

Curriculum Development in Nuclear Technology

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Abstract

The number of nuclear-related programs of higher learning has decreased in the last decade or so. However, the need for nuclear-related skilled personnel is increasing and will continue to do so, creating a gap in the supply and demand. The Hazardous Materials Management program and Emergency Management Technology program at Jackson State University have introduced a unique opportunity to bring students into the nuclear profession.

This project is a cooperative effort of Jackson State University, Alcorn State University, and Mississippi Valley State University. We have developed three new courses, one lab module, and a virtual reality training program, and revised four existing courses. These efforts can promote and encourage students to pursue careers in the nuclear field as well as ensure that they can better understand the problems of dealing with nuclear safety and problems related to nuclear/radiation emergency preparedness and response. In this paper, the key elements of the project will be highlighted and the challenges discussed.

1. Introduction

On March 11, 2011, the earthquake and tsunami caused a series of equipment failures and nuclear meltdowns that led to the release of radioactive materials at the Fukushima Daiichi Nuclear Power Plant in Japan. This accident shocked a lot of people in the world, especially the people living in the vicinity of the nuclear power plant [1]. There is one nuclear power plant (Grand Gulf Nuclear Station) located in Mississippi. Responding to a nuclear or radiation accident is one of the most difficult aspects of a disaster response. Effective response to a nuclear or radiation incident requires a broader scope of planning.

Radioactive materials are used in a wide variety of applications. The need for nuclear-related skilled personnel is increasing and will continue to do so. However, the number of nuclear-related programs of higher learning has decreased. This creates a gap in the supply and demand. Educators need to monitor relevant trends in the US economics. The Hazardous Materials Management (HMM) program and Emergency Management Technology (EMT) program at Jackson State University (JSU) can introduce a unique opportunity to bring students into the nuclear profession. In 2014, Jackson State University received a grant from Nuclear Regulatory Commission (NRC). This NRC project has expanded and improved those two programs to deal with nuclear technologies.

Nuclear technology, emergency management, and hazardous materials management encompass a wide range of activities and are a multi-disciplinary endeavor. Faculty and programs collaboration is becoming increasingly necessary in the preparation of the future workforce. To further enhance programs, the Department of Technology at JSU made efforts to collaborate with other academic disciplines. The project is operated in cooperation with faculty from the Biological Sciences Department at Alcorn State University (ASU) and Environmental Health Department at Mississippi Valley State University (MVSU). The partnership among these three universities can improve and increase nuclear related education in Mississippi.

We are developing three new courses (“Introduction to Nuclear Technology” and “Nuclear Emergency Preparedness and Exercise” at JSU as well as “Radiation Safety and Health” at MVSU) and a virtual reality training program, revising several existing courses (“Principle of Hazardous Materials Management” and “Risk Assessment” at JSU, and “Environmental Risk Assessment and Management” at ASU), as well as establishing a laboratory. These efforts can promote and encourage undergraduate and graduate students to pursue careers in the nuclear field as well as ensure that they will better understand the problems of dealing with nuclear safety and problems related to nuclear/radiation emergency preparedness and response.

This paper describes the nature of this project, presents preliminary results, and discusses the challenges it presents. Finally, we present some conclusions and future plans.

2. Emergency Management Technology Program at JSU

As natural and man-made disasters pose greater risks to communities, the demand for skilled professionals who can manage and mitigate their effects continues to grow. During the Spring of 2010, JSU’s Technology Department was selected to receive a grant from the US Department of Homeland Security (DHS) to establish an Emergency Management Technology (EMT) program and to provide a number of scholarships to outstanding undergraduate students. The EMT program offers students a combination of homeland security related science, technology, engineering and mathematics (HS-STEM) coursework, skill-development activities, experiential research opportunities, and efforts that connect students to internships and employment in homeland security and first responder disciplines. The EMT program strives to prepare the next generation of emergency management professionals with the knowledge and skills they need to improve outcomes in disasters of all types.

