The Journal of Effective Teaching
an online journal devoted to teaching excellence

Educational Innovation in the Design of an Online Nuclear Engineering Curriculum

Simin Hall[1], Brett D. Jones, Catherine Amelink, and Deyu Hu
Virginia Polytechnic Institute and State University, Blacksburg, VA 24061

Abstract

The purpose of this paper is to describe the development and implementation phases of online graduate nuclear engineering courses that are part of the Graduate Nuclear Engineering Certificate program at Virginia Tech. Virginia Tech restarted its nuclear engineering program in the Fall of 2007 with 60 students, and by 2009, the enrollment had grown to three times its initial size. In this paper, we present the innovative ways we employed to differentiate the program from other programs nationwide. Starting in 2009, with education grants from the Nuclear Regulatory Commission (NRC), we began transforming the distance courses from video conferencing to an online format that uses asynchronous and synchronous technologies. We used design principles drawn from research and theories in disciplines such as adult learning, cognitive science, motivation, and education. During these phases we worked closely with the distance learning institute at Virginia Tech which employs a structured life cycle methodology for online course development. We discuss the instructional design approaches used to provide a meaningful learning experience for adults, particularly non-traditional students. In addition we examined observational data to indicate instances for experiential learning.

Keywords: Nuclear engineering graduate courses, online learning, adult learning theories, motivation, MUSIC Model of Academic Motivation.

In recent years, the growing energy needs (U.S. Department of Energy, 2008) due to the projected increase in electricity demand in the U.S. and the world (Energy Information Administration, 2007), has led to increasing interest in nuclear power, and thus, to a nuclear renaissance. One of the challenges of this nuclear renaissance is the lack of an appropriate workforce. There is a significant need for educating nuclear engineers who can engage in research in designing newer, safer, better, and advanced reactors, as well as design and optimize 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 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. Most of the graduate students were located off-campus and employed in the nu-

[1] Corresponding author's email: thall57@vt.edu

clear industry at various sites within Virginia. Given this enrollment population, the graduate nuclear engineering courses were offered via live video teleconferencing to remote sites. Although the classes were offered at a distance, this delivery format required students to attend the classes at particular sites as scheduled.

The classes are recorded for later viewing, yet even so, students who had extensive travel schedules or heavy workloads during the week were unable to enroll in these classes. These barriers prevented some employees from enrolling in any of these graduate courses. Even some of those who could attend classes experienced significant stress in balancing classroom and homework deadlines with family and work obligations. In addition, the program had received frequent requests to transmit the classes to sites that could not support high resolution live video teleconferencing or to sites out of Virginia. These demands led to the need to create an asynchronous online option for the Graduate Nuclear Engineering Certificate program.

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 (Knowles, 1990). To be inclusive of the diverse educational needs of the off-campus students, as well as accommodate and enhance the on-campus nuclear engineering program, we proposed to incorporate innovative educational approaches derived from current research and theory in the areas of adult learning, cognitive science, motivation, and education.

This paper presents the development and implementation of online graduate nuclear engineering courses that are part of the Graduate Nuclear Engineering Certificate program at Virginia Tech. These courses were made possible with education grants from the Nuclear Regulatory Commission (NRC). This certificate program consists of the following four courses: 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 that influenced the design decisions and the iterative approach employed to design, deploy, and assess the effectiveness of these four graduate nuclear engineering courses. At the time we wrote this paper, the Nuclear Engineering Fundamentals course was the only one that had been taught, which allowed us to collect and report data related to this course. To respond to the needs of industry personnel, as well as increasing enrollment and interest in nuclear engineering, the focus of our approach has hinged on balancing current pedagogical methods and best practices, fundamental learning and motivation research and theory, and participants' personal experiences.

Course Design

In this section, we discuss four design factors that guided the design of the online courses. One factor was the profile of the students likely to enroll in the courses. A second factor was the life-cycle model, which was the approach we adopted for the design of the online courses. A third factor was the consideration of students' math skills, which led to the design of a refresher module on math to help those who needed additional help with these concepts. The fourth factor was the technology that was available.

