Developing a Minor Program in Nuclear Science and Engineering

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Abstract

The Department of Mathematics and Computer Science at Fort Valley State University (FVSU) has recently developed an academic minor program in Nuclear Science and Engineering for students majoring in science, technology, mathematics, and engineering (STEM).

The minor program is structured around four courses that will feature progressively more advanced topics, and hands-on laboratory-based projects and experimental analysis. These courses are: a two-course sequence in Nuclear Science and Engineering with laboratory components, a course in nuclear radiation, and an introductory course in health physics.

This paper describes the opportunities and challenges for offering a minor program in this field with respect to curriculum development, student recruitment, faculty development, and funding sources.

Introduction

The field of nuclear science and engineering encompasses various areas such as power generation, radiation protection, health physics, medicine, defense, service industries, and research and development. The main workforce for these areas are trained and educated by colleges and universities with academic programs in this field. The nuclear power-generation sector and its allied service industries are the primary avenues for employment for many college graduates with training and degrees in the field of nuclear science and engineering.

The nuclear power generation industries provide approximately 20% of total energy productions in the U.S. through its 104 operating nuclear power plants and, in 2009, employed over 120,000 skilled workers[1]. However, it has been reported that nearly one-third of aging workforce in the existing plants could retire within the next five (5) years[2]. Also, the new plant constructions and capacity expansion in the existing plants necessitates additional workforce that is well-trained.

The possible shortage of trained workers in various nuclear industries sectors is an important issue that has been recognized by both government and the nuclear industry. For this reason, Nuclear Regulatory Commission (NRC) has established various funding programs to facilitate training and educating future nuclear workforce through colleges and universities. These programs are[3]: Minority Serving Institutions Program (MSIP), Nuclear Education Grant Program - Curricula Development, and Nuclear Education Program that itself includes three subprograms; namely, Scholarship and Fellowship, Faculty Development, and Trade School and Community College Scholarship.

The MSIP supports funding for various projects and activities such as mentoring, training, curriculum development, instruction, research and development, internships, and scholarships. The funded projects and activities are competitively selected from grant proposals related to the above programs and activities submitted by minority-serving institutions. The ultimate goals of

this program are to enhance STEM programs at minority-serving institutions and to further diversify the workforce in nuclear industries.

In 2011, Fort Valley State University (FVSU) submitted a grant proposal to NRC under MSIP program to develop a minor program in nuclear science and engineering. The proposal was funded in 2012 for a period of 3 years (2012-2015) to establish and offer the minor program as well as to build the infrastructure needed to support of the program which was officially initiated on our campus in September 2012.

Motivation

The motivation for developing a Nuclear Science and Engineering program comes from three sources:

- Currently, undergraduate students in Middle Georgia do not have sufficient academic opportunities to gain knowledge and training in nuclear energy sciences since no academic institution in this region offers a structured program in the field.
- Minority students in Middle Georgia have even fewer opportunities to gain education in this field, since many students cannot afford the cost and/or meet the admission requirements of colleges and universities that have such programs
- The need for educating more and diverse student groups in nuclear science and engineering, either as future scientists or as members of a technological society, is an important issue that is well-recognized by NRC, American Nuclear Society (ANS), other institutions involved in this field, and more recently the president of the U.S.A.

Through this minor program, FVSU is now able to provide science and engineering students undergraduate teaching and research programs that not only increases their knowledge in the field of nuclear engineering, but will also enhances overall student achievement in science, technology, engineering and mathematics (STEM).

Curriculum Development

The curriculum in Nuclear Science and Engineering at FVSU has been structured around four main courses that feature progressively more advanced topics, and hands-on laboratory-based projects and experimental analysis. The curriculum also includes a calculus course that serves as pre-requisite for the main courses. The total number of credit hours for the minor program is eighteen (18) which is in compliance with the University System of Georgia (USG) requirements. According to USG policies, a minor program must contain 15-18 credit hours of coursework of which at least nine (9) hours must be upper level course work[4] (junior or senior level).