The EMT program started to accept students in 2011. In addition to providing coursework for students in the program, several of the EMT classes have significant enrollment as electives for students in other technology disciplines. In September of 2011 and 2014, the Department of Technology received two additional grants from DHS. Those grants have allowed JSU to offer scholarships to more academically talented students as well as to augment the EMT program with new curriculum and state-of-the-art laboratories [2]. One benefit of the scholarship is to alleviate the financial burden for deserving students who wish to pursue a HS-STEM field.

A bachelor degree with a concentration in Emergency Management Technology requires the successful completion of 124 credits of coursework. Students are required to complete the university’s 43-hour Liberal Studies component. Other program requirements, outside the major department, supplement the major with additional mathematics and science courses that will enhance the student’s success in the major and in practice. Those requirements include Trigonometry, Calculus, Biology, Chemistry, and Physics.

As mentioned, Mississippi has a nuclear power plant (Grand Gulf Nuclear Station). Nuclear disaster in Japan led to serious concerns related to the contamination in public domain. Nuclear emergencies can arise due to factors beyond the control of the operating facilities. However, through certain pre-planned and established structural and non-structural measures, various stakeholders can still manage such emergencies to minimize risks to health, life, and the environment. The EMT program at JSU needs to train its students to not only be emergency management and preparedness professionals who protect the general public from any potential

nuclear/radiological incidents, but to also be radiation protection specialists who work at nuclear facilities.

3. Hazardous Materials Management Program at JSU

The Master's degree program in Hazardous Materials Management (HMM) received approval from the university and state oversight body, after an extensive review of similar program around the country. The program is mainly designed to teach students to deal with hazardous materials, hazardous waste, transportation of toxic/hazardous materials and wastes, occupational safety, and environmental protection areas. The Hazardous Materials Management program integrates science and technology disciplines. This multidisciplinary program has attracted not only students from the US but also students from foreign countries. HMM program can provide students with a solid foundation in the principles, regulations, and technologies required to manage hazardous materials and hazardous waste. Its graduates have the skills and knowledge to coordinate and manage major hazardous material/waste projects and programs.

The Hazardous Materials Management program has very successful student placement records. Many of its graduates currently work at Federal Emergency Management Agency (FEMA), Occupational Safety and Health Administration (OSHA), Environmental Protection Agency (EPA), Department of Energy (DOE), Mississippi Department of Environmental Quality (MDEQ), and Mississippi Emergency Management Agency (MEMA), as well as in the private sector.

Not only can the HMM program be concentrated in the area of hazardous materials, but it can also be combined with the areas critical to the Nuclear Regulatory Commission. We need to make additional changes to meet those needs and to well prepare our students to take a variety of nuclear technology related positions.

4. Project Overview

As radiation technology expands, the potential of a nuclear/radiological emergency is real. Universities in Mississippi need to train students to have the technical capability to respond to nuclear and radiation incidents. In recent years, nuclear energy production has been re-emerging as vital economic sector in need of workers. Universities in Mississippi need to produce graduates who have a familiarity with and have a clear understanding of nuclear technologies and who will seriously consider employment in nuclear or related industries upon graduation.

In 2014, Jackson State University received a grant from Nuclear Regulatory Commission. The grant can help us attain our goals and help students pursue professions pertaining to nuclear safety, nuclear emergency preparedness, radiological and nuclear consequence management, radioactive waste management, and associated environmental protection.

5. Programs Collaboration

Nuclear technology, emergency management, and hazardous materials management encompass a wide range of activities and are a multi-disciplinary endeavor. Faculty and programs collaboration is becoming increasingly necessary in the preparation of the future workforce. To further enhance programs, the Department of Technology at JSU made efforts to collaborate with other academic disciplines. This project is operated in cooperation with faculty from the Biological Sciences at Alcorn State University and Environmental Health Department at

Mississippi Valley State University, JSU, Alcorn State University, and Mississippi Valley State University are historically black colleges and universities (HBCUs).

