Opportunities for International Students in Nuclear Security Education

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INTRODUCTION

The U.S. Department of State's Partnership for Nuclear Security (PNS) has supported Universitas Gadjah Mada (UGM-Indonesia) in developing nuclear security education since 2012. Through various programs, faculty members and the International Nuclear Materials Management (INMM) student chapter at UGM has increased the knowledge and awareness of nuclear security in nuclear engineering undergraduate program at UGM. The nuclear engineering undergraduate program at UGM revised its curriculum in 2016 to incorporate nuclear security and safeguards courses in addition to a nuclear safety component. The PNS support has successfully raised nuclear security awareness and education among international students.

The Nuclear Security Science and Policy Institute (NSSPI) at Texas A&M University (TAMU) promotes graduate-level research-based education by focusing on topics related to nuclear material safeguards and security. NSSPI joins local and international experts and students from nuclear engineering department and Bush School of Government and Public Service to address complex nuclear threats and proliferation problems. Unfortunately, a lot of nuclear security research projects and fellowships are unavailable to international students at U.S. universities due to its either classified or sensitive nature.

PARTNERSHIP FOR NUCLEAR SECURITY (PNS) SUPPORT FOR UNIVERSITAS GADJAH MADA (UGM)

The U.S. Department of State's Partnership for Nuclear Security (PNS) seeks to promote a self-sufficient nuclear security culture, ingrained in the partner country's nuclear technical community by encouraging responsible science and nuclear security-related best practices[1].

The PNS has been supporting UGM to develop a new curriculum in order to enhance nuclear security topic in the undergraduate program. In 2012, PNS team visited UGM to develop a partnership program in curriculum development, research, and publication, as well as the founding of the Institute of Nuclear Material Management student chapter (INMM SC) at UGM. The purpose of the partnership was to strengthen the nuclear engineering program at UGM to be regional center of expertise for nuclear security[2]. Since then, UGM has been involved in the International Atomic Energy Agency (IAEA) - International Nuclear Security Education Network (INSEN) [3] and attended the Nuclear Security Insider Threat Exercise (NSITE) at Oak Ridge National Laboratory, INMM Annual Meeting in 2013 [4], and International Academic Nuclear Security Roundtable [5]. UGM participation in those programs were supported by PNS.

In October-November 2013, UGM faculty members visited six universities in the United States and some research and development facilities to conduct a comparative study about the nuclear security curriculum in each of these university programs[6]. The six universities they visited were the University of Georgia, University of Tennessee, Texas A&M University[7], University of Texas at

[1] "Overview" *About Us*. Partnership for Nuclear Security. Web. Accessed March 2, 2017.

[2] "Tamu dari Partnership for Nuclear Security USA" Departemen Teknik Nuklir dan Teknik Fisika, October 17, 2012. Web. Accessed 2 March 2017.

[3] "Kunjungan delegasi dari office of nuclear security iaea dan centre for international trade and security the university of georgia ke jurusan teknik fisika" Departemen Teknik Nuklir dan Teknik Fisika, October 18, 2012. Web. Accessed March 2, 2017.

[4] "Nuclear security insider threat exercise" Departemen Teknik Nuklir dan Teknik Fisika, July 9, 2013. Web. Accessed March 2, 2017.

[5] "INS hosts an International Academic Nuclear Security Roundtable" *Institute for Nuclear Security*. University of Tennessee, July 24, 2013. Web. Accessed March 2, 2017.

[6] "Studi banding kurikulum nuclear security di beberapa PT di AS" Departemen Teknik Nuklir dan Teknik Fisika, 27 Oct. 2013. Web. 2 March 2017.

[7] "NSSPI hosts Indonesian delegation for nuclear security education" College of Engineering, Texas A&M University, December 17, 2013. Web. Accessed March 2, 2017.

Austin, North Carolina State University, and Virginia Commonwealth University. The faculty members learned about basic concepts of nuclear security, about their ongoing research and about nuclear security culture education, along with its assessment method and indicators. Beside discussions, the faculty members attended several course lectures to observe and learn how the classes were taught as well as experienced the laboratories firsthand. Moreover, the three-week visit resulted in a positive impact on the faculty. Some universities offered funding to support paper writing and presentations at international conferences for nuclear engineering students at UGM. The Nuclear Security Science and Policy Institute (NSSPI) of Texas A&M University has its nuclear security and safeguards education portal which then could be accessed and used by students at UGM.

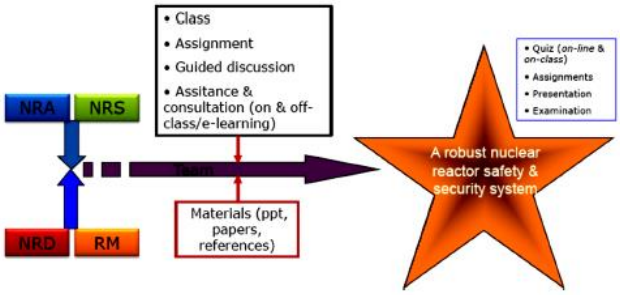


Figure 1. Synergy of four courses in fall semester [9]

In December 2013, PNS held a nuclear security curriculum development workshop in Abu Dhabi, with 51 participants from 10 countries[8]. Five faculty members from UGM were there to be supervised by experts from international institutions and universities to develop nuclear security materials in the curriculum and syllabus. There, UGM faculty members arranged a Professional Development Course (PDC) for Southeast Asia region with King's College London (KCL), and other nuclear security programs particularly for UGM.

