

Enhancement of Nuclear Security Culture with Implementation of Nuclear Security Education at PIEAS (Pakistan Institute of Engineering and Applied Sciences)

T. Majeed¹, I. Haq¹

¹Pakistan Institute of Engineering and Applied Sciences (PIEAS), P. O. Nilore, Islamabad, Pakistan.

E-Mail: dolupi@yahoo.com, tariqmajeed@pieas.edu.pk

Abstract. Nuclear Security education and training is very important for all personnel who are directly or indirectly involved with the nuclear industry. Pakistan Institute of Engineering and Applied Sciences (PIEAS) is the leading educational and training institute in Pakistan for master programs in various fields related to nuclear engineering and technology. Recognizing the importance of nuclear security education, PIEAS offers a sub-specialization in Nuclear Security in its MS Nuclear Engineering program to ensure its long terms policy of developing nuclear security expertise among nuclear scientists and engineers at post graduate level. PIEAS started its nuclear security education program as subspecialty of its Master of Science (MS) in Nuclear Engineering Program in October 2009. Two courses, **Nuclear Security** and **Physical Protection Systems** have been offered regularly since then. These courses are offered to scientists and engineers who work either as operator or as regulator at various nuclear facilities. So far, 99 students have graduated with this specialty. It has been observed that nuclear security education at PIEAS has instilled security culture in their actions as second nature and is helping them in the development of nuclear security culture in their respective departments. The graduates who are working as operators have set a positive example for personnel by complying with nuclear security requirements, following nuclear security procedures, remaining vigilant, executing their work more diligently, and exhibiting high standards of personal and collective accountability by being a nuclear security culture role model. They have been able to promote an overall positive work environment by improving productivity, to reinforce safety-security interface by adhering to the better safety precautions, and to reduce the potential for an insider threat by decreasing the possibility that the facility personnel will perform, support, or ignore any malicious acts. Those who joined as regulators, have facilitated in updating the nuclear security regulations by upgrading the nuclear security and the physical protection requirements for nuclear materials and facilities. This has also made them capable of inspecting and evaluating (in collaboration with security personnel) the existing security systems, predicting their performance against changing threat scenarios, and stay ahead of evolving threats, capabilities and tactics by an intelligent adversary. An assessment process for nuclear security culture among the scientists and engineers, as per guidelines of IAEA, is currently in progress also. This paper will present the experiences and lessons learnt related to enhancement of nuclear security culture by implementing nuclear security education for scientists and engineers working at various national nuclear facilities. The results of the nuclear security culture assessment survey will be presented. The mechanisms and the efforts for improvement of nuclear security culture among scientists and engineers through nuclear security education at PIEAS and through interaction of PIEAS with other national and international NSSC institutions will also be highlighted. The role of nuclear security educational labs, established recently at PIEAS in collaboration with IAEA and PNRA, in enhancement of nuclear security culture will also be discussed.

Key Words: Nuclear security education, Nuclear security culture, NSSC, nuclear security educational labs

1. Introduction

The use of energy has a pivotal role in the prosperity and sustainable development of a country. Nuclear energy is a clean, safe, reliable and competitive energy source which can contribute significantly and effectively to sustainable development objectives of a country. It is the only source of energy that can replace a significant part of the fossil fuels (coal, oil and gas) which massively pollute the atmosphere and contribute to the greenhouse effect. Use of the nuclear energy in the health sector has contributed significantly in improving the quality of life of humanity at global level by providing diagnosis and treatment of many diseases. The demand of nuclear energy and its important applications in all sectors of life is increasing day

by day. With this increase in its demand, the use of nuclear materials and other radioactive materials is increasing along with the required infrastructure for their use. Terrorist activities have been a major threat to the world. Particular attention has been paid to potential threats by terrorists on nuclear facilities, nuclear materials and other radioactive materials as these might be used for malicious, criminal, or terrorist actions if they fall into the wrong hands. The IAEA is facilitating member states to protect people, property, society and the environment against the malicious use of nuclear and other radioactive material.