Mississippi Valley State University has historically drawn the majority of its students from throughout the Mississippi Delta. MVSU offers concentrated study in the arts, business, education, humanities, public services, pre-professional health services, social sciences, sciences, social work, and technology. Master's level programs are offered in Environmental Health and Bioinformatics. MVSU also endeavors to provide additional programs that are vital and unique to the needs of the population it serves.

Alcorn State University is located 12 miles south wind of the Grand Gulf Nuclear site. ASU is at a high risk for nuclear exposure in the event of a nuclear power plant incident. This project can help ASU to lay the foundation for its own Emergency Management Technology program.

The project team (including faculty members from JSU, ASU, and MVSU) has visited each other's campuses. The team members are developing the new courses and/or revising c existing courses at their home campus. After the pilot tests at the home campus, the team will join their efforts to develop the on-line version for each of the nuclear-related courses.

6. Curriculum Enhancement

As mentioned earlier, this project intends to encourage undergraduate and graduate students to pursue careers in the nuclear field as well as ensure that they will have the set of skills needed in the future workplace. To accomplish these, we are offering three new courses, revising several existing courses, developing a virtual reality program, and introducing a nuclear-related laboratory module into the curricula.

6.1 Development of New Courses

The following two new courses have been developed at JSU: *Course 1*: Introduction to Nuclear Technology and *Course 2*: Nuclear Emergency Preparedness and Exercises. The first new course will replace an existing course (Introduction to Technology) in the undergraduate EMT curriculum. Another new course (Radiation Safety and Health) has been developed at MVSU. The new course (Introduction to Nuclear Technology) is an elective course for undergraduate Technology students this semester (Spring 2016). A learning laboratory environment is essential to draw the attention of students and to promote recruitment and retention. Adding a laboratory facility, along with new courses, is critical for the productivity and viability of the new courses. The new laboratory can facilitate learning enhancement of the courseware with hands-on activities.

6.1.1 New Course 1: Introduction to Nuclear Technology

This new course consists of introducing five new modules. These modules provide students with broad and in-depth knowledge of the nuclear field. The course is open to all interested students in all STEM disciplines. The topics covered can facilitate the students to become self-sufficient in seeking higher education, research, or employment in nuclear industry and associated fields.

Nuclear Radiology

This module focuses on radioactivity, radioisotopes, nuclear radiation, interaction of radiation with matter, radiation dosimetry, safety levels of radiation, and radiation emergency management.

Nuclear Power Technology

This module presents an overview of the nuclear power technology including nuclear reactions, nuclear reactor principles, reactor components, types of nuclear reactors, nuclear power plant layout, and nuclear fuel cycle: enrichment, fabrication, reprocessing, waste production and disposal.

Nuclear Safety

This module provides an introduction to nuclear safety, including the following topics: nuclear safety and security, safety assessment of nuclear facilities, quality assurance and accident analysis, radioactive materials transportation, in-plant accident and management, offsite protective actions, emergency planning, current and future nuclear policy, and safety regulations.

Nuclear Health

The topics include radiation hazards, living organisms and radiation damage, radiation exposure and health impacts, food irradiation, radiation controlling methods, nuclear fall out, and health safety measures in nuclear industry,

Nuclear Waste Management

This module introduces the basic concepts of nuclear waste management, with a focus on radiation sources, nuclear cycle, reactor dismantling, fuel storage, radiological hazards, disposal of radioactive wastes, and safety culture.

Nuclear industry also requires many new professionals whose areas of expertise lie outside of the classical nuclear science/engineering disciplines. We need to reach out to students who will fill these roles. This project is designed to appeal to a wide range of students who are interested in STEM. For instance, the Electronics and Computer Technology students can take this new course. They can become the instrumentation and controls technicians/specialists at nuclear facilities. This project can provide students with the knowledge they will need when working in proximity to a nuclear reactor or in an environment where radiological hazards are present.

