AC 2007-2892: TEACHING NUCLEAR ENGINEERING TO ELECTRICAL ENGINEERING STUDENTS

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Teaching Nuclear Engineering to Electrical Engineering Students

Abstract

Many undergraduate electrical engineering students in major universities are required to enroll in an elective course that is technical in nature and outside the mainstream of electrical engineering. This paper discusses the structure of a course in nuclear engineering to meet this requirement.

Introduction

In the spring semester of 2004, The Citadel Electrical and Computer Engineering department offered a three credit hour lecture course in Nuclear Engineering as a technical elective for junior and senior level students. The course catalog[1] description was "Introduction to the theory and application of nuclear energy. Topics include fission; nuclear fuels; nuclear reactor principles, concepts, examples, construction, operation, and ecological impact; heat transfer and fluid flow; radiation hazards and shielding; nuclear propulsion; and controlled fusion."

The nuclear engineering course has been taught twice, once in the spring of 2004, and again in the summer of 2006. In the first attempt, a number of problems were encountered. The primary difficultly was that the planned number of topics was too ambitious and only a percentage of the topics were actually covered. This required the instructor to make significant mid-course corrections to the syllabus and resulted in reduced student acceptance.

The second time the course was offered the number of topics was reduced significantly. This resulted in a more focused curriculum. The remainder of the paper will discuss the details of topic and text selection, the structure of the course, and student acceptance and performance.

The paper is organized into four remaining sections. The first is background on The Citadel and its engineering programs. The second section describes the trials and tribulations of the first attempt at teaching this course. This is followed by the changes made to improve the course during the second attempt. Next, a discussion of the future plans for the course is provided. The last section of the paper is a summary.

Background

The Citadel is a military teaching college in Charleston, S.C., with a day program student body numbering about 2000, and an evening program of graduate and professional studies with a student body of about 2000. The Citadel School of Engineering has two departments: civil and environmental engineering and electrical and computer engineering. The electrical and computer engineering department is composed of seven full-time faculty, teaching 36 courses to about 125 students from both the day and evening college program.

In 2003, the electrical and computer engineering department decided to offer a technical elective in nuclear engineering in response to a reduction in electives offered by other departments. This course which was in the catalog had not been taught in seven years because of the lack of

sufficient faculty expertise. The renewed interest in nuclear power as an energy source, along with a new faculty member interested in the topic provided the motivation to revive the course.

Spring 2004 First Offering

The major challenge in preparing a course of this type is in deciding on how to condense the abundant information into the time allotted, while still providing significant technical content. Since a survey course in nuclear engineering was not desired, the course content was limited to nuclear power. The reasons for focusing the course on nuclear power were that most nuclear engineers were concerned with nuclear energy and that this concentration would be of interest to electrical engineering students, especially those pursuing the electrical power option.

Even with this reduction in content, topic selection was critical to ensure a reasonably robust but comprehensive coverage of the area. The text, Introduction to Nuclear Engineering[2], by John R. Lamarsh, and Anthony J. Baratta, was selected because of its focus on nuclear power, and because it provided the right mix of theory and practice.

In the spring of 2004, ELEC 307 Nuclear Engineering was offered as a three credit hour technical elective. The prerequisite courses were completion of both the physics and chemistry sequences required of engineering freshman and sophomores. Table 1 and Table 2 provide a quick overview of the course. Table 1 provides a list of the course objectives while Table 2 depicts the plan for how the classroom hours would be allotted.

ELEC 307 Nuclear Engineering Spring 2004 Course objectives
1. Introduction to nuclear engineering concepts including; • Introduction to atomic and nuclear physics. • Fission and fusion • Nuclear fuels • Operation & construction of nuclear reactors and power plants. • Introduction to reactor kinetics. • Introduction to radiation effects and shielding • Heat transfer and fluid flow • Ecological impact 2. Performance of a student report and presentation to promote; • Teamwork skills • Written communication skills • Oral presentation skill

Table 1: Spring 2004 Course Objectives

The student projects topics category was included to provide a student self study component to the course, and required the students to investigate and present information on instructor provided topics. These topics included; biological effects of radiation, radiation shielding, reactor safety, dosimeters, and nuclear instrumentation. The intention was to expose the students to an

ELEC 307 Nuclear Engineering Spring 2004 Course Schedule	Hours Scheduled	Hours Actual
Introduction to nuclear engineering.	1.0	1.0
Atomic and nuclear physics.	6.0	9.0
Radiation and matter	6.0	9.0
Nuclear fuels and Fission	4.0	6.0
Operation & construction of power plants	3.0	5.0
Construction of nuclear reactors	4.0	6.0
Reactor kinetics	4.0	3.0
Radiation effects and shielding	4.0	0
Heat transfer and fluid flow	4.0	0
Ecological impact	3.0	0
Student projects	2.0	2.0
Examinations	3.0	3.0
Total	44.0	45.0

Table 2: Spring 2004 Course Schedule showing hours scheduled vs. hours actually spent.

assortment of related nuclear power topics in a less formal fashion, and provide an opportunity for in-depth study of isolated areas by individual students.

The introduction to nuclear engineering topic was designed as a single lecture overview of the field of nuclear engineering to expose the students to the breath of the field. Although this topic required an effort on the instructor's part, the material was easily conveyed to the students. The atomic and nuclear physic topic followed the course text and covered the areas of fundamental particles, nuclear reactions and nuclear models. As seem from Table 2, this topical area required 9.0 hours vice the allotted 6.0 hours. This 50 percent over-run is attributed to the instructor's overestimation of the students recall of the prerequisite knowledge in chemistry. Unexpected time was spent covering topics on atomic and molecular weights, density and concentrations.