Design Factor 1: Profile of Students Interested in the Online Offering of a Graduate Nuclear Engineering Certificate Program

The majority of engineers hired by the nuclear industry are not nuclear engineers; instead, they are mechanical engineers, electrical engineers, structural engineers, chemical engineers, among others. These types of engineers must apply their specialized engineering field toward nuclear power plant applications. Having a solid foundation in nuclear engineering basics could provide significant gains for those engineers who were hired without ever having any knowledge about nuclear power. A graduate certificate in nuclear engineering could provide this foundation. In fact, we found that about half of our industry distance-learning students were interested in obtaining only a graduate certificate and not continuing on to complete a Master's degree of any kind. In addition, we had had a large demand for these courses in just the short time since we started the program. Consequently, there was a clear need that could be served by providing the certificate program in asynchronous online format. We designed the Graduate Nuclear Engineering Certificate Program to meet that need.

Design Factor 2: Life-Cycle Model

Although a classical approach to design and delivery of online courses is a linear model relegating assessment of teaching and learning to the end of the course, the method employed for course development at Virginia Tech emphasized a parallel model that integrated consideration of the various factors influencing the learning environment into the initial phases of the online course development. This systems-based approach was designed to allow for more effective integration of course objectives with online strategies, pedagogies, and best practices (Royce, 1970). We worked with the Virginia Tech distance learning institute and used their process that follows a life-cycle model with seven phases: (1) Planning Phase, (2) Analysis Phase, (3) Design Phase, (4) Development Phase, (5) Testing Phase, (6) Implementation Phase, and (7) 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.

Planning Phase of Online Courses: The Role of Self-Regulation

The design of the nuclear engineering 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 did to support or meet course objectives in the traditional format, and then considered alternatives to accomplish these objectives in the online format. Both students and instructors face many challenges when making the transition from the face-to-face courses to an online format where: (a) in the computer-mediated learning environment, social presence (i.e., 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 levels of self-regulated learning (SRL) behavior than the students in a traditional classroom setting.

Schunk (2001) defined self-regulated learning (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 (2002) 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 (Hmelo-Silver, 2004). To facilitate students with self-regulated learning, the assessment has to be formative and promote continued improvement in student performance in addition to assisting students in reflecting on their own learning during the assessment exercises.

Students must have motivation to use the SRL strategies and regulate their learning efforts. The instructional strategy in a recent study by Shih, Zheng, Leggette, and Skelton (2011) addressed three motivational components from Pintrich's (2000) model for promoting use of SRL by enhancing self-efficacy, increasing task value, and goal orientation (instruction designed to help students to shift their focus from comparing their performance with peers to self-comparison towards an 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. Students' performance was better when the instructor explicitly supported their use of self-regulated learning strategies (Shih et al., 2011). In the design of our online courses, we operationalized 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 was to provide timely corrective feedback that was positive and motivating.

Theoretical Foundation for Teaching and Motivating Adult Learners

Instruction is more effective for adult students when they are motivated to learn (Hofer, 2009; Jones, 2009; Wlodkowski, 1999, 2003). Quiñones (1997) draws the same conclusion in the context of corporate training: that improving the participants' motivation to learn the content increases the program's effectiveness. We mapped our instructional design to the five attributes of a learning environment that, according to Jones (2009) and Wlodkowski (1999), have motivational effects on adults. The factors that Wlodkowski (1999) identified as being important to motivating adults are shown in the left-hand and center columns of Table 1 and include expertise, relevance, choice, praxis, and groupwork.

Table 1. Factors that Motivate Adult Learning.