Nuclear security is the means and ways of preventing, detecting and responding to theft, sabotage and unauthorized access to, or illegal transfer of, nuclear and other radioactive material, as well as associated facilities. An effective implementation of a comprehensive nuclear security regime requires a comprehensive approach, which includes many factors. This would require all possible means, systems and measures used for implementation of effective prevention, detection and response related to nuclear security at a State Level. All these nuclear security systems and measures require the development of highly trained human resource. Development of human resource requires education and training of all personnel involved at all levels. Nuclear security education and training not only prepares all personnel involved to perform their assigned tasks more effectively but also helps them develop a sense of responsibility in their minds for their tasks related to nuclear security. This sense of responsibility, developed through nuclear security education and training, among the personnel involved greatly facilitates them in developing their norms of behaviour to fulfil their responsibilities to their best of their abilities. The collective effect of these norms of behaviour is referred as “Nuclear Security Culture”. The ultimate of this developed sense of responsibility or “Nuclear Security Culture” for an organization is that every pair of eyes at a nuclear facility feels its responsibility to achieve the best for all implemented nuclear security systems and measures [1, 2].

This paper discusses the systematic approach, currently in practice, at PIEAS for educating scientists and engineers in the area of nuclear security with ultimate objectives to create a sense of responsibility among them and among the staff they supervise for nuclear security of the facilities and the materials. It covers a brief introduction to the MS Nuclear Engineering Program at PIEAS, initiation of nuclear security education program along with the current status and the future prospects. It also covers the basis of the survey conducted among the scientists and engineers regarding their day-to-day responsibilities at their workplaces and interaction with security arrangements at their workplaces. Finally, the results of the survey conducted and the lessons learnt are discussed.

1.1. Introduction to MS Nuclear Engineering Program at PIEAS

Pakistan started its nuclear program in 1960s to make use of the nuclear energy for peaceful purposes. Pakistan Atomic Energy Commission (PAEC) was mainly responsible for this peaceful nuclear program. Highly trained human resource plays a vital role in sustainability of any program. Initially, young scientists and engineers were sent out of the country to different institutions of the world for the development of human resource. This method was very expensive on the national resources. In this regard, Pakistan Institute of Engineering and Applied Sciences (PIEAS), formerly known as Centre for Nuclear Studies (CNS), was established in 1969 by PAEC and nuclear engineering related academic educational program was initiated to fulfil the national needs. It started an MS program in Nuclear Engineering as an affiliated Department of Quaid-i-Azam University, Islamabad, Pakistan. Two more MS programs, MS Systems Engineering and M.Sc. in Nuclear Medicine began afterwards. A degree award status was bestowed upon PIEAS in year 2000 by Government of Pakistan [3,

4].

Currently, PIEAS runs MS and PhD programs in Nuclear Engineering, Mechanical Engineering, Medical Physics, Materials Engineering, Nuclear Medicine, Process Engineering, Radiation Medicine & Oncology, and Radiation Physics. The BS programs include Computer Science, Electrical Engineering, Mechanical Engineering, Chemical Engineering, Materials Engineering and Physics. In addition, specialized refresher short courses, with duration ranging from 3 days to 9 months, are also conducted at PIEAS from time to time for engineers, scientists and other professionals for their continuing professional development. These short courses cover areas related to advanced reactor safety, health physics, medical physics, laser technology, vacuum technology, computer applications, and management sciences. PIEAS's highly qualified faculty matched with excellent infrastructure are instrumental in its endeavours to offer high quality education in the emerging disciplines of engineering and applied sciences, fulfil national and regional requirements for highly qualified professionals and contribute to the welfare of humanity through education, research and development [3, 4].

MS Nuclear Engineering Program at PIEAS consists of five semesters (four full semesters and one summer semester). The core courses of nuclear engineering, related to nuclear physics, radiation detection, thermal hydraulics, nuclear materials, nuclear reactor statics & dynamics, etc. are covered in the first two semesters. All elective courses related to advanced applications of nuclear engineering in various disciplines such as geophysics, nuclear materials, mining, reactor control instrumentation, nuclear safety are offered in third and fourth semesters. Students are familiarized with practical aspects of nuclear engineering principles, such as nuclear radiation measurements using nuclear radiation detectors, by taking advanced nuclear engineering laboratory courses. These laboratory courses are offered in third and fourth semesters. Every student is required to write a thesis research project report and defend with oral presentation in front of a committee of examiners. For this purpose, seminar thesis research projects are 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 [3, 4].

