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Nuclear Security Education at the Pakistan Institute of Engineering and Applied Sciences (PIEAS): Current Status, Future Prospects, and Lessons Learned

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Abstract

In this paper, the details of nuclear security education at the Pakistan Institute of Engineering and Applied Sciences (PIEAS) are discussed. Nuclear security education was initiated at PIEAS as a sub-specialty of its Master of Science (MS) in Nuclear Engineering Program in October 2009. Two courses, Nuclear Security (NE-581) and Physical Protection Systems (NE-582), have been offered on a regular basis in the third and fourth semesters. To date, 72 students have graduated with this sub-specialty. Lessons learned during this process have been discussed in detail. The most important lesson learned is that the introduction of nuclear security-related courses in nuclear engineering programs has gradually opened new avenues of application for nuclear engineering principles in nuclear security. It is also helping in the development of nuclear security culture among nuclear engineering professionals to deal effectively with the security related challenges, while working inside nuclear facilities. PIEAS has maintained a close collaboration with all stakeholders at the national level to facilitate the development of human resources in the area of nuclear security. PIEAS has also extended its full cooperation with the International Atomic Energy Agency (IAEA) for the development of nuclear security educational networks, such as the International Nuclear Security Education Network (INSEN), and the Nuclear Security Support Centers (NSSC) Network. PIEAS plans to continue its long journey of imparting quality nuclear security education towards a complete MS in nuclear security by introducing more security-related courses, initiating faculty development programs, and developing required nuclear security education-related infrastructure at PIEAS in the form of laboratories in the future.

I. Introduction

Pakistan's nuclear program began in the 1960s. The main purpose was to make use of nuclear energy for peaceful purposes. The vital role of the highly trained human resource was realized in the very beginning. Young scientists and engineers were sent out of the country to renowned institutions of the world. This

method was very expensive on the national resources. A need was felt to initiate academic programs within the country related to nuclear engineering education to fulfill future national needs. In this regard, the Pakistan Institute of Engineering and Applied Sciences (PIEAS), formerly known as the Center for Nuclear Studies (CNS), was established in 1969. In the beginning, it was an affiliated department of Quaid-i-Azam University in Islamabad, Pakistan. An MS in Nuclear Engineering was the first program. It was followed by two more MS programs, MS in Systems Engineering and M.Sc. in Nuclear Medicine. PIEAS received its degree award status in year 2000 [1].

After the degree award status, more master's degree programs have been initiated in the areas of process engineering, materials engineering, mechanical engineering, radiation physics, medical physics, nuclear medicine, and radiation medicine and oncology after receiving degree award status. At the same time, PhD programs have also been initiated in all major disciplines mentioned above. Three undergraduate programs, in computer science, electrical engineering and mechanical engineering have also been initiated in PIEAS. In addition to the degree programs, PIEAS also offers specialized short courses to engineers, scientists and other professionals for their continuing professional development. The length of these courses varies from three days to nine months and the areas covered have included reactor supervision and operation, health physics, medical physics, laser technology, vacuum technology, computer applications advanced reactor safety and management sciences [1].

The MS Nuclear Engineering Program at PIEAS consists of five semesters (four full semesters and one summer semester). The main core courses of nuclear engineering, related to nuclear physics, radiation detection, thermal hydraulics, nuclear materials, nuclear reactor statics and dynamics, etc. are covered in the first two semesters. The third and the fourth semesters cover elective courses related to various disciplines of nuclear engineering, such as geophysics, nuclear materials, mining, reactor control instrumentation, nuclear safety, etc., to familiarize students with advanced applications of nuclear engineering principles in these disciplines. Advanced nuclear engineering laboratory courses are offered in the third and fourth semesters to familiarize students with radiation measurements using radiation detection equipment and other practical aspects of nuclear engineering. Seminar thesis research projects are also initiated in the beginning of third semester. Preliminary research work is done in the third and fourth semesters along with theory courses. The fifth semester is fully devoted for this research project. Every student is required to write a thesis research project report and defend with oral presentation in front of a committee of examiners [2].

The MS Nuclear Engineering Program is the oldest MS program at PIEAS. Around 1,500 engineers and scientists have graduated from this program since the institution was established. These graduates form the backbone of nuclear energy program of Pakistan. The participants of the MS Nuclear Engineering Program are selected from almost all engineering and scientific disciplines as nuclear engineering is a multi-disciplinary program. The nuclear security education program at PIEAS is part of its MS Nuclear Engineering Program supervised by Department of Nuclear Engineering at PIEAS [2]. The initiation process of nuclear security education at PIEAS, courses evaluation methodology, student selection criteria, and the main lessons learned during this process are discussed in detail in Section II.