Factor (Wlodkowski, 1999)	Rationale (Wlodkowski, 1999)	MUSIC Components — Can lead to students' increased perceptions of: (Jones, 2009)
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.	• Success • Individual Interest
2. *Relevance* of content	Adults may quickly become impatient with material they cannot easily relate to their personal interests or professional needs.	• Individual Interest • Usefulness
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.	• Empowerment • Usefulness
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.	• Usefulness • Empowerment • Success
5. *Groupwork*	Adults enjoy and benefit from sharing their knowledge and experiences with their colleagues.	• Caring

Felder, Brent, and Prince (2011) explain that *How People Learn* (HPL) criteria is compatible with Wlodkowski's (1999) motivational factors. HPL, a cognitive-based framework for effective instruction, has been shown to provide a good basis for the design of engineering instruction (Bransford, Brown, & Cocking, 2000; VaNTH-ERC, 2010). HPL criteria are 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 the 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. Jones' (2009) MUSIC Model of Academic Motivation provides a means through which instruction could be designed to operationalize the theories presented in the HPL criteria and in Wlodkowski (1999, 2003) to motivate adult learning.

In the MUSIC model, MUSIC is an acronym for five important motivational components that should be considered when designing instruction to motivate students: eMpowerment, Usefulness, Success, Interest, and Caring (see www.MotivatingStudents.info for more information). These components were derived from a synthesis of the research and theory in the field of motivation and related fields (Jones, 2009). When these five components are present in an educational learning environment, students have been shown to be more motivated and engaged in their learning. The empowerment component refers to the amount of perceived control that students have over their learning. Instructors can empower students by providing them with choices and allowing them to make decisions. The usefulness component involves the extent to which students believe that the coursework (e.g., assignments, activities, readings) is useful for their short- or long-term goals. One implication is that instructors need to ensure that students understand the connection between the coursework and their goals. For the success component, students need to believe that they can succeed if they put forth the appropriate effort. Instructors can foster students' success by doing such things as making the course expectations clear, challenging students at an appropriate level, and providing students with feedback regularly. The interest component includes two sub-components: situational interest and individual interest. Situational interest refers to the interest in and enjoyment of instructional activities, whereas individual interest refers to one's longer-term personal values and interest in a topic. Instructors can create situational interest by designing instruction and coursework that incorporates novelty, social interaction, games, humor, surprising information, and/or that engenders emotions. Instructors can develop students' individual interest in a topic by providing opportunities for them to become more knowledgeable about the topic and by helping them understand its value. The caring component includes the degree to which students feel cared for by others in their academic pursuits. To support caring, instructors can demonstrate that they care about whether students successfully meet the course objectives and that they care about students' general well-being.

Our instructional design approach was informed by HPL criteria, Wlodkowski's motivational factors, and Jones' MUSIC model. The right-hand column of Table 1 shows the MUSIC model components that Wlodkowski's motivational factors would likely affect most directly. Of course, changes in any one of the MUSIC model components might affect changes in other components as well for any one particular student. For example, if a student begins to see the usefulness of the material, she might also become more interested in it, which could lead to increased engagement with the material and success in learning it.

Implications to Instructional Development: Students' Data

The profile of students participating in the Graduate Nuclear Engineering Certificate program consists of industry personnel and 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 of the program was developed using Wlodkowski's (1999, 2003) five principles along with HPL criteria and Jones' MUSIC model (2009) to accommodate these learner characteristics. In addition, course design took into account students' survey responses from those who completed the previous video teleconferencing version of the Nuclear Engineering Fundamentals course. To demonstrate connections between theory and practice we include some of these responses below followed by the possible implications of these responses on students' perceptions of the MUSIC model components (as noted in brackets).

- "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 recorded lectures help students feel that they can *succeed* and *empowers* them by providing the option of repeating recorded sections.]
- "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." [The annotated class notes and videos help students feel that they can *succeed*.]
- "I really enjoyed the class, it has helped me in my job more than you can imagine!" [The class is *situationally interesting* (enjoyable) and is seen as *useful* to this individual's goals.]
- "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." [Students have *caring* relationships with other students that can increase their academic *success*.]
- "It is fun when you believe you suddenly understand how to solve a problem!" [*Success* can lead to *situational interest* (enjoyment).]
- "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 [homework] 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. As a result of the above three issues, I am extremely concerned that I would not pass the up-coming mid-term exam." [Several issues led to this individual's perception that he would not *succeed*.]