MS Nuclear Engineering Program is the oldest MS program at PIEAS, supervised by Department of Nuclear Engineering. Around 1600 engineers and scientists have graduated under this program since the institution was established. These graduates form the backbone of nuclear energy program of Pakistan. Since nuclear engineering is a multi-disciplinary program, therefore, the participants of MS Nuclear Engineering Program are selected from almost all engineering and scientific disciplines [3, 4]. Nuclear security education program at PIEAS was initiated in October 2009 as sub-specialty of its MS Nuclear Engineering Program.

2. Nuclear Security Education at PIEAS

Nuclear Security education program was initiated at PIEAS in 2008 at the request of Pakistan Nuclear Regulatory Authority (PNRA). Different options were explored to initiate nuclear security education at PIEAS in the meetings held by PIEAS and PNRA officials. Existing curriculums of MS Nuclear Engineering Program of PIEAS and the IAEA's Educational Program in Nuclear Security (it was available as draft at that time and was published later as IAEA's Nuclear Security Series-12 [5]) were thoroughly analyzed. 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 regular basis in MS Nuclear Engineering Program at PIEAS [4, 5, 6]. Finally, it was decided to start the Nuclear Security education as a sub-specialty of MS Nuclear Engineering Program in October 2009 in close collaboration with 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), 3 credit hours each, have been offered on regular basis in 3rd and 4th semesters. The curriculum of these two courses was prepared in accordance with guidelines provided by IAEA's Educational Program in Nuclear Security. As part of the academic administrative procedures for offering a new course in MS Nuclear Engineering Program, the contents of these courses were first scrutinized by Board of Studies of Department of Nuclear Engineering. Later, these were thoroughly reviewed by 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 MS Nuclear Engineering Program. So far, 99 students have graduated with Nuclear Security as sub-specialty of the MS Nuclear Engineering program [5, 6, 7].

2.1 Collaboration with other National Institutions

At the Nuclear Security Summit of 2014, Pakistan announced the establishment of Center of Excellence (CoE) in Nuclear Security [8]. This CoE is a concept and is comprised of the three main institutions, (1) Pakistan Centre of Excellence for Nuclear Security (PCENS, Islamabad), (2) National Institute of Safety and Security (NISAS, PNRA), and Pakistan Institute of Engineering and Applied Sciences (PIEAS, PAEC). At 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 national level and international level), exchange of resource persons for conduction of courses, special lectures, practical training sessions for faculty/trainers/students on need basis.

3. Nuclear Security Culture Enhancement

The International Atomic Energy Agency defines nuclear security culture as “the assembly of characteristics, attitudes and behaviour of individuals, organizations and institutions which serves as a means to support and enhance nuclear security.” Security culture is a supporting and enhancing tool for nuclear security. Its role can be deduced from the definition of nuclear security, which is “the prevention and detection of, and response to, theft, sabotage, unauthorized access, illegal transfer or other malicious acts involving nuclear material, other radioactive substances or their associated facilities.” Developed in the aftermath of the 9/11 malicious acts, this new concept of nuclear security culture is worth mentioning in the sense that it goes beyond physical protection, accounting, and control measures. The concept of nuclear security culture covers a much wider scope of areas related to nuclear security. It includes cargo inspection; customs and border security; export control; national and international cooperation to identify and interdict shipments of dangerous materiel; interception of illicit trafficking; and personnel reliability screening, education and training of all personnel involved. This is the main reason that the concept of nuclear security culture is applicable to the entire workforce at a nuclear facility and can be an effective tool to address both intentional and unintentional breaches of security. A well-designed nuclear security education and training program, combined with improved ergonomics, which will result in improved human performance and productivity, and efficient personnel recruitment policies can help in dealing very effectively with unintentional security problems, deliberate breaches

stemming from outside adversaries having malicious intentions. At the same time, the security culture resulting from better awareness of the security threats and the development of the sense of responsibility by everyone inside the facility through security education and training, will serve as a major tool to address the insider threat in a nuclear facility, as insiders may divert nuclear materials or commit acts of sabotage, either on their own or in collusion with outsiders [1, 2, 9].

An effective security culture can yield numerous other benefits. It encourages the entire workforce to remain vigilant, question irregularities, execute its work diligently, and exhibit high standards of personal and collective accountability. Although it may not serve as a magic bullet for all security related problems, but it can contribute significantly to a vibrant and robust security regime spanning the entire workforce. It is also responsive to a threat environment in which risks are too numerous to predict, even for the most visionary leader. Other potential benefits of security culture include improved safety arrangements, an overall reduction of theft and diversion; reduced risks of vandalism and sabotage by employees and outsiders; improved mechanisms for personnel control, better information security and protection of trade secrets, accountability under emergency conditions; and better relationships with local authorities and surrounding communities. In addition, an institutionalized security culture across a given sector, introduced in coordination with the government, may further facilitate auditing and inspections when compliance with required security standards is verified by government officials [1, 2, 9].