During the academic year, nuclear security content began to be introduced by UGM faculty members without disturbing the existing curriculum at UGM [9]. A synergy of four existing courses (nuclear reactor design, nuclear reactor analysis, research methodology, and nuclear reactor safety) conducted in a 2013 semester is shown in Figure 1. Several mixed groups of students from four courses were assigned to design a safety and security system for a medical isotope production facility. Nuclear security topics, such as 3S (security, safeguards, and safety) definitions and integration, insider threats, and physical protection, were introduced to students, along with a tabletop exercise to get a more realistic picture on threat analysis and response.

Questionnaires were given before and after to measure the level of understanding of the students about nuclear security issues. The level of understanding was categorized using six values (1, 2, 3, 5, 6, and 7), where 7 is the best value. Category 4 was not used to avoid ambiguity on the level of understanding, because 4 is the middle number between 1 and 7. Fifteen questions in both questionnaires were provided to the students, which were grouped into four themes:

- Nuclear safety, security and safeguards concepts,
- Threat assessment,
- Nuclear security system analysis, and
- The role of technology in nuclear security systems

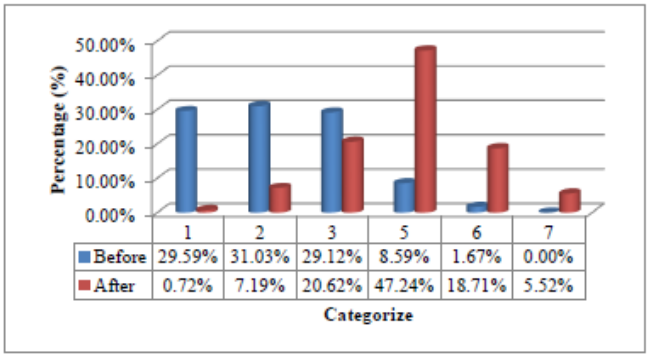


Figure 2. Student's nuclear security knowledge shifted[9]

Figure 2 shows us the shift in level of understanding among students, measured by the questionnaires given before and after. The blue bars show that, at the beginning of the semester, 89.74% of the students in the class were in categories 1-3. Only 10.26% of the students had good nuclear security knowledge, categorized as 5-6 in their levels of understanding. By the end of the semester, the red bars show that 71.47% of the students were in categories 5-7 in their level of understanding. Meanwhile there were still students (28.53%) with low-level nuclear security knowledge, in categories 1-3, after attending the course.

However, there were some things that needed some improvements. In the threat assessment question group, risk assessment was the most difficult thing to understand. Nuclear security system analysis was also difficult for undergraduate students to understand due to its social subject approach in facing the problem comprehensively. Among the role of technology questions, defense-in-depth application was the most difficult to explain and apply in the

[8] "Workshop pengembangan kurikulum nuclear security" Departemen Teknik Nuklir dan Teknik Fisika, December 17, 2013. Web. Accessed March 2, 2017.

[9] S.H. PUTERO, SIHANA, H.B. SANTOSA. "Introducing Nuclear Security Topics Through Synergizing Several Existing Course in Nuclear Engineering Curriculum of Universitas Gadjah Mada". *INMM 55th Annual Meeting Proceeding*, Atlanta, Georgia USA, July (2014).

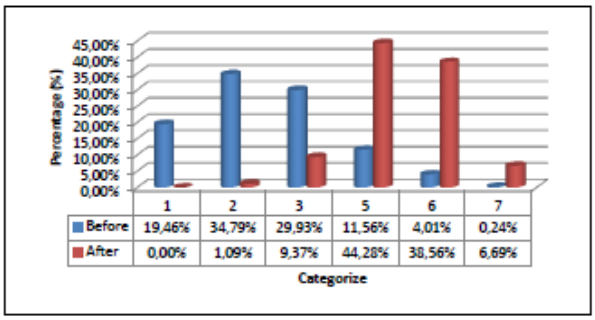
assigned project. Limited time provided for lectures was one big factor of the difficulty because nuclear security was not part of the syllabi of the courses[9]. 3S topics distribution and nuclear security topics redundancies among the courses were the other problems that need to be tackled[10].

Figure 3. Synergy of courses in spring semester[11]

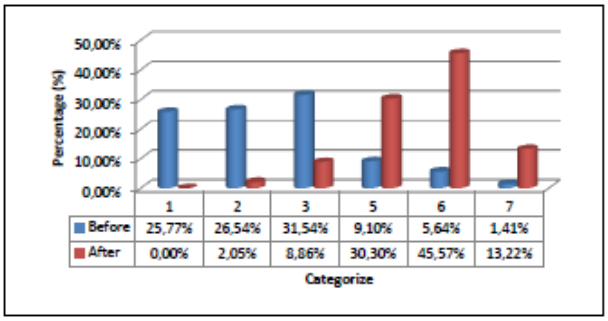
In the next semester, student groups were assigned to create a simulation company to develop advanced reactors fuel cycle-based industry and business in the synergy of courses, as shown in Figure 3. During the semester, nuclear security was lectured by introducing and discussing case studies. A modified tabletop exercise was also delivered to the students. Questionnaires were also given to the students before and after measure the improvement of nuclear security knowledge with the same question groups[11].