The above quotations demonstrate that there are many challenges faced by graduate students from the nuclear industry while working at a job, completing coursework, and balancing other personal demands. We identified the aspects that were favorable, which included that the program empowered them with choices, helped them to see the usefulness of the material, helped them to succeed, created interest, and fostered a caring learning environment. In our course re-design we attempted to address most of the identified issues in the redesign of the Nuclear Engineering Fundamentals course and the subsequent Graduate Nuclear Engineering Certificate courses. Data collected from student survey responses indicated that the two key factors desired most by students for effective instruction were (a) providing an asynchronous self-paced course with just-in-time modules (such as mathematics) and (b) providing a virtual collaborative environment among fellow students with multiple channels for communication.

Design Factor 3: Mathematics Review

The Nuclear Engineering Fundamentals course that was offered online in Spring 2011 required 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 had not been in a classroom environment for over 10 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, those students who needed a review got up to speed much quicker and the more competent students got a quick review. It allowed students to take the path through the course that was most appropriate given their current knowledge of mathematics. Doing so empowered students through choices that enabled them to succeed in the courses. Given the success in relation to student learning we plan to incorporate this format into our online courses.

Design Factor 4: Technology Use

The course management system at our institution is a local implementation of open source Sakai software called *Scholar*. Tools offered through Scholar include: discussion forums, chat rooms, electronic assignments, calendar, announcements, lesson modules, resources, document folders, class listserv, electronic grade book, online quizzes, blogs, podcasts, and collaboration wikis. 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 PowerPoint format and saved in *Scholar* in the *Resources* section in PDF format. These notes were annotated using a tablet PC inking tool and also as an electronic white board. We used the *Assignment* features in *Scholar* to outline the weekly expectations in terms of readings, corresponding videos, notes, homework, 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 course syllabus provided straight forward directions about how to access the materials and the expectations of the course. We pilot testeded these features with similar students in previous terms to ensure that the use of the tools and technology were not overly demanding and simple enough to increase the likelihood that students would feel that they could succeed in using the course tools and technology.

First Distance Online Offering of Nuclear Engineering Fundamentals

The first course we revised and taught in the new online format was titled *Nuclear Engineering Fundamentals*. The faculty members teaching the nuclear engineering fundamentals courses were experts in the subject of nuclear engineering. This corresponds to the first factor in Table 1, which should also lead to students' increased perceptions of success and individual interest. For course materials, the third edition of *Introduction to Nuclear Engineering* (Lamarsh & Baratta, 2001) and other supplementary materials were used. The topics in the course included: 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. To increase students' perceptions of usefulness, we also prepared course notes to be relevant and applicable to students who worked in industry for a number of years. The PowerPoint 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 and discussed additional interesting topics (e.g., a video about Chernobyl accident). Further, in the first week, to assess students' individual interests and career goals, we asked students to tell us what they expected to get out of course.

The discussion forums allowed students to ask questions about homework, quizzes, tests, or any other topics. Our hope was that students would feel that the instructors cared about their learning and that this would lead them to believe that they could succeed. The topics in the discussion forums 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, these forums allowed students to communicate their conceptual understanding of the materials with application examples. As an example, in one of the discussions, 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 had 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 by couching the reasoning in their experiences and using conversational words and phrases common among engineers in the work place. In contrast, the last response provided in the Appendix, although accurate, lacks of familiarity with industry verbiage and was from a graduate student. This is an example of experiential learning as well as 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 two to three online weekly quizzes depending on the materials covered. Students received feedback on these quizzes after the deadline. The feedback was available to students throughout the term for reflection and preparation for final exam. All of these design elements were included to help support students' success.

Homework problems were provided for each of the topics covered. We provided additional online help for some of the homework. For example in the case of estimating the current lifespan of the world's uranium, they used a "Nuclear Fuel Supply Calculator" which is an online resource (http://www.wise-uranium.org/nfcs.html) that was needed to make assumptions about the input data. Assignments were graded using PDF annotator and re-uploaded to *Scholar*. Detailed feedback was provided through these homework assignments to help foster a deeper understanding of the materials. The final exam was a comprehensive take-home exam and students uploaded their solutions in *Scholar*.