3.1 Capacity Building for Nuclear Security Culture

There are several ways to achieve the goals of an effective and sustainable security culture in an organization [1, 2, 9].

1. The commitment, dedication and involvement by the top management, who also serve as role models for all the employees of the organization,
2. Involvement of the employees of the organization in IAEA training activities and methodology development workshops related to nuclear security culture,
3. Continuous learning on the organizational level, including initial training, periodic training, education programs, and quality assurance for training and trainers conducting the training,
4. Flexible management systems that conform to risk and vulnerability assessments and emphasize the role of the human element in nuclear security at the facilities,
5. Participation in national and international events relevant to nuclear security, both at manager and staff level,
6. Increased emphasis on nuclear security courses to be included in university syllabi and making it compulsory for graduation at higher-education institutions.

All these approaches have been adopted at global level by various organizations, depending upon their national needs and available resources. PIEAS, being an academic institution, has adopted a combination of the above mentioned approaches for the enhancement of the nuclear security culture among its students, who eventually would join as operators to PAEC and as regulators to PNRA. Initiation of the nuclear security education as sub-specialty of its MS Nuclear Engineering program symbolizes the commitment and involvement by top management of PIEAS/PAEC and PNRA. Several IAEA training courses related to nuclear

security have been conducted at PIEAS. PIEAS faculty and students have fully participated in these courses. PIEAS faculty have also participated in IAEA training courses related to nuclear security conducted at NISAS (PNRA) and PCENS both as participants as well as national experts [8].

Physical security arrangements, like perimeter security, access control to facilities, background checks of all employees, implementation of intrusion detection systems, continuous surveillance through CCTV camera systems, roaming patrols, etc. are flawlessly taken care of by SPD/state departments at all nuclear facilities of Pakistan. The main focus of nuclear security culture enhancement in this paper is with reference to the scientists and engineers working at management level within the nuclear facilities of Pakistan, both as operators and regulators, as all the graduates of MS Nuclear Engineering program of PIEAS join these organizations at the lower management level. With the passage of time, these graduates are promoted to higher levels of management. The nuclear security related skills of these graduates are further enhanced by participation, from time to time, in the short training courses conducted by IAEA at PCENS, NISAS and PIEAS. Participation in these courses further facilitate these graduates in staying abreast with evolving threat scenarios, new capabilities and tactics by an intelligent adversary having malicious intentions against nuclear facilities.

The graduates who are working as operators have set a positive example for personnel, for both of their colleagues and for the staff working under their guidance, by complying with nuclear security requirements. They have also served as nuclear security culture role model for their colleagues and the staff by strictly following implemented nuclear security procedures, executing their work more diligently, and exhibiting high standards of personal and collective accountability. They have been able to promote an overall positive work environment by improving productivity, to reinforce safety-security interface by adhering to the better safety precautions. They have also made significant contribution to reduce the potential for an insider threat by promoting the culture of remaining vigilant all the time and strictly adhering to the two-person rule in vital areas to decrease the possibility that any facility personnel will perform, support, or ignore any malicious acts.

Those who joined as regulators, have facilitated in updating the nuclear security regulations in the existing regulatory oversight documents as well as in the development of the new documents, for nuclear security and the physical protection requirements for nuclear materials and facilities. This has also made them capable of serving in the role of regulatory inspectors for inspecting the implemented security arrangements during routine use of various radioactive sources at operational facilities, like medical centres, educational institutions. These inspections have helped in improving the performance of the security arrangements against the changing threat scenarios to avoid any unforeseeable event that could harm the safety and security of the workers, general public and the environment. The thorough background, provided by nuclear security education, has also helped them in evaluating the existing security systems and predicting their performance.