PIEAS's highly qualified faculty matched with excellent infrastructure are instrumental in its endeavors to offer high quality education in the emerging disciplines of engineering and applied sciences, fulfill national and regional requirements for highly qualified professionals and contribute to the welfare of humanity through education, research and development [1].

II. Nuclear Security Education at PIEAS

In 2008, the Pakistan Nuclear Regulatory Authority (PNRA) requested PIEAS to initiate nuclear security education. Several meetings of officials from PIAES and PNRA were held to explore different options to

do so. A thorough analysis of the IAEA's Educational Program in Nuclear Security (draft at that time and later published as IAEA's Nuclear Security Series No. 12 [3]) and the existing curriculum of MS Nuclear Engineering at PIEAS was performed. This analysis revealed that some of the required courses for MS Nuclear Security have similar contents to some of the existing core courses offered on a regular basis in MS Nuclear Engineering Program [2, 3]. Finally, it was decided to start the nuclear security education as a sub-specialty of the MS Nuclear Engineering Program in October 2009, in close collaboration with the International Atomic Energy Agency (IAEA) and Pakistan Nuclear Regulatory Authority (PNRA). Since then, two elective courses, Nuclear Security (NE-581) and Physical Protection Systems (NE-582), three credit hours each, have been offered on a regular basis in the third and fourth semesters.

These courses were designed in accordance with guidelines provided by IAEA's Educational Program in Nuclear Security. The contents of these courses were first scrutinized by Board of Studies of Nuclear Engineering Department. Then these were thoroughly reviewed by the Board of Faculty of PIEAS and were finally approved by the Academic Council of PIEAS (the highest academic accreditation body of PIEAS) to be offered in the MS Nuclear Engineering Program [1, 2, 3].

A. Nuclear Security Course Material Preparation

The main source for lecture material preparation was the material available from IAEA training courses related to nuclear security topics. It was collected from the scientists and engineers who had undertaken relevant IAEA training courses. Other sources were searched and located through the Internet. This material was tailored for the courses and relevant assignments were also prepared. Later, when nuclear security courses related material became available through the INSEN web portal, the original lecture material was modified [4]. These course materials are updated on regular basis.

B. Course Evaluation Methodology

It was decided to take two one-hour sessional tests and one terminal exam for the purpose of course evaluation. 30 percent of the credit was allocated to class assignments, which included term projects allocated to individual students. Different nuclear security and physical protection related topics were assigned to the students and each was required to search the topic and submit a term project report and give a presentation to the class. Assignments related to physical protection systems were mainly based on a hypothetical nuclear facility used in the course. Other assignments included several nuclear security-related video documentaries. Students were required to watch these documentaries at home and note the lessons learned. Every student was required to share the lessons they learned with the rest of the class during discussion sessions [2, 4].

C. Student Support System (Terms & Conditions)

In order to attract students to the educational programs offered at PIEAS, it offers a fellowship to all students. Currently, the amount of fellowship stipend is Rs. 25,000/(\$250) per month. Additional benefits include complete waiver of tuition fee, single or shared fully furnished accommodation at the PIEAS hostels in Nilore, free transport to and from Rawalpindi/Islamabad at scheduled hours, and free indoor medical treatment. Some minor deductions are made from the student stipend for upgrades and maintenance of PIEAS hostel facilities. At the time of joining PIEAS, all recipients of fellowship must submit a surety bond (legal agreement), which contains a condition that they will be required to serve the organization for five years after graduation or pay back all the expenditure incurred (in lump sum) as bond money to PIEAS. The continuation of the fellowship is contingent upon satisfactory academic performance of the students during the MS program, reviewed at the end of each semester. All successful graduates of this program are offered jobs with three advanced increments and promotion to the next cadre after two years, subject to satisfactory job performance [1, 2].

D. Student Selection Criteria

Eligibility criteria for the award of a fellowship to applicants has been set to have a main professional degree with first division (overall minimum of 60% marks) and throughout the rest of their academic career. The age limit for the award is set at 30 years at the time of joining the program. All applicants go through a comprehensive written examination conducted on a nation-wide scale simultaneously. The written test is multiple choice questions and contains both a general knowledge part and a technical part related to the professional degree of the applicant. A certain number, from the top of the merit list (depending upon the requirement set by organizations) are called for an oral interview. The final selection is strictly on open merit, determined by written test and interview [1].

III. Current Status and Future Prospects of Nuclear Security Education at PIEAS

Nuclear security related courses have been offered without any break since October 2009. So far, 72 students have graduated with this option. The overall percentage of the students taking nuclear security education as a sub-specialty of nuclear engineering is about 10% with an average class size of 100 in recent years. A proposal is also under consideration for declaring the nuclear security course (NE-581) as a compulsory course for MS Nuclear Engineering program. Two years ago, a new, two-year MS Radiation Physics program has been initiated at PIEAS to fulfill the requirements of the qualified radiation physicists at different nuclear facilities, including nuclear power plants. The nuclear security related courses have been declared as compulsory for the students of MS Radiation Physics program. The average number of students enrolled in this program is nine, so far. This has increased enrollment in nuclear security related courses significantly.