6.1.2 New Course 2: Nuclear Emergency Preparedness and Exercises

The new course “Nuclear Emergency Preparedness and Exercises” is a one-semester course. This new course serves as an elective for the Hazardous Materials Management Program. The undergraduate Emergency Management Technology students at senior level can also take this course. This course can reinforce several important topics (such as nuclear radiation, health and safety in the nuclear industry) and also further discuss the nuclear emergency, major nuclear reactor disasters, 10 miles and 50 miles protection action areas, community reception centers, population monitoring, emergency preparedness equipment, and potassium iodine medicine distribution.

6.1.3 New Course 3: Radiation Safety and Health

This course is essential for those involved with planning and implementing homeland security and emergency response for a radiological disaster. This course provides a guide to understanding the myriad details needed during a nuclear crisis. This course has masterfully woven the numerous details into a highly understanding text and into concepts in which the students can easily understand. This course can prepare student who desire to be an emergency manager to be knowledgeable of the issues that develop during a nuclear or radiation event.

6.1.4 Student Learning Outcomes

On completion of the above courses (see Table 1), the student should be able to:

- Understand the basic nuclear principles and radiation protection
- Demonstrate an ability to deal with problems related to nuclear emergency preparedness and response
- Have a critical understanding of nuclear plant health, safety, nuclear waste management, and environmental issues
- Use the radiation detection system

Table 1. List of the New Courses

Class Name	Institution	Classification
Introduction to Nuclear Technology	Jackson State University	undergraduate
Nuclear Emergency Preparedness and Exercises	Jackson State University	graduate
Radiation Safety and Health	Mississippi Valley State University	undergraduate

To measure student learning, besides completing all the instructor assigned works, students also need to pass several Federal Emergency Management Agency (FEMA) Independent Study (IS) courses [3]. The courses include: IS-3: Radiological Emergency Management, IS-301: Radiological Emergency Response, IS-303: Radiological Accident Assessment Concepts, etc.

6.2 Laboratory Module

This project also adds a laboratory module on radiation instrumentation and measurements. Radiation detection and measurement is used to monitor normal operations, detect and analyze abnormal conditions, and ensure safe operation in nuclear facilities. Radiation detection equipment can also be used to screen, identify, and monitor populations for exposure to radiation or contamination from radioactive materials. Handheld instruments, such as Geiger-Muller (GM) pancake survey meters, are suitable for either detailed or spot surveys. Since handheld instruments are portable, rugged, versatile, and easy to use, they are common in the radiation protection community. Walk-through portal monitors can be best employed in community reception centers (CRCs) or in entrances to critical structures, such as hospitals and public buildings.

This project has purchased new radiation detection equipment for teaching laboratory. The equipment includes Radiation Emergency Response Kit (Ludlum Model 2241-3RK2) [4], Portable Portal Monitor (Ludlum Model 52-1-1) [5], and Electronic Personal Dosimeter (Canberra's UltraRadic-Plus) [6]. Radiation Emergency Response Kit, Electronic Personal Dosimeter, and Portal Monitor are shown in Figure 1, Figure 2, and Figure 3, respectively.



Figure 1. Radiation Emergency Response Kit



Figure 2. Personal Dosimeter



Figure 3. Portal Monitor

Several experimental sessions and an accompanying comprehensive laboratory manual have been developed and introduced into the curriculum. The laboratory activities introduce students to various types of detectors used to measure radiations and the general properties of radiation detection systems. The hands-on equipment operation training can further enhance the students' educational experience. This laboratory module has been infused in the new courses ("Nuclear Emergency Preparedness & Exercises" and "Introduction to Nuclear Technology").

6.3 Revising Existing Courses

The Department of Technology at JSU has revised two existing courses, ITHM 300 (Principles of Hazardous Materials Management) and ITHM 520 (Introduction to Hazardous Material Management), to emphasize nuclear waste. The new topics include: nuclear waste transportation, the nuclear fuel cycle, methods of storage and disposal of nuclear waste, and chemistry of nuclear waste. These two courses can help students develop a working knowledge of the technology necessary to address issues such as security and safeguards of radioactive waste as well as environmental and health challenges. This new emphasis can motivate both graduate and undergraduate students to learn various aspects of nuclear technology. At JSU, ITHM 300 and ITHM 520 are required courses for the EMT and HMM programs, respectively.