In the project, the students could design a simple yet comprehensive nuclear material physical protection system in the facility as well as about the material transport. Students considered both insider and outsider threats. microprocessor application course joined the synergy in 2015 and resulted in an increase of the students' ability to understand the role of technology in nuclear security. The microprocessor application course tasked the students to design a technology that could detect and respond to a nuclear material theft scenario. Thus, students were able to measure the probability of detection in their system designs[11].

Figure 4 shows that the synergy significantly improved nuclear security knowledge among students throughout the semester. In each semester of years 2014 and 2015, 89.53% and 89.9% of the students respectively were in categories 5-7 in their levels of understanding after they attended the course. Figure 4 also reflects a continual improvement of nuclear security education in the department, as we see that the students' prior knowledge of nuclear security concepts was relatively better in 2015 than in 2014. Moreover, the majority of the students in 2015 were in category 6, in a higher level of understanding compared to category 5 in 2014. It was believed that INMM events in the years 2014 and 2015 had an impact to students' knowledge before and after the synergy 2015[11].



2014



2015

Figure 4. Nuclear security knowledge improvement in synergy of courses in 2014 and 2015[11].

The PNS internationally supports a network of INMM national and student chapters. In this role, PNS assists chapters with substantive content development, grants, subject matter experts' travel, chapter sustainability training, event logistics, membership fees, and travel to the INMM annual meeting [12]. Over the 2014-2015 academic year, INMM SC held two major programs: (1) a physical protection system short course by Indonesian National Nuclear Energy Agency (BATAN) and (2) an insider threat webinar from a professor of Idaho State University (ISU)[13]. For the 2015-2016 academic year, UGM INMM SC had

[10] S.H. PUTERO et al., "Integrating Security Issues in Nuclear Engineering Curriculum in Indonesia: Classical vs Policy Approaches" ICONE *23rd Proceeding*, Chiba, Japan, May (2015).

[11] S.H. PUTERO.,et al. "Introducing Nuclear Security Topic into Non-Traditional Nuclear Engineering Course in Universitas Gadjah Mada: Technopreneurship Course". *INMM 56th Annual Meeting Proceeding*, Indian Wells, California USA, July (2015).

[12] "The Partnership for Nuclear Security's Role" *INMM Chapter Highlights*. Partnership for Nuclear Security. Web. Accessed March 2, 2017.

[13] UGM INMM SC. "Executive Committee Report Annual Year 2014/2015". *Annual Report*, Yogyakarta (2015).

significant growth in the number of its programs. Project collaborations with other student chapters, guest lectures and workshops, and Nuclear Orientation School (NOS) held in that period[14] inevitably had an impact on the nuclear security knowledge of the students at UGM.

NUCLEAR ENGINEERING CURRICULUM AT UNIVERSITAS GADJAH MADA (UGM), INDONESIA

The 2016 nuclear engineering undergraduate program curriculum has been revised largely compared to its 2011 version. Enhancement on safety, security, and safeguards in the curriculum is a response to align with the global needs. Preparations of syllabi and learning materials were possible through a teaching grant given by PNS from the U.S. Department of State through CRDF Global. Workshops and supervisions from experts in United States, United Kingdom, and all international universities within the International Nuclear Security Education Network (INSEN) of the International Atomic Energy Agency (IAEA) have been vital for this purpose. Information and instruction materials for the nuclear security and safeguards have been collected since 2013 through participation in international seminars and workshops as well as through study tours to six universities in the United States. There were also workshops conducted in UGM in the years 2014 and 2015 for curriculum evaluation and revision framework[15].

Table 1. Core courses with 3S content in undergraduate curriculum at Universitas Gadjah Mada (UGM)

Course Title	Credits	3S Content
Introduction to Nuclear Engineering	3.0	Safety Security Safeguards
Radiation Detection and Measurement	3.0	Safety Security Safeguards
Nuclear Reactor Physics	3.0	Safety Security
Radiochemistry	2.0	Safety Security
Radiation Protection	2.0	Safety
Nuclear Computation	2.0	Safety Security Safeguards
Radioactive Waste Management and Treatment	3.0	Safety Security Safeguards
Nuclear Safety, Security, and Safeguards System	3.0	Safety Security Safeguards
Radiation Detection and Measurement Laboratory	1.0	Safety Security Safeguards
Radiochemistry Laboratory	1.0	Safety Security
Nuclear Reactor Physics Laboratory	1.0	Safety Security
Total Credit Hours	24.0	

Compared to the previous curriculum, there is a major improvement in safety, security, and safeguards content in the courses. Total credits required for undergraduate completion is 144 credit hours. It consists of 120 credits of core courses and 24 credits of concentration and elective courses. There are 24 out of 120 core credits which have 3S content in the course. Table 1 shows core courses with which 3S component is introduced in the course. One important point is that the Nuclear Safety, Security, and Safeguards course was a Nuclear Safety course in the previous curriculum. Security and safeguards aspects were then added to the course and become a new course.

Table 2. Nuclear energy technology concentration courses with 3S content in undergraduate curriculum

Course Title	Credits	3S Content
Nuclear Reactor Thermal Hydraulics	3.0	Safety
Nuclear Power Plant Technology	2.0	Safety
Nuclear Instrumentation	2.0	Safety Security Safeguards
Nuclear Material	2.0	Security Safeguards
Nuclear Reactor Analysis	3.0	Safety Safeguards
Nuclear Fuel Management and Processing	3.0	Safety Security Safeguards
Radiation Chemistry	2.0	Safety Security
Nuclear System Design	3.0	Safety Security Safeguards
Total Credit Hours	20.0	

Students with interests in nuclear energy technology for their concentration will have to take 20 credits with 3S content as shown in Table 2. On the other hand, medical physics students will have 13 out of 20 credit with 3S content as shown in Table 3.