A summary of the course design elements discussed in this section with the corresponding design principles from Wlodkowski (1999), HPL (Bransford et al., 2000), and the MUSIC model (Jones, 2009) are provided in Table 2.

Observations and Discussion

The first online offering of *Nuclear Engineering Fundamentals* was distributed through the distance learning institute at Virginia Tech. Observational data (students' actions observed through *Scholar*) revealed that distance students in an industry setting appeared to be very comfortable in using all the tools offered. One noteworthy observation is the interaction that took place among students in the discussion forum. Students' responses to open-ended questions in forums reflected the influence of their work experience on their learning. This was a valuable experiential learning opportunity to those students who did not have nuclear work experience because they were able to learn from the responses of those who did have work experience. In the first offering of the Nuclear Engineering Fundamentals course, we did not provide a feedback rubric nor did we grade postings to these discussion forums because our previous research (Hall, Dancey, Amelink, & Conn, 2011) showed the value of grades associated with these postings was useful only for the undergraduate students.

A survey was administered to students by the Virginia Tech distance learning institute at the end of the course (reported on a Likert-type scale ranging from 1= *strongly disagree* to 6 = *strongly agree*). The mean value was a 6 for the following items: "The instructor

Table 2. Instructional Elements and Design Principles.

Instructional elements	Wlodkowski	HPL	MUSIC model
1. Using faculty experts in nuclear engineering	• Expertise of presenters	• Learner-centered • Knowledge-centered	• Success • Individual interest
2. Course notes relevant to students in industry	• Relevance of content • Praxis	• Learner-centered • knowledge-centered	• Usefulness
3. Annotated Power-Point slides posted online	• Relevance of content	• Knowledge-centered	• Success
4. Videos of lectures with interesting topics	• Relevance of content	• Knowledge-centered	• Situational interest • Usefulness
5. Asking students what they want in course	• Choice in application	• Learner-centered	• Empower-ment • Individual interest • Usefulness • Caring
6. Discussion forum	• Groupwork	• Community-centered	• Caring • Success
7. Online office hours	• Praxis	• Learner-centered • knowledge-centered	• Caring • Success
8. Weekly quizzes with feedback	• Praxis	• Assessment-centered	• Success
9. Homework problems with online help	• Relevance of content • Praxis	• Assessment-centered • Learner-centered	• Success • Caring

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." 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."

These comments provide evidence that the factors presented in Table 1 led to some of the anticipated outcomes. These findings also show the inherent limitations discussed in our previous research (Hall, Amelink, Conn, & Brown, 2010) in regard to asynchronous technology in engineering courses requiring real-time interaction during problem solving. For example, we offered synchronous office hours to take advantage of aspects of technology and real-time interactions. Sometimes students would participate in these sessions, but when they did not, the instructor would use the time to record the steps to solving some example problems. Students communicated that they found these recordings helpful in doing their homework.

Conclusion and Future Plans

The first online offering of the Nuclear Engineering Fundamentals course was successful in meeting our expectations to provide a meaningful learning experience for adult students. Although we designed the online course based on current theory and empirical research, we made many adjustments during the actual offering based on observational data and plan to make other adjustments in the future. As an example of a possible adjustment, a few of the students were not native English speakers which made some of the communications with the students difficult. Their forum responses tended to be directly from the notes and textbook, which was not as helpful as they could have been if they had done more to elaborate on these ideas and provide further examples. In the future, we plan to provide a rubric for the online discussion forums and help improve the interactions among the students for these asynchronous learning opportunities. Because upper-level undergraduate students sometimes participate in these Graduate Nuclear Engineering Certificate courses, expanding the use of these online discussion forums should provide an experiential learning setting for collaborations between these students and those with industry experience. To further improve the course quality, we will continue collaborating with the distance learning institute at Virginia Tech.

The asynchronous nature of the course helped those with heavy travel schedules as they completed the coursework. We expect to expand the reach of our online nuclear engineering graduate courses nationwide. We are currently developing our Master's-level courses for online asynchronous delivery. 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 discussed 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 developing a course online.