The minor program is primarily designed for STEM students to learn about nuclear science and technology and thus increase their career opportunities in nuclear industries. The STEM majors at FVSU include biology, chemistry, computer science, computer information systems, mathematics, and electronic engineering technology. The biology major has the highest student enrollment and comprises approximately 50% of all STEM students. Thus, the curriculum for the minor is designed with more emphasis on radiation protection and health physics topics that

could be more relevant and appealing to biology students. STEM students at FVSU are usually required to take a minimum of two major electives and two free electives. Thus, it is possible for students to obtain this minor without having to take more than two courses beyond their major requirements. The main four courses of the minor program are described below:

Course One: Radiation and Life (NSEN 1143)
This three-semester hour course is designed to introduce the basic concepts and methods of health physics. Students in this course will be provided with a descriptive overview of everyday exposure of people to ionizing and non-ionizing radiation. Topics include: exposure and biological damage, exposure protection guides, and shielding. The pre-requisite for this course will be PHYS 1112: Introductory Physics II.

Course Two: Physics of Ionizing Radiation (NSEN 3333)
This junior level (three-semester hour) course is designed to introduce to students the fundamentals of atomic and nuclear structure, basic quantum mechanics, radioactivity and decay kinetics, charged particle interaction, Geiger-Muller counters, scintillation counters, neutron detectors, and fission chambers.

Course Three: Nuclear Science and Engineering I (NSEN 3400)
This is the first course of a junior-level two-course sequence. The course contents will include an introduction to: energy sources, atoms and nuclei, radioactivity, nuclear reactions and processes, radiation and materials, fission and fusion, diffusion equations, criticality calculations, nuclear reactors and nuclear power, and radiation detection. This course will be delivered through three hours of lecture and one two-hour laboratory session each week. The pre-requisite for this course is MATH 1115: Calculus.

Course Four: Nuclear Science and Engineering II(NSEN 3500)
This is the second course of the above sequence. The contents of this four-semester hour course will include topics in neutron interactions, transport theory, steady state reactor core, transient reactor behavior and control, radiation shielding, radiation damage and reactor materials problem, nuclear heat transfer, nuclear safety and environmental considerations, and nuclear reactor design and licensing issues. The course materials will be offered in the form of three lecture hours and a two-hour laboratory session per week.

The minor curriculum proposed above is comparable with that offered in various academic institutions in the country.

Nuclear Science and Engineering Laboratory

To support the curriculum of the proposed minor program, it was necessary to establish a basic laboratory in nuclear science and engineering. The last two courses of the minor program include laboratory components to reinforce the focus of each course and provide hands-on training--essential for understanding of key concepts. The lab experiments and projects are also used to support basic undergraduate research activities.

The lab experiments include both physical nuclear experiment and computer simulations. The laboratory textbook "Experiment in Nuclear Science[5]" is used to select and conduct the nuclear experiments that only need radioactive sources that are NRC license exempt and considered to be safe. A laboratory manual has been developed to provide safety instructions for handling of the radioactive sources. According to the established policies of both university and key project personnel, students can only conduct nuclear experiments under constant supervision of their instructors.

Computer simulation experiments are used to expose students to the operation of typical nuclear power plant such as Pressurized Water Reactor (PWR) and Boiling Water Reactor (BWR). The simulation experiments include steady state and transient operations of both PWR and BWR plants. Computer simulations of plant startup, shutdown, and accident cases are also conducted.

Project Website and Online courses

A Web site has been designed to include program information and other useful information related to Nuclear Science and Engineering including links to world-wide resources in this area.

The online equivalent of each of the first four courses will be developed after successfully offering the above courses using traditional (face-to-face) format. The online courses will be developed under Desire-to-Learn (D2L) platform and each course will contain lecture notes, homework assignments, self-test exercises, discussions, and a chat room.