The next topic was on radiation interactions with matter, and covered; neutron interactions, cross-sections, attenuation, and fission; gamma rays, and charged particle interactions. As seem from Table 2, this topical area required 9.0 hours vice the allotted 6.0 hours. This over-run is attributed to the instructor's overestimation of the student's recall of the prerequisite knowledge in physics. Unexpected time was spent covering topics such as elastic and inelastic scattering: neutron flux and intensity; and gamma ray interactions, such as photo-electric effect, and Compton scattering.

Included with the discussion of nuclear fuels and fission the topic of nuclear cycles was also discussed. Once again, additional time was required, primarily due the instructor's unfamiliarity with how long the topic would take to cover. The operation of power plants focused on the non-nuclear portion of the plant. This topic was covered with little difficulty and completed in the time allotted.

The nuclear reactors topic focused on the pressurized water reactor components, however many of the other reactor types found in the course text[2] were discussed in less detail. Significant

additional time was devoted to this topic primarily due to instructor and student interest. In a sense, this was what I envisioned the course to be about, and I had a lot to say.

The final lecture topic actually covered was reactor kinetics. Although a thorough discussion of Fick's law, and the diffusion equation were planned, time permitted only a cursory review. Only the solutions for the slab and spherical reactor were hastily covered. The remaining topics on the initial list were not covered due to time constraints.

Although in hindsight, this topical list seems overwhelming; at the time, it really did seem to be reasonable to an uninitiated instructor. After all, these were the topics listed in the initial course catalog. Figure 2 demonstrates the unreasonableness of the proposed schedule showing that less than half of the initial objectives were met and many were not even attempted.

Student course evaluations suggested that too much emphasis was placed on the early introductory topics on atomic and nuclear physics. In particular the students were not fond of the chemistry related sub-topics on molecular concentrations. On the positive side, students thoroughly enjoyed the power plant and reactor plant operation and construction portions of the course. Student also commented positively on the student research project portion of the course.

Student performance generally followed their likes and dislikes, with the poorest performance occurring on the first exam (covering the introductory topics), and better performance on the two later exams and the student research project.

Summer 2006 Second Offering

In the summer of 2006, ELEC 307 Nuclear Engineering was offered for the second time. Table 3 provides revised course schedule for this three credit technical elective. The changes to the course were a result of the lessons learned from the first attempt. Specifically, the time allotted to earlier topics was expanded to permit more instruction in this area. Additionally, a number of sub-topics were deleted to permit a more thorough coverage of the reactor kinetics topic. A comparison of Table 2 and 3 reveal these changes.

Inspection of Table 3 shows a number of changes. The introduction to nuclear engineering topic was left unchanged. The atomic and nuclear physics topics were allotted additional time, and deleted sub-topics on the shell and liquid drop models, and discussion of gases, liquids and solids.

The radiation and matter topic was given additional time without changing the content. Less time was spent discussing nuclear fuel cycles reducing 2 hours from the time spent in this area. This permitted expansion of the time allotted to the operation and construction of power plants, and nuclear reactor topics. Finally, as a result of the above changes, more complete coverage of the final topic on reactor kinetics was possible.

The student project list was expanded to include some of the topical areas that would not be covered in the course in this second offering. This provided a means to expose the students to some of the material removed from the lecture portion of the course.

ELEC 307 Nuclear Engineering Summer 2006 Course Schedule	Hours Scheduled	Hours Actual
Introduction to nuclear engineering.	1.0	1.0
Atomic and nuclear physics.	8.0	8.0
Radiation and matter	8.0	8.0
Nuclear fuels and Fission	4.0	4.0
Operation & construction of power plants	5.0	5.0
Construction of nuclear reactors	6.0	7.0
Reactor kinetics	6.0	5.0
Student projects	2.5	2.5
Examinations	3.0	3.0
Total	43.5	43.5

Table 3: Summer 2006 Course Schedule showing hours scheduled vs. hours actually spent.

Student response to the change in course content was positive. By devoting more time to a less diverse set of topics during the initial portion of the course improved both student interest, and their performance.

Future Offering of ELEC 307

The plans for the next offering of ELEC 307 Nuclear Engineering include a number of changes intended to improve the quality of the course. The project portion of the course will be expanded to include contemporary issues from nuclear engineering news, reviews, and journals. The reactor plant construction topic will focus on a single reactor type (probably the pressurized water reactor) to allow a more in-depth coverage. This should permit adding a lecture or two on radiation hazards and shielding.

Summary

This paper discussed the structure of a technical elective course in nuclear engineering intended for non-nuclear engineering majors. The paper discusses the difficulty in topic selection, and how these difficulties were overcome. Although the course has only run twice because of scheduling availability, student response to the course has been universally positive. Improvements to the design of the course include providing a wider selection of project topics, and adding topics on reactor kinetics, and radiation shielding.

Bibliography

1. The Citadel®, The Military College of South Carolina, Charleston, S.C., Catalog Issue 2003-2004.
2. John R. Lamarsh, Anthony J. Baratta, Introduction to Nuclear Engineering, 3rd ed. Prentice Hall Inc., 2001