[14] UGM INMM SC. "Executive Committee Report Annual Year 2015/2016". *Annual Report*, Yogyakarta (2016).

[15] Departemen Teknik Nuklir dan Teknik Fisika. "Kurikulum 2016 Program Studi S1 Teknik Nuklir". *Curriculum*, Yogyakarta (2016).

Table 3. Medical physics concentration courses with 3S content in undergraduate curriculum

Course Title	Credits	3S Content
Radiodiagnostic Technique	3.0	Safety
Radiotherapy Technique	3.0	Safety Security
Nuclear Medicine	2.0	Safety Security
Radiotherapy Planning	3.0	Safety Security
Radiodiagnostic Technique Laboratory	1.0	Safety
Radiotherapy Technique Laboratory	1.0	Safety
Total Credit Hours	13.0	

From the core and concentration courses, students will have 140 credits already to fulfill 144 minimum credits for the degree. The remaining credits are for elective courses. Table 4 shows courses totaling 12 credits that have 3S content out of 30 credits available in the department. Practically (and it happens many times), students can take up to 8 credits for their degree completion. Moreover, there is a chance to expand the knowledge of nuclear security, safeguards, and nonproliferation by taking other department courses, such as international affairs.

Table 4. Elective courses with 3S content in undergraduate curriculum at Universitas Gadjah Mada (UGM)

Course Title	Credits	3S Content
Advanced Reactor Technology	2.0	Safety Security Safeguards
Nuclear Fuel Management in Reactor Core	2.0	Safety Security Safeguards
Nuclear Fusion Reactor Technology	2.0	Safety Security Safeguards
Radioisotope Application	2.0	Safety Security
Radiation Application	2.0	Safety Security
Isotope Separation Technique	2.0	Safety Security Safeguards
Total Credit Hours	12.0	

NUCLEAR SECURITY EDUCATION, TRAINING, AND RESEARCH AT TEXAS A&M UNIVERSITY

The Nuclear Security Science and Policy Institute (NSSPI) is a multidisciplinary organization at Texas A&M University which combines the talented student researcher and experts from the nuclear engineering department and Bush School of Government and Public Service. NSSPI has unique capabilities to address the complex nuclear threats and proliferation problem involving both policy and technology in nuclear security and safeguards[16].

NSSPI was established in 2006 to promote graduate-level research-based education by focusing on topics related to nuclear material safeguards and security[17]. NSSPI's mission is to employ science, engineering and policy expertise (a) to conduct research and development to help detect, prevent, and reverse nuclear and radiological proliferation and guards against nuclear terrorism, (b) to educate the next generation of nuclear security leaders, (c) to analyze the interrelationship between policy and technology in the field of nuclear security, and (d) to serve as a public resource of knowledge and skills to reduce nuclear threats.

NSSPI faculty and staff have developed a robust technical nuclear nonproliferation and safeguards graduate education program at Texas A&M University[18]. Table 5 shows the curriculum for the nuclear engineering degree (M.S.) with nuclear nonproliferation specialization in the nuclear engineering department. M.S. and Ph.D. students are able to choose elective courses from several courses listed in Table 6. The electives are multidisciplinary and vary to provide comprehensive approaches to nuclear security and nonproliferation research. Total credit hours are 32 for M.S. students and 64 for Ph.D. students.

Table 5. Nuclear Engineering M.S. Degree Curriculum with Nonproliferation Specialization

Semester	Course Title	Class Hours per Week
Year 1 Fall	Radiation Interactions and Shielding	3.0
	Radiation Detection and Materials Measurement	3.0
	Nuclear Non-Proliferation and Arms Control	3.0
Year 1 Spring	Nuclear Reactor Theory	3.0
	Nuclear Reactor Analysis and	4.0

[16] C. GARIAZZO, et al., "The nuclear security science and policy institute at Texas A&M University," *International Journal of Nuclear Security*, Vol. 1: No. 1, Article 10 (2015).

[17] R. MICHAL, "A new nuclear security initiative is established at Texas A&M," *ANS Nuclear News*, August, pp 29-30, (2006).

[18] S. CHIRAYATH, et al., "Ten years of Nuclear Security Education, Research and Training at Texas A&M University," *ANS Summary*, Santa Fe, New Mexico USA (2016).

	Experimentation	
	Nuclear Fuel Cycles and Nuclear Material Safeguards	3.0
	Seminar	1.0
Year 2 Fall	Design of Nuclear Reactors with Safety, Security, Safeguard (3S) Focus (Capstone Course)	4.0
	Seminar	1.0
Year 2 Spring	Technical Electives and Research	7.0
	Total Credit Hours	32.0

In the non-proliferation and arms control class, student groups are assigned a semester-long simulation project. Each group utilizes open source intelligence and data provided by the faculty to conduct a weekly investigation. For example, in 2016 a student group was tasked to investigate nuclear materials and radiological materials, and if a device may have been produced after the discovery of a nuclear weapon material manufacturing facility in a cave. There was another group assigned to investigate a significant deficit of nuclear material shipped from one country to another country. Another group was assigned to analyze and determine the capability of a suspicious facility which was possibly an undeclared nuclear fuel cycle facility. The last group was assigned to verify a report of a suspected nuclear weapon test and to determine the location by using seismic analysis. Those cases turned out to be related to each other in a grand scenario at the end. The project was interesting and expanded the knowledge on diverse approach in facing the issue of nuclear security and nonproliferation.