3.2 Nuclear Security Culture Assessment Survey

An assessment process for nuclear security culture among the scientists and engineers, as per guidelines of IAEA, was initiated. This assessment process is just a part of the large scale nuclear security culture assessment process, to be conducted later, which will also cover staff working as technicians and scientific assistants to facilitate the technical work. This current assessment has included the scientists and the engineers graduating from PIEAS, who have

studied nuclear security course at PIEAS or elsewhere and those who did not take nuclear security course during their MS Nuclear Engineering program or have not taken any nuclear security related course. The questions have been particularly selected with reference to the workplace environment. The questions used for the survey have been prepared in accordance with the guidelines provided by IAEA and World Institute of Nuclear Security (WINS) [10, 11]. The complete survey is given at the in Annex 1.

4. Enhancement of Nuclear Security Culture: Lessons Learnt

The survey questions were presented to the participants and their responses have been graphically presented in Figure 1. The graphs represent the comparative response of those who have not taken any nuclear security related course versus those who have taken one semester long course on nuclear security at PIEAS. Some of the important lessons learnt are mentioned below:

1. The trend of survey results suggests that the graduates who have taken nuclear security course exhibit the added advantage of developing a sense of responsibility for security of the facility they work in and facilitate the security personnel in carrying out their responsibilities in protecting the vital assets inside the nuclear facilities from the probable threat of an outsider adversary, and particularly for an insider adversary. This has shown an overall improvement in nuclear security culture at national nuclear facilities, where technical professionals, being aware of the security issues and challenges during their routine technical job, extend helping hand to security professionals in implementing nuclear security measures.
2. Nuclear engineering students with nuclear security education have exhibited a broader vision of the technical aspects of nuclear safety combined with technical aspects of nuclear security requirements inside the vital assets of the nuclear facilities.
3. The graduates with nuclear security education have developed better understanding of the possible threat scenarios to the nuclear facilities and are always prepared to facilitate the security personnel in carrying out necessary security measures.
4. The development of special sense of security responsibility among these nuclear security graduates with thorough nuclear security awareness has helped them in improving nuclear security at nuclear facilities of Pakistan, preferring security concerns over friendship or relationship.
5. These nuclear security graduates working with nuclear regulatory body, having through knowledge of nuclear security and nuclear safety, have played an important role in updating the required regulatory requirements for the national nuclear facilities and other related infrastructure as per latest IAEA requirements. This has helped in effective upgradation of existing overall physical protection regime at national level to keep abreast with dealing more effectively with the latest developing threat scenarios.
6. Nuclear security education has facilitated in the development of a platform among the future nuclear engineering professionals with better synergy among the scientists and engineers working in the areas of nuclear safety and nuclear security.
7. Nuclear security education has helped in reducing the inherent conflict among safety-and security professionals with better understanding of nuclear security and nuclear safety requirements.
8. The survey also indicates a critical need for creating nuclear security awareness, among all professionals working at nuclear facilities, by systematic implementation of nuclear

