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Assessing The Effectiveness Of Nuclear Security Training And Education In Ghana

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Abstract

Growing attention is being given to nuclear power across several African countries, including in Ghana. The world is depending on nuclear energy as a reliable and efficient means of energy generation. Ghana as a country is developing nuclear energy; thus, equal attention must be directed toward nuclear safety and security. Ghana is gradually developing interest in and is devoting substantial required resources to educating and training on nuclear security to meet the standards required by international bodies. Institutions such as the Nuclear Safety and Security Centre and the School of Nuclear and Allied Sciences of the Ghana Atomic Energy Commission are responding to the growing demands of imparting training and education in nuclear and radiation security. Ghana's attention to nuclear security training and education has led to the development of programs from international agencies, and this development is making significant contributions toward nuclear security in the African region. This paper presents a well-structured curriculum model for a master's program in nuclear security and makes possible recommendations to effectively train persons in the nuclear-related fields of the country of Ghana. Prospects of employment at stakeholder facilities in Ghana are carefully assessed in the research.

Keywords: nuclear energy, nuclear security, education, course planner, safety

1. Introduction

Education has an enormous role to play in the nuclear security field, and this importance on education is relevant to worldwide efforts to improve nuclear security culture. In recent years, we have recognized a fast-growing interest in the need to continuously improve nuclear security education. There was little attention paid to nuclear security education until an unexpected event occurred [1]. The dangers that nuclear and other radioactive materials pose to humans and the environment, as well as the associated concern of when those materials get into the wrong hands (unauthorized or criminal activities), continually remain high. This danger is considered a significant threat to international peace and stability [2]. It is critical that each country develops an adequate and efficient nuclear security regime to improve the country's, and thus the world's, efforts to combat nuclear terrorism [3].

The worrying trend of polluting our environment with gases affecting our climate demands the use of clean energy sources to save the Earth. Also, the constant rising demand for energy has led to a reliance on nuclear energy because it is a clean source of power. Following the Fukushima tragedy in 2011, many nations abandoned the use of nuclear energy. Nevertheless, because nuclear energy is still one of the best and most environmentally benign forms of energy, several states choose it to satisfy their expanding needs. According to an International Atomic Energy Agency (IAEA) assessment titled *Energy, Electricity and Nuclear Power Estimates for the Period up to 2050*, nuclear energy production capacity is expected to increase by between 1.9% and 56% by 2030 [4].

As much as nuclear energy is necessary for Ghana to combat climate change, measures to make sure that nuclear energy will be safer to use without any form of sabotage, theft, or unauthorized use must be in place.

Operating a nuclear power station comes with some threat, thus the necessity to educate workers and the general public. These threats lead to severe social, psychological, health, economic, political, and environmental consequences [5]. These threats that can befall a country with nuclear developments includes the dispersal of nuclear and radioactive substances around crowds or in public spaces, such as a radiological dispersal device; the deliberate placement of hazardous radioactive material, such as a radiological exposure device, in public spaces with the goal of irradiating those nearby the source; the creation of homemade nuclear weapons; a sabotage attack on a nuclear facility with the intention of causing a release of radioactive material; or a deliberate act to contaminate food or water supplies with radioactive material [6]. The obligation for nuclear security rests solely with individual states. Every country's competent authorities are in charge of creating and enforcing a nuclear security program that is compliant with relevant international legal agreements.

Protecting people, including those working in nuclear and radiation facilities, as well as the environment, from unlawful or unapproved acts involving nuclear and other radioactive material is the main goal of the state's nuclear security system [7]. State rules and regulations serve as the foundation for the nuclear security regime, which are

derived from international instruments and that of IAEA Nuclear Security Series recommendations. Making provisions for nuclear security during major public events is a necessary, crucial component of a country's overall security strategies. The basic requirements by states to establish a well-planned nuclear security regime relies on the creation of a legal and regulatory framework, the employment of preventive measures, the provision of effective border security and/or detection systems, the employment of effective response measures, improving human resources, and the augmentation of nuclear security culture.

One major problem that has been slowing down the expansion of nuclear energy in Africa, including Ghana, is how unenlightened the general public is when it comes to discussions related to nuclear energy. Many people in Africa view it as a very dangerous form of energy that can destroy the continent. However, everyone needs to be made aware of the value and numerous advantages of nuclear energy. International bodies are putting in much effort to increase public knowledge in this aspect. The current *Nuclear Security Plan* covering 2010