Table 6. M.S. and Ph.D. Elective Courses at TAMU for the Multidisciplinary Nuclear Nonproliferation Education

Elective Course Title	**Department**
Monte Carlo Methods for Particle Transport	Nuclear Engineering
Emergency Response Dose Assessment	Nuclear Engineering
Nuclear Security Systems Design	Nuclear Engineering
Radiochemistry and Nuclear Forensics	Chemistry
Inverse Problems: Nuclear Forensics	Mathematics
Deterrence and Coercion	The Bush School of Government & Public Service
International Security	The Bush School
The Role of Intelligence in Security	The Bush School
Nuclear Terrorism Threat Assessment and Analysis	The Bush School

NSSPI issues a graduate certificate in nuclear security for students with a solid understanding of the policy and technical aspects behind nuclear security, safeguards and nonproliferation. This multidisciplinary certificate program made students uniquely qualified for positions in the federal government, national laboratories and at the International Atomic Energy Agency (IAEA). To qualify for the certificate, students must complete 12 semester credit hours of 4 of 5 courses from the following list:

- Nuclear security system design
- Radiation detection and nuclear material measurement
- Nuclear non-proliferation and arms control
- Nuclear fuel cycle and nuclear material safeguards
- Nuclear terrorism threat assessment and analysis

NSSPI is at the forefront in carrying out research on all aspects of nuclear safeguards, security, and nonproliferation. Students who join NSSPI conduct a research in one of these following areas:

- Arms Control
- Combatting Nuclear Terrorism
- Ensuring the Peaceful Use of Nuclear Energy
- Nuclear Forensics and Attribution
- Nuclear Security and Risk Analysis
- Safeguards Systems Analysis and Instrument Development

After more than 10 years, NSSPI has produced various research results. NSSPI website provides a detailed list and information about past and ongoing research carried out at NSSPI [19]. Some of the major research accomplishments are:

- Designed the Self-Interrogation Neutron Resonance Densitometry (SINRD) detector for nuclear safeguards measurement with LANL for testing by the IAEA
- Developed the PRAETOR tool and a latency method for proliferation risk analysis
- Devised a safeguards system concept for pebble-fueled high temperature gas-cooled reactors, and
- Devised a methodology for determining which States will go nuclear

Nuclear Facility Experience (NFE) is one unique opportunity for university students to visit nuclear facilities and discuss applied safeguards and security measures with actual practitioners and facility operators. Originally named Foreign Field Experience (FFE), it was altered to Nuclear

[19] "Research Areas" *Research*. Nuclear Security Science and Policy Institute (NSSPI). Web. Accessed March 3, 2017. http://nsspi.tamu.edu/topical-subsections/research/research-areas

Facilities Experience in 2013 [20]. The NFE took students to nuclear facilities in Japan in 2013, then visited UK nuclear facilities in 2015, then back to Japan in 2016. This program provides the students with insight and knowledge to complement knowledge received in the class.

NSSPI provides a nuclear security and nonproliferation education portal[21] with free educational resources available for the worldwide community of students and professionals[18]. Each module can take 1-3 hours to complete and consists of reading materials, videos, links to additional resources, and self-assessment quizzes. This supplemental resource is essential and beneficial for the graduate student at Texas A&M University. As of March 2017, the courses are:

- Basic Nuclear and Atomic Physics
- The Nuclear Fuel Cycle
- Basic Radiation Detection
- Introduction to Statistics
- Containment and Surveillance
- Nuclear Material Accountancy
- Physical Protection Systems
- Threats to Nuclear Security
- Insider Threats
- Nuclear Security Culture
- Spent Nuclear Fuel Safeguards
- Nuclear Security Terminology
- Technical Safeguards Terminology
- Safeguards Treaties and Legal Issues

User statistics collected from NSSEP for the years 2012-2015 showed that there were more than 69,000 unique users of NSSEP. This is a level of outreach that would have been impossible to produce with traditional learning methods.

In the past 11 years, NSSPI students in the Texas A&M Department of Nuclear Engineering earned 54 M.S. degrees, five M.E. degrees, and 20 Ph.D. degrees through sponsored research in nuclear security and related topics. The total number of graduate degrees produced through the NSSPI program stands at 79 as of fall 2016 semester. These graduates have gone on to jobs in various national laboratories, federal agencies, academia, and the nuclear industry. A pie chart of the employment sectors of the graduate students of the NSSPI program is shown below in Figure 5.

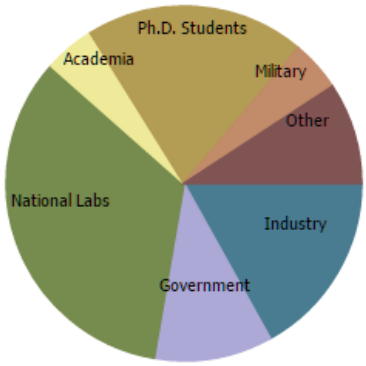


Figure 5. Employment Sectors of NSSPI M.S. and Ph.D. Graduates[18].

