actual offering based on observational data. A few of the graduate students were not English speaking students and it made some of the communication difficult. Their forum responses tended to be straight from the notes and the book. As the term progressed, these problems diminished. We plan to provide a rubric for the online discussion forums and help improve the interactions among the students for these asynchronous learning opportunities. In the past, upper class levels of our undergraduate students have participated in these graduate nuclear certificate courses. Expanding the use of these online discussion forums should provide an experiential learning setting for collaborations between students with industry experience and other students. To further improve the course quality, we will continue collaborating with our distance learning institute that has recently adopted Quality Matters rubrics for online quality assurance.

The asynchronous nature of the course helped those with heavy travel schedules. We expect to expand the reach of our online nuclear graduate courses nationwide. Currently, we are developing our Master level courses for online asynchronous delivery in 2011-2012 with the NRC grant we received recently. We attribute the success of this first offering to the research based approach taken to align the design and delivery of this online course with students' profile, prior knowledge, and their expectations from these courses. The framework provided in section 2 offers a platform for instructors and administrators to examine their own student populations, available technology, various learning obstacles and opportunities that should be addressed before placing a course online.

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Appendix: Students' Responses to the Forum Question Presented in Section 3

Students' responses to the forum question in section 3 are below. All identifying words are removed from these responses.

One Student responded:

If I were the VP of such a company I would look at the new Generation III Reactor design that has been recently been certified by the NRC. This is a Westinghouse AP1000, a PWR that has been vastly simplified in a standardized design. This standard design shrinks the overall footprint of the core and site facilities, and it's projected cost is ~ $1200 per KW. The AP1000 will have a gross power rating of 1200 MWe, and an estimated build time of 36 months.

It's almost a toss up decision between the Advanced BWR and The AP1000 because the latest generation designs have many safety improvements along with standardized designs, but the PWR design still has some inherent advantages.

1.) The control rods are electromagnetically actuated from above the core so if power is lost they can SCRAM the reactor and the CRs would use gravity to drop into the core and shutdown the reaction.

2.) The obvious reduced exposure to radiation due to the containment of the radioactivity in the primary cooling loop inside the primary containment. It's best to just not have your workers worry about radiation exposure limits. Such as 100millirem per hour.

3.) Its ability to follow the power demand load on the steam turbines and adjust power accordingly by control rod actuation.

4.) It's power density is high, which makes for a smaller core and smaller footprint.

Another student responded:

I am strongly biased because my Company has most experience with PWRs and I am an Electrical Systems Engineer for my Company. As Vice President, I would recommend a PWR for the following reasons:

1. There is truly a lesser spread of contamination. Therefore it is safer to the workers and safer to the public.
2. The ability of using gravity for rod insertion during scram conditions makes the PWR ideal for Nuclear Safety.
3. Seeing that my Company's experience greatly is centered around the PWR, building new PWRs would be cost effective to the company. Persons from within the company can be used for training new employees to staff the new PWR.
4. The ability of dumping steam directly to atmosphere allows for a rapid and simple method for cool down. Cool down during emergent conditions becomes complicated for the BWR and therefore the PWR design would be preferred.

Another student responded:

From this week's lectures, I have concluded that I prefer PWRs over BWRs and would recommend building PWR reactors if I were the VP of NO. I prefer PWRs because:

1) With a PWR the reactor power follows the electrical load. I find this to be an amazing feature that is completely automated by the reactor itself. When an ISO/energy market tells a nuclear plant with a PWR that it needs to output more power (if possibly not at a peak) or reduce its output power, the operator just has to set the generator and allow the reactor to compensate. I imagine this is a huge help in operating a PWR.

2) The PWRs use of gravity to move the reactor control rods during SCRAM. In a BWR, a hydraulic system is needed to push the control rods up into the reactor, which adds costs, complexity, and more chances of failure.

3) PWR's have non-radioactive steam systems, allowing for all access during reactor operation, which I can see as being extremely beneficial in an failure of a (non-critical) component or a full-on emergency. This benefit also reduces radiation exposure, making it safer for all workers.

4) Less core instrumentation is required in the core of a PWR than a BWR, reducing some costs/complexity/chances of failures.