Jackson State University and Alcorn State University work together to re-structure each of their own Risk Assessment course. In the revised Risk Assessment course, a great deal of emphasis is placed on Probabilistic Risk Assessment (PRA) techniques. PRA (also known as probabilistic safety assessment) is used to predict the future behavior of processes generally in terms of

likelihood and outcome (severity). PRA has been used to assess the designs of high hazard, complex, low risk systems (such as chemical manufacturing plants and nuclear power plants). PRA examines events that contribute to adverse outcomes through the use of event tree analysis and determines the likelihood of event occurrence through fault tree analysis.

6.4 Virtual Reality Teaching Program

The greatest challenge facing emergency response personnel is the ability to train effectively. Recent information technologies make it possible to have a wide set of innovative training tools [7-10]. Among these, virtual reality and environments have a great potential to enhance the learning process. Virtual environments (like Second Life) can provide users with the opportunity to create an emergency situation that could not otherwise be experienced due to safety, cost, and environmental factors [11-13]. This can provide students with a hands-on experience that is more realistic and immersive than any classroom scenario can provide. Thus, students have the opportunity to become better equipped to handle real life situations. Students can make appropriate decisions on urgent matters because virtual environments have given them a tool through which they have developed skills in a safe yet virtually real environment. Due to these advantages in practice, virtual reality and visual simulation have been widely used in emergency training.

Second Life is an Internet-based multiuser virtual environment. This social network allows its users from various geographical locations to interact with one another in the virtual world. The members of this social network can communicate by text-based or voice-based chat [14]. In Second Life, users are represented by their avatars. An avatar is an online, self-created, animated characterization of the user that can act in any role. Second Life offers a useful medium for role playing.

This project has used Second Life to develop computer-based training materials and exercises (see Figure 4). The training materials offer a variety of environments with customized buildings, objects, and scripting tailored to various scenarios of nuclear/radiation emergencies. Some structures, furniture, and equipment can be purchased within Second Life from vendors. Students can have the chance to learn by reading, listening, and seeing. By using Second Life, instructors can involve a group of students to conduct a virtual live nuclear/radiation emergency exercise. Thus, students can have the chance to practice the skill that they are taught through exercises. Before entering role-playing sessions, instructor can organize virtual seminars facilitated by chat and voice communication functions that can be used with or between students to interact with each other. The virtual reality training program can pique student interest and create an enjoyable interactive experience. Virtual reality program can also be used as a tool to educate the general public and schoolchildren.

Located on an “island” in Second Life, this virtual training program (as shown in Figure 4) includes a medical center, portable decontamination facilities, washing facilities, and medical tent, along with a gymnasium. The training program also includes a nuclear power plant and fire station. The gymnasium can be used as a shelter or community reception center. Community reception centers need to be established to provide contamination screening and decontamination services to people displaced by a radiation incident. Community reception centers are also needed to register people for follow-up monitoring, medical assessment, or medical management if necessary [15].



Figure 4. Virtual Training Program

7. Course Offerings and Status

As the project recently moved into its second year, several nuclear-related courses have been offered. At JSU, ITHM 300 “Principle of Hazardous Materials Management” and ITHM 520 “Introduction to Hazardous Material Management” have been revised to include nuclear related chapters. The ITHM 300 course was offered in Spring 2015 (face-to-face instruction). The course was also offered in Fall 2015 (on-line class). This is the first time using distance learning format. ITHM 520 is scheduled to be offered in Spring 2016. ITHM 405 “Risk Assessment” has also been revised to include nuclear related topics. The course was offered in the Fall 2015.

The two new courses (Introduction to Nuclear Technology and Nuclear Emergency Preparedness and Exercises) that have been approved by the Jackson State University are scheduled to be offered in Spring 2016. Assessment data will be gathered with each new course offering. Data from this survey will be used as a means of presenting student perceptions on the impacts, strengths, and weaknesses of the course. The Department of Technology at JSU is accredited by the Association of Technology, Management, and Applied Engineering (ATMAE). The course modification should not impact program accreditation.