NSSPI also participates globally through partnership with countries and organizations around the world to develop safeguards capabilities and enhance the global nuclear security culture [22]. NSSPI faculties conducted several lecture series and workshops at universities in other countries as a response to the call of global issue of human capital development in nuclear security culture. These programs have been done by NSSPI:

- Curriculum development support for Russia, Nigeria, Jordan, India, Indonesia, and Brazil through NNSA, IAEA, or PNS program.
- Nuclear security training programs under PNS sponsorship for groups from Japan, Brazil, Indonesia, Jordan, Nigeria, India, as well as multinational groups through courses, seminar, tours, experiments, hands-on activities, and projects.
- International visiting scholars program from Brazil, India, China, Japan, Jordan, and Russia.
- The Gulf Nuclear Energy and Infrastructure Institute (GNEII) at Abu Dhabi. NSSPI worked with Sandia National Laboratories to develop the curriculum and supply the GNEII instructors for the classroom modules.
- The Nuclear Security Training Series (NSTS) sponsored by PNS for Indian universities to inculcate the tenets of nuclear security and culture to initiate discussion on nuclear security research.
- Exchange program with the Tokyo Institute of Technology (TiTech) where Texas A&M students attend a two-week-long symposium in Japan, and TiTech students participate in a week-long security and incident response exercise in Texas.

[20] "Nuclear Facilities Experience" *Education*. Nuclear Security Science and Policy Institute (NSSPI). Web. Accessed March 3, 2017.

[21] "Nuclear Security and Safeguards Education Portal" *NSSEP*. Nuclear Security Science and Policy Institute (NSSPI). Web. Accessed March 3, 2017. http://nsspi.tamu.edu/nssep

[22] "International Engagement" *International Engagement*. Nuclear Security Science and Policy Institute (NSSPI). Web. Accessed March 3, 2017.

- Participation in the IAEA International Nuclear Security Education Network (INSEN) as one of the founding members, developed textbooks and curricula, supplied lecturers for professional development courses, and also participated in the drafting of IAEA's Nuclear Security Series No. 12.

In the last five years, NSSPI's activities expanded into nuclear security workforce development abroad in countries such as India, Indonesia, Brazil, Jordan, and Nigeria to reach non-traditional students and professionals outside of Texas A&M[18]:

- The National Security Affairs graduate certificate program in partnership with Institute for National Security Education and Research (INSER)
- Short courses at national laboratories by NSSPI
- An eight-week summer nuclear security certificate program
- Safeguards and security short courses for international students and professionals
- Nuclear and radiological emergency response component for first responder training
- Synchronous distance education courses

OPPORTUNITY OF FELLOWSHIP, RESEARCH, INTERNSHIP AND SHORT COURSE IN NUCLEAR SECURITY FOR INTERNATIONAL STUDENTS

However, there are still some challenges for international students who pursue nuclear security and nonproliferation education in United States. The U.S. citizenship requirement for fellowship and research projects, internships, and summer short courses inhibits international students to maximize their nuclear security education potential in the United States.

First, a lot of the research projects and/or fellowships are not available for international students at U.S. universities. The National Nuclear Security Administration (NSSA) has granted a total of $100 million in awards for three universities to lead consortiums for nuclear security and nonproliferation related programs. NNSA announced a $25 million grant to the University of Michigan-led consortium in 2014 for research and development in nuclear arms control verification technologies, including nuclear safeguards effectiveness[23]. In the same year, North Carolina State University (NCSU) was awarded the same amount in a grant by NNSA to develop the next generation of leaders with practical experience in technical fields relevant to nuclear nonproliferation [24] . University of California, Berkeley (UCB) had the $25 million award from NNSA for Science and Security Consortium in 2011[25] and received the same amount of award from NNSA to lead Nuclear Science and Security Consortium (NSSC) in 2016[26].

Sadly, none of those funded programs are available for international students. University of Michigan's Consortium of Verification Technology (CVT) requires U.S. citizenship for its fellowship program in its partner universities[27]. The Consortium for Nonproliferation Enabling Capabilities (CNEC), led by NCSU through its website, does not restrict the fellowship to the partner institution, but recipients must be U.S. citizens or permanent residents[28]. The department of nuclear engineering at UCB [29] and Lawrence Livermore National Laboratory (LLNL)[30], as part of the NSSC, limit the program only for U.S. citizens.

Fortunately, private institution fellowships do not restrict their funds and fellowships to U.S. citizen only. The Stanton Foundation has a nuclear security fellowship program through these leading institutions in the nuclear security field[31]:

[23] "NNSA Announces Recipient of $25 Million Grant to Improve Nuclear Arms Control Verification Technology" *Press Release*. NNSA, March 31, 2014. Web. Accessed March 3, 2017.

[24] "NC State Awarded $25 Million NNSA Grant to Develop Leaders, Improve Technological Capabilities for Detecting Nuclear Proliferation" *NC State News*. NC State University, April 16, 2014. Accessed March 3, 2017.

[25] "NNSA, UC Berkeley Announce $25 Million Award for Science and Security Consortium" *Press Release*. NNSA, June 9, 2011. Web. Accessed March 3, 2017.

[26] "Consortium Led by University of California, Berkeley Awarded $25M NNSA Grant for Nuclear Science and Security Research" *Press Release*. NNSA, March 31, 2014. Web. Accessed March 3, 2017.