Undergraduate Research Program

An undergraduate research component was added to the minor program to further enhance student learning of key concepts and provide an environment for collaborative learning and team work as well as strengthen students' problem solving, critical thinking, analytical, and computer skills. The research activities will also teach students time-management and project planning skills and expose them to the advanced technologies used in nuclear science and engineering. The research component will also bolster student aptitude to pursue graduate studies and motivate them to become future scientists in this field.

The undergraduate research program in this field will be implemented by engaging students in the research activities of the project key personnel. These activities initially are being carried out on a small scale since this is a new academic program and the research facilities needed for the program may not be fully available (especially, during the first year of the project).

Recruitment Activities

The project also encompasses two main components designed to recruit students, particularly STEM majors, for the minor program. The first component includes aggressive recruitment of FVSU students enrolled in STEM majors by making presentations in orientation classes for lower-division undergraduate students, and by mentoring other interested students. The second component involves the preparation of recruitment materials to include printed materials and/or CD/DVDs that can be distributed to the university library as well as the libraries of other

institutions including colleges and high schools in Central Georgia. Detailed information about the program has been already posted on the Nuclear Science and Engineering Web site. Media exposure for the program will be solicited from area newspapers and community interest television programs in Central Georgia.

Additionally, the authors are in process of writing grant proposals for scholarships and internships for students enrolled in the minor program. We are also planning to partner with a number of universities that offer graduate programs in nuclear engineering to provide our students a pathway to graduate studies in nuclear engineering with possible financial supports from the host universities. The establishment of scholarship, internship, and graduate study opportunities for students taking the minor creates a value system that significantly helps with student recruitment to the minor program and that is critical to its future survival and sustainability.

Challenges

There are many challenges to establish a minor program in nuclear science and engineering for colleges/universities that do not have a major program in this field. These are:

- Qualified faculty members. Fortunately, both the author and his first co-author with Ph.D. degrees in nuclear engineering and atomic physics, respectively, are highly qualified to teach the courses of the minor. Colleges/universities that do not have qualified faculty members in this field but offer programs such as physics, mechanical engineering, and/or chemistry may apply for NRC faculty development funds through writing grant proposals with the objective of establishing academic program in this field.
- Obtaining academic approval to offer the minor program. During the approval process, several questions arose in curriculum committees of department, college, and university regarding the structure of the minor program, student recruitment, program sustainability, and appropriate academic unit to host the program. The approval process took more time than it was initially expected. Due to a lengthy approval process, the program courses (NSEN 1143 and NSEN 3400) were not included in the university master schedule during the pre-registration for fall semester 2013. As a result, only few students enrolled in NSEN 3400 during regular registration for fall semester 2013.
- Student recruitment. The success of the minor program is generally measured by the number students enter and subsequently complete the program. As mentioned earlier, a major challenge in absorbing students to the program is to provide an attractive value system for students.
- Course scheduling. It is important to schedule the courses of the minor program in such way that does not conflict with major courses particularly, junior and senior levels. In fall 2013, there were students who were interested in taking the offered course (NSEN 3400) of the minor program but they could not enroll in the course due to time conflict in the minor course and their major courses.

Conclusions

The minor program in nuclear science and engineering is an opportunity for STEM students at FVSU to receive training in this field and thereby enhance their career opportunities. Currently,

FVSU is the only institution of higher education in Middle Georgia that offers a structured program in this field. The successful implementation of this program could produce a positive impact in science and engineering curricula of the university as well as skill sets of students who complete the program.

In fall 2013, one of the courses (NSEN 3400) of the minor was offered. Due to the lengthy approval process, the courses of the minor program were not placed in the university enrollment system during the pre-registration for fall semester 2013. As a result, the offered course in fall 2013 had a very low enrollment. It is hoped that the student enrollment for the minor program significantly increases during the second and third year of the project with aggressive recruitment and better planning for course scheduling.

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