References

Bransford, J., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How people learn: Brain, mind, experience, and school: Expanded edition*. Washington, DC: National Academies Press.

Energy Information Administration. (2007). *International energy outlook 2007*. Report no. DOE/EIA- 0484.

Felder, R. M., Brent, R., & Prince, M. J. (2011), Effective instructional development strategies, *Journal of Engineering Education, 100*(1), 89-122.

Hall, S., Amelink, C., Conn, S., Brown, E. (2010). Online Course Design Informed by Students' Epistemic Beliefs: A Case Study of a Thermodynamics Course, *Proceedings of the ASME 2010 International Mechanical Engineering Congress & Exposition,* IMECE2010 November 12-18, 2010, Vancouver, British Columbia, Canada.

Hall, S., Dancey, C., Amelink, C. T., Conn, S. (2011). Our first online offering of introduction to thermal fluid engineering, *Proceedings of the ASME 2011 International Mechanical Engineering Congress & Exposition*, IMECE2011, Denver, Colorado November 11-17 2011.

Hmelo-Silver, C. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review,16*(3), 235-266.

Hofer, B. (2009). Motivation in the college classroom. In W. J. McKeachie & M. Svinicki (Eds.), *McKeachie's teaching tips: Strategies, research, and theory for college and university teachers* (pp. 140–150). Boston, MA: Houghton Mifflin.

Jones, B. D. (2009). Motivating students to engage in learning: The MUSIC Model of Academic Motivation. *International Journal of Teaching and Learning in Higher Education*, *21* (2), 272-285.

Knowles, M. (1990). *The adult learner: A neglected species*. Houston: Gulf Publishing.

Lamarsh, J.R., & Baratta, A.J. (2001). *Introduction to Nuclear Engineering* (3rd ed.). New Jersey: Prentice-Hall, Inc.

Pintrich, P. R. (2000). The role of goal orientation in self-regulated learning. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of Self-regulation* (pp. 452-502). San Diego: Academic Press.

Pintrich, P. R., & Schunk, D. H. (2002). *Motivation in education: Theory, research, and applications* (2nd ed.). Englewood Cliffs, NJ: Prentice Hall.

Quiñones, M. A. (1997). Contextual influences on training effectiveness. In M. A. Quiñones & A. Ehrenstein (Eds.), *Training for a rapidly changing workplace: Applications of psychological research* (pp. 177–199). Washington, DC: American Psychological Association.

Royce, W. (1970, August). Managing the development of large software systems. *Proceedings of IEEE WESCON*, 26, 1–9. Retrieved from http://www.cs.umd.edu/class/spring2003/cmsc838p/Process/waterfall.pdf

Schunk, D. H. (2001). Social cognitive theory and self-regulated learning. In B. J. Zimmerman & D. H. Schunk (Eds.), *Self-regulated learning and academic achievement: Theoretical perspectives* (Vol. 2, pp. 125-152). Mahwah, NJ: Lawrence Erlbaum Associates.

Shih, H., Zheng, W., Leggette, E. J., & Skelton, G. (2011, November). Enhancing student performance by promoting Self-regulated learning. *Proceedings of the ASME 2011 International Mechanical Engineering Congress & Exposition*. Denver, CO. Retrieved from http://www.asmeconferences.org/Congress2011/PaperAccepted.cfm?noToolbar=yes: IMECE2011-62446.

U.S. Department of Energy. (2008). *Annual energy outlook 2008*. Report No. DOE/EIA-0383.

VaNTH-ERC. (2010, October). Retrieved from https://repo.vanth.org/portal

Wlodkowski, R. J. (1999). *Enhancing adult motivation to learn: A comprehensive guide for teaching all adults*. New York, NY: John Wiley and Sons.

Wlodkowski, R. J. (2003). Fostering motivation in professional development programs. *New Directions for Adult and Continuing Education, 98,* 39–47.

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.

Student 1 Response

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.

Student 2 Response

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.

Student 3 Response

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.