[27] Consortium for Verification Technology. "Fellowship Program". *Flyer*, USA (2016). https://cvt.engin.umich.edu/wp-content/uploads/sites/173/2014/10/Flyer-4.pdf

[28] "CNEC Fellowships" *Fellowship*. Consortium for Nonproliferation Enabling Capabilities, North Carolina State University. Web. Accessed March 3, 2017.

[29] "FAQ for students" *FAQ*. Department of Nuclear Engineering, University of California, Berkeley. Web. 3 March 2017.

[30] "Stanton Nuclear Security Fellows" *International and Nuclear Security*. Stanton Foundation. Web. 3 March 2017.

[31] "Stanton Nuclear Security Fellows" *International and Nuclear Security*. Stanton Foundation. Web. 3 March 2017.

- Belfer Center for Science and International Affairs
- Carnegie Endowment for International Peace
- Council on Foreign Relations
- Center for International Security and Cooperation
- Massachusetts Institute of Technology
- RAND Corporation
- Texas A&M University

Among those institutions, only Council on Foreign Relations restricts the fellowship applicant to U.S. citizenship or permanent resident[32]. The rest of institutions do open the fellowships to non-U.S. citizens[33][34][35][36][37][38][39]. Generally, unlike private institutions, most of the funding from the federal government such as Department of Homeland Security and Department of Energy through NNSA, are not available for international students.

Second, in terms of internship opportunities, most of the national laboratories in the United States have U.S. citizenship as their requirement for nuclear security-related internship positions. Savannah River National Laboratory (SRNL), through Savannah River Nuclear Solutions (SRNS), require U.S. citizenship from their internship applicants [40]. Brookhaven National Laboratory (BNL) require the same thing for their Graduate Research Internship Program (GRIP)[41]. Sandia National Laboratories (SNL) also strictly require U.S. citizenship for both the general internship program[42] and the nuclear detection R&D summer internship position[43]. Pacific Northwest National Laboratory (PNNL), in the National Security Internship Program (NSIP), have Signatures Science and Technology internship positions, in which the website says: some projects may require U.S. citizenship[44]. PNNL also have Next Generation Safeguards Internship Program for U.S. citizen only[45]. Lawrence Livermore National Laboratory (LLNL) have two internship positions related to nuclear security. The first one is a national security engineering division student internship which does not require U.S. citizenship[46]. The other one is global security, which has anticipated clearance of none, L, or Q depending upon location assignment[47]. It requires the applicant to renounce non-U.S. citizenship in order to get L or Q clearance for the position. Los Alamos National Laboratory (LANL) does not

[32] "Stanton Nuclear Security Fellowship" *Fellowship*. Council on Foreign Relations. Web. Accessed March 3, 2017.

[33] "Stanton Nuclear Security" *Fellowship*. Belfer Center for Science and International Affairs. Web. March 3, 2017.

[34] "Stanton Nuclear Security Fellowship" *Career Center*. Carnegie Endowment for International Peace. Web. March 3, 2017.

[35] "Stanton Nuclear Security Fellowship" *All Student Opportunities*. Stanford Center for International Security and Corporation. Web. Accessed March 3, 2017.

[36] "The Stanton Nuclear Security Fellowship at LNSP" *Laboratory for nuclear security and policy*. Massachusetts Institute of Technology. Web. Accessed March 3, 2017.

[37] "Stanton Nuclear Security Fellows Program" *About*. MIT Security Studies Program. Web. Accessed March 3, 2017.

[38] "Nuclear Security Fellows Program" *Internships and Fellowships*. RAND Corporation. Web. Accessed March 3, 2017.

[39] "Stanton Nuclear Security Fellows Program" *Research*. NSSPI. Web. Accessed March 3, 2017.

[40] Savannah River Nuclear Solutions. "Internship Program Overview". *Announcement*, USA (2017). http://www.savannahrivernuclearsolutions.com/docs/srns_intern.pdf

[41] "(Internship-GRIP) Graduate Research Internship Program" *Educational Program*. Brookhaven National Laboratory. Web. Accessed April 8, 2017.

[42] Sandia National Laboratory. "Student Internship Program". *Flyer*, USA (2017). http://www.sandia.gov/careers/_assets/documents/StudentPrgmFlyer_MECH.pdf

[43] "Job Description" *Career Job Search*. Sandia National Laboratory. Web. Accessed April 8, 2017.

[44] "Masters Intern – Signatures Science and Technology" *Jobs*. Pacific Northwest National Laboratory. Web. Accessed, 8 April 2017.

[45] Pacific Northwest National Laboratory. "Next Generation Safeguards Internship Program". *Flyer*, USA (2012). https://theuhp.files.wordpress.com/2012/01/ngsi_fy12_flier-1.pdf

[46] "National Security Engineering Division Student Intern" *Jobs*. Lawrence Livermore National Laboratory. Web. Accessed April 8, 2017.

[47] "Global Security Summer Student Intern" *Jobs*. Lawrence Livermore National Laboratory. Web. Accessed April 8, 2017.

require U.S citizenship for their Graduate Internship Program[48].

Argonne National Laboratory (ANL) has various programs such as the Graduate Research Program (GRP), graduate research aide program, graduate cooperative program, and visiting student program for graduate students in which they do not require U.S. citizenship from the applicant. However, their nuclear security-related internship such as the Summer Strategic Trade-Control internship program[49] and International Nuclear Safeguards internship program[50] are available for U.S. citizens only.