A. Nuclear Security Education for Senior Management

The senior management of any organization has a vital role in determining an organization's strategic security policies, resource management, budget allocations, and managing the overall organization's security environment. Therefore, it is very important that senior management has a complete picture of the nuclear security threats to the organization and the relevant nuclear security infrastructure to deal effectively with these threats. A one-week module related to nuclear security has been added to Senior Officers Management Course (SOMC), offered three times a year at PIEAS for senior officers of all strategic organizations of Pakistan. This one-week module consists of topics related to national nuclear security policies, nuclear non-proliferation issues, nuclear security related, international obligations of Pakistan and associated international and national legal framework. These topics are thoroughly covered by experts from the Ministry of Foreign Affairs (MOFA), the Strategic Plans Division (SPD), and the Arms Control and Disarmament Affairs (ACDA) of SPD [1].

B. Collaboration with Other National Institutions

At the Nuclear Security Summit of 2014, Pakistan announced the establishment of the Centre of Excellence in Nuclear Security [5]. This Centre of Excellence is a concept comprised of three main institutes: (1) Pakistan Centre of Excellence for Nuclear Security (PCENS, SPD) at Chakri Academy, Rawalpindi, Pakistan, (2) National Institute of Safety and Security (NISAS, PNRA), and Pakistan Institute of Engineering and Applied Sciences (PIEAS). At the national level, PIEAS maintains a close collaboration with these national institutions responsible for nuclear security education and training in Pakistan. This collaboration includes the conduction of training courses (both at the national level and international level), exchange of resource persons for the conduction of courses, special lectures, and for practical training sessions for faculty, trainers, and students on a need basis.

C. Contributions of PIEAS to Nuclear Security Education at International Level

PIEAS has actively participated in the development of curricula for IAEA's educational program in nuclear security. PIEAS has been a member of INSEN (International Nuclear Security Education Network) since its inception [6]. PIEAS faculty has contributed significantly to the INSEN mission by becoming actively involved in the development of INSEN infrastructure, the preparation of manuscripts of nuclear security related textbook chapters along with instructional materials, and by serving as the first chair-person of INSEN. PIEAS faculty members have also served as resource persons for several IAEA's nuclear security related courses held in South East Asia. PIEAS is also an active member of the Nuclear Security Support Centers (NSSC) network. PIEAS faculty members have served as Working Group-C Vice-Chair, and now as the Chairperson for the same group. This Working Group-C is responsible for the promotion of nuclear security training at global level under NSSC.

D. Future Prospects

In the future, more elective courses from Nuclear Security Series-12 will be added gradually to this program, depending upon the availability of faculty and the required infrastructure (such as labs etc.), until the number of nuclear security related courses become sufficient enough for the awarding of a full-fledged MS Nuclear Security degree [3]. Three more courses are already in the approval process by the course accreditation committees of PIEAS: "Nuclear Forensics", "Nuclear Materials Accounting and Control" and "Detection of Criminal Acts involving Nuclear and Radioactive Materials". The curricula of these courses have been designed in light of guidelines provided by Nuclear Security Series-12. The establishment of practical laboratory facilities related to these topics are currently in progress at PIEAS. This work will be accomplished in collaboration with IAEA and the Pakistan Nuclear Regulatory Authority (PNRA). The establishment of these laboratory facilities will facilitate PIEAS in offering the above-mentioned nuclear security related courses as these will greatly facilitate in-depth understanding of the concepts introduced in these courses. The required faculty training for these courses are planned to be accomplished through participation in IAEA training courses offered at the national level and the international level related to these topics. Faculty exchange programs through IAEA's INSEN will also be explored.

IV. Lessons Learned

Many lessons have been learned during the process of initiating nuclear security education as a sub-specialty of MS Nuclear Engineering Program. Some of the main lessons are mentioned below:

1. Initiating the nuclear security education as a sub-specialty of the MS Nuclear Engineering degree program has the added advantage of these students graduating being able to also work as nuclear engineers, if required, as they have taken all the core courses of Nuclear Engineering Program.
2. Taking nuclear security related courses provide nuclear engineering students with a broader vision of the technical aspects of both nuclear security and nuclear safety.
3. It helps develop a nuclear security culture among nuclear engineering professionals working in nuclear facilities with awareness about nuclear security issues and challenges related to their routine jobs.
4. It provides a platform among future professionals in nuclear engineering and nuclear security to generate synergy and helps diminish an inherent security-safety conflict that existed between these professionals.
5. It facilitates the sequential introduction of new academic disciplines in a university environment until the requirements are completed for the awarding of a new degree in the future.