At ASU, the course “Environmental Risk Assessment and Management” has been revised and reconstructed. The course was offered in Spring 2015. The course is also offered in Spring 2016. At MVSU, the course “Radiation Safety and Health” is scheduled to be offered in Spring 2016.

8. Partnerships

This project team has partnered with Mississippi Radiation Response Volunteer Corps (MRRVC) [16], which is sponsored by Mississippi State Department of Health (MSDH). MRRVC is composed of a group of professionals whose expertise is in the field of radiation

safety and control. The MRRVC was developed to serve the public during radiological emergencies. The mission of the MRRVC volunteer is to aid community through preparedness by educating, training, and assisting during a radiological incident. While population monitoring during a mass causality will be the foremost role that the group will perform, all trained volunteers will be available to provide assistance as needed.

All JSU students concentrating in Emergency Management Technology and Hazardous Materials Management are encouraged to join MRRVC. After receiving proper training, the students can help the public in emergency response during a radiological event. They can provide assistance at community reception centers, shelters for displaced populations, emergency operations centers, hospitals, and communications facilities. ASU and MVSU students who are interested in emergency management and nuclear technology are also encouraged to participate in the MRRVC training.

9. Future Work

The goals of this project are (1) expanding curriculum options for undergraduate and graduate students by introducing new courses focused on nuclear/radiological areas, and (2) increasing the number of minority students pursuing a career in the nuclear or related industries.

Although this project has not yet been completed, excellent overall progress is being made by all of the participating institutions. A survey will be conducted on the students who have taken the nuclear related courses to investigate the effect, if any, that this experience may have had on students' careers. This team also intends to continue assessment. We want to know if students who have graduated and secured a job are working in a nuclear related field. We will ask students who have graduated but have not yet secured a job and those who are still in school which field they would like to be employed.

This project team has been working to accommodate a variety of course formats (traditional classroom, on-line/distance education, etc.) to make coursework accessible to a much broader student community, and to flexibly meet the needs of each individual student. The new and revised courses developed under this project will also be expanded to include on-line learning. As mentioned in the previous section, ITHM 300 was offered as an online course in Fall 2015.

Some hands-on laboratory experiments can not be effectively converted for on-line delivery. Several classes may be designed for so called "Hybrid" to accommodate hands-on laboratory sessions. Therefore, there is the possibility of requiring on-line students to have an on-campus weekend to participate in the laboratory exercises.

Another challenge facing the project team involves marketing the program to increase awareness and interest in the program with the ultimate objective of increase enrollment. The project director currently coordinates all the student recruitment tasks with the support from the team members. The project team intends to seek help from other groups within the university to address challenges in this area.

We have gained substantial experience in developing nuclear/radiation, hazardous materials management, and emergency management related courses. We wish to share our experience with others. Therefore, we will facilitate connections with faculty at other institutions doing relevant work. There is no similar program in the state of Mississippi. We will do a nationwide study to learn which institutions offer similar courses, and do a comparison on the course offerings.

10. Conclusions

This paper provided an overview of continuing effort at Jackson State University on curriculum development for nuclear/radiation emergency preparedness and response. In order to have broader impacts, the project also involves Alcorn State University and Mississippi Valley State University. This project which introduces nuclear related subjects to curriculum can increase the number of students graduating with skills in nuclear technology as well as supply new well-trained scientists/technologists to fill nuclear industry, emergency management, and homeland security positions. The funding from NRC provides the necessary support to enrich both the content of lectures and laboratory exercises as well as the way in which they are taught. From a course-offerings perspective, this program is unique. It is the only program offered in Mississippi. The impact of this project on education infrastructure will be substantial. The development and delivery of the new teaching materials can improve faculty teaching competencies. This project is the first step in cultivating future nuclear related curriculum development and research efforts among universities.

Acknowledgements

This material is based upon work supported by the Nuclear Regulatory Commission under grant NRC-HQ-84-14-G-0066. This support is gratefully acknowledged.

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