Among U.S. national laboratories, Oak Ridge National Laboratory (ORNL) and Idaho National Laboratory (INL) probably are the most open laboratories for international students who seek nuclear security-related internship. ORNL, through their Nuclear Engineering Science Laboratory Synthesis (NESLS) program, which has no U.S. citizenship requirement, provide various research areas of interest for the applicant[51]. Nuclear security technology is one of the research area options that covers: material protection, control and accounting; radiation detection; safeguards transportation technologies; arms control assessment; fissile material; detection export control; fissile material disposition; and nuclear threat reduction[52]. Like ORNL, INL also have internship program that does not require U.S. citizenship[53]. There are cross-discipline internship projects, such as nuclear nonproliferation which is available for students with academic backgrounds of nuclear engineering, analytical chemistry, material science and engineering, chemical engineering forensics, geology, and public/international policy[54].

There are some nuclear security-related short courses usually held in summer semesters in the United States. But again, some of them are unavailable for international students. PNNL have a Radiation Detection for Nuclear Security Summer School in the summer. Based on 2012[55] and 2014[56] reports, 25 total participants from both events were all U.S. citizens due to its citizenship restriction. LANL have a four-week Dr. G. Robert Keepin Nonproliferation Summer School in June 2017 which provides seminars, tours, and hands-on training that could lead to another six-week internship at LANL for U.S. citizens only[57].

Gratefully, there are still some courses which are available to international students. Brookhaven National Laboratory (BNL) have Nuclear Nonproliferation, Safeguards, and Security (NNSS) two-week course in June 2017, and they make it available for non-U.S. citizen[58]. The course is designed to give students a sound understanding of the framework created by the international community to address the threats of nuclear proliferation and nuclear terrorism. The Lawrence Livermore National Laboratory (LLNL) and the James Martin Center for Nonproliferation Studies (CNS) co-host the International Nuclear Safeguards Policy Summer Course, which is also available for foreign

[48] "Graduate Research Assistant Program" *Graduate Program*. Los Alamos National Laboratory. Web. Accessed April 8, 2017.

[49] "Summer Strategic Trade Control Internship Program" *Educational Program*. Argonne National Laboratory. Web. Accessed April 8, 2017.

[50] "International Safeguards Summer Internship Opportunities" *Educational Program*. Argonne National Laboratory. Web. Accessed April 8, 2017.

[51] "Graduate Student Opportunities at ORNL" *Science Education Programs at ORNL*. Oak Ridge National Laboratory. Web. Accessed April 8, 2017.

[52] "ORNL NESLS Summer 2017" *Opportunity Details*. Zintellect. Web. Accessed April 8, 2017.

[53] Idaho National Laboratory. "INL Internship Opportunities". *Flyer*, USA (2014). https://www.inl.gov/wp-content/uploads/2014/11/Intern_Opps-3.pdf

[54] "Idaho National Laboratory University/College Internships – Application for 2016 Fall/Winter and 2017 Spring/Summer" *Job Description*. Idaho National Laboratory. Web. Accessed April 8, 2017.

[55] R.C. BUNKLE, J.E. BACIAK, J.A. STAVE. "Summary Report for the Radiation Detection for Nuclear Security Summer School 2012". *Summary Report for U.S. DoE*, USA, August (2012).

[56] R.C. BUNKLE, et al., "Summary Report for the Radiation Detection for Nuclear Security Summer School 2014". *Summary Report for U.S. DoE*, USA, September (2014).

[57] Los Alamos National Laboratory. "Dr. G. Robert Keepin Nonproliferation Summer School at Los Alamos National Laboratory". *Flyer*, USA (2016). https://www.lanl.gov/collaboration/internships/service-academy-research-associates/_assets/doc/Summer_School.pdf

[58] Brookhaven National Laboratory. "Nuclear Nonproliferation, Safeguards, and Security (NNSS) in the 21st Century". *Flyer*, USA (2016). https://www.bnl.gov/nnsscourse/files/flyerPoster/flyerPoster.pdf

national participants[59]. The course focuses on providing the participants with a solid foundation for understanding the policy facet of international safeguards and how the policy dimension interplays with the legal and technical dimensions underpinning the safeguards work of the IAEA. This course could lead 4-6 U.S.-citizen participants to a 10-week internship at LLNL.

CONCLUSIONS

PNS has successfully raised nuclear security awareness and education internationally, especially among students in UGM, Indonesia through various programs for the faculty members and support for the INMM Student Chapter at UGM activities. Major improvements in nuclear safety, security, and safeguards in nuclear engineering undergraduate program curriculum is one main result of the partnership.

NSSPI at Texas A&M University, as one of leading institutions in nuclear security and nonproliferation research and education in the United States, has provided service and resources for local and international students, and also an international community who seeks nuclear security knowledge. Their research and education activities need to be supported by the government and institutions whose concerns are national and international nuclear security education.

Despite the U.S. citizenship requirement for most of federal funding of fellowships and research projects, international students still have opportunities for funding from private institution. They also could optimize their chance of having an internship in a national laboratory by applying to INL or ORNL, which are relatively more open to non-U.S. citizen applicants. Nuclear security-related summer courses are also options for international students to maximize their pursuance of education in the United States.

[59] James Martin Center for Nonproliferation Studies. "International Nuclear Safeguards Policy". Flyer, USA (2016). http://www.nonproliferation.org/wp-content/uploads/2015/11/international-nuclear-safeguards-internship-and-course-flyer.pdf