6. Allocating term projects for the courses related to nuclear security helps broaden the student vision about nuclear security and bringing innovative ideas to develop and improve national nuclear security regime.
7. Introducing nuclear security as an elective course for graduating nuclear engineers in their curriculum adds new dimensions of knowledge and understanding for the applications of nuclear engineering and nuclear security. There was a strong need for graduates to have combined technical- and policy-based skills in nuclear industry, government services like regulatory bodies, foreign offices, etc. The proposal of making one nuclear security course compulsory for all nuclear engineering students is also in progress.
8. Introducing nuclear security education at the university level in Pakistan has given a good face to the institute as very few universities in the world are imparting education in nuclear security. It has also opened new horizons of cooperation at international and national levels in nuclear security and has played a role improving the image and confidence of the nation in our national institute and at the IAEA member states level.
9. Nuclear Security education also helps meet the demand/requirement of capacity building in the latest techniques of prevention and detection of, and response to, malicious acts against nuclear facilities, which was an essential requirement for the expansion of the nuclear power program that Pakistan has adopted for its future energy security plan.
10. Launching this program by PIEAS proves it is a strong pillar of Center of Excellence in Nuclear Security in Pakistan.

V. Conclusion

Nuclear security education and training is vital for the effective implementation of a comprehensive nuclear security regime in a state. Nuclear security education at PIEAS is playing a vital role in the development of human resources required in nuclear security in Pakistan. It also has made significant and important contributions at the international level. Gradual introduction of more nuclear security related courses at PIEAS, faculty development through qualification improvement courses, a faculty exchange program with other renowned institutions of the world, and the development of a required infrastructure in the form of laboratories for hands-on practical training, will greatly facilitate PIEAS in imparting quality nuclear security education. The successful continuation of this program will lead to an MS in nuclear security, as proposed by IAEA. This will also help develop nuclear security professionals who would certainly make a difference in the prevention, detection and response to nuclear terrorism incidents at the national and global levels.

VI. Notes and References

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VII. Authors' Bios and Contact Information

Dr. Tariq Majeed is currently working as Deputy Chief Engineer (and Professor) at PIEAS. He completed his BS in Electrical Engineering from the University of Engineering and Technology, Lahore in 1984. He received his MS in Nuclear Engineering from Quaid-i-Azam University, Islamabad in 1986. He was awarded a scholarship for higher studies leading to a PhD degree at the Ministry of Science and Technology of Pakistan. Then he moved to Purdue University (USA) to complete his PhD in Nuclear Engineering. After completing it in 1993, he served as a visiting lecturer at Purdue University for one semester. Then he joined the Pakistan Institute of Engineering and Applied Sciences (PIEAS) as a full-time faculty member. He has been involved in teaching graduate and undergraduate subjects related to nuclear power plant systems, renewable energy systems, gamma camera instrumentation, project management and managerial communications in organizations. In 2008, he was assigned the responsibility of initiating nuclear security education at PIEAS in collaboration with Pakistan Nuclear Regulatory Authority (PNRA) and IAEA. Since then, he has actively participated in IAEA's efforts for the development of curricula for the MS in nuclear security education, establishment and development of International Nuclear Security Education Network (INSEN). He also served as INSEN Chairperson, 2010-2011. He successfully initiated nuclear security education at PIEAS in October 2009 by introducing two subjects, *Nuclear Security (3rd Semester)* and *Physical Protection Systems (4th Semester)* as a sub-specialty of the MS Nuclear Engineering Program at PIEAS in accordance with the guidelines provided by IAEA's Nuclear Security Series-12.

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Dr. Inamul Haq is currently working as Principal Engineer (and Associate Professor) at Pakistan Institute of Engineering and Applied Sciences (PIEAS). He completed his BS in Agricultural Engineering from the University of Agriculture Faisalabad in 2002. He received his MS in Nuclear Engineering from PIEAS in 2004 and joined PIEAS as full time faculty member. In 2007, he was awarded a scholarship for a PhD degree from Imperial College London by Higher Education Commission of Pakistan. After completing his PhD in Nuclear Reactor Safety in 2011, he joined PIEAS again as a faculty member. He has been involved in teaching graduate and undergraduate subjects related to Fundamentals of Nuclear Engineering, Nuclear power plant systems, Thermal Engineering Principles, Heat Transfer, Reactor thermal Hydraulics, Two phase flow, and Fluid Mechanics, among others. Currently, he is working in the area of nuclear safety and security. He is also working as the chair of working group C of IAEA Nuclear Security Support Centres (NSSC) Network.

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