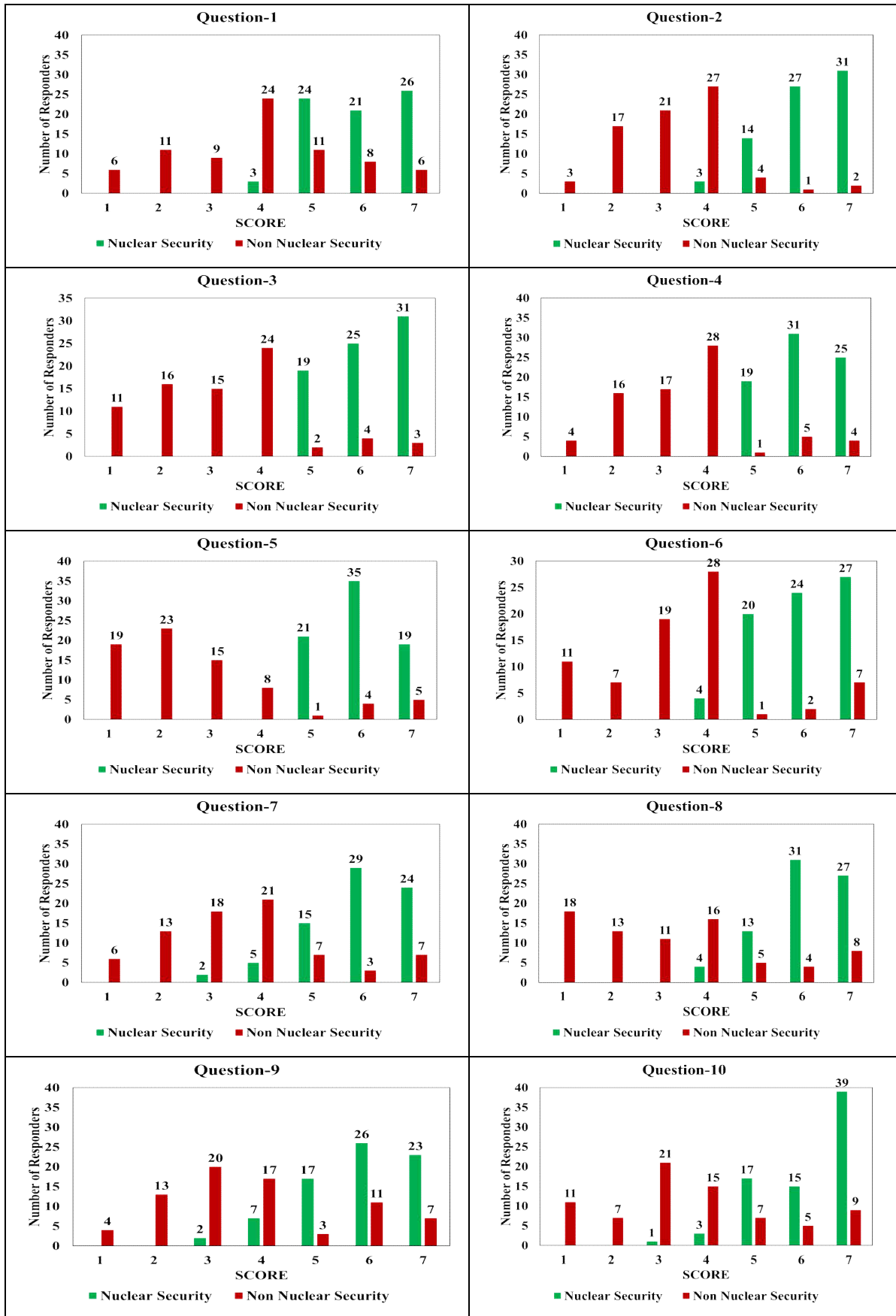


Figure 1: The survey graphs related to questions given in survey.

security training/awareness program at the respective establishments.

9. As PIEAS conducts its nuclear security education program in close collaboration with NISAS and PCENS and other relevant national institutions, interaction of these nuclear security graduates with professionals working at NISAS and PCENS further grooms them about practical aspects of nuclear security culture implementation within their workplaces.
10. Launching of the nuclear security education program by PIEAS has proved it as a strong pillar of Pakistan's Nuclear Security CoE in development, promotion and implementation of an effective nuclear security culture at nuclear facilities of Pakistan.

5. Conclusion

Nuclear security education has become a regular part of MS Nuclear Engineering program of PIEAS. Graduating nuclear engineering professionals with this specialty, working in close collaboration with NISAS, PCENS and IAEA, have developed a special sense of responsibility towards the security of nuclear facilities. This will play a vital role in implementing a comprehensive nuclear security regime at national level in Pakistan.

6. References

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Annex-1

Survey Questionnaire for Nuclear Security Enhancements

Have you taken any course on nuclear security in your study program?

YES <input type="checkbox"/>	NO <input type="checkbox"/>
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Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree Nor Disagree	Somewhat Agree	Agree	Strongly Agree
1	2	3	4	5	6	7

Following are the Question Statements of the Nuclear Security Culture Enhancement Survey:

No.	Statement	Encircled Answer						
		1	2	3	4	5	6	7
1	Senior management of the facility thinks that security of the facility is very important and visibly promotes security.							
2	Nuclear security and safety are considered equally important at my workplace.							
3	I fully understand the main nuclear security threats that we could experience here at my workplace.							
4	I fully understand the security requirements with which I am expected to comply at my workplace on daily basis.							
5	The education and training that I have received on nuclear security is clear and comprehensive.							
6	I feel confident about the implemented security arrangements at my workplace.							
7	Good security arrangements at my workplace help protect my job and are important for my safety.							
8	If I were to become aware of security issues that concern me or my workplace, I would report them even if they involved a work colleague.							
9	I feel comfortable with following daily routine security checks implemented at my workplace.							
10	I feel that my understanding of the importance of the routine security procedures implemented at my workplace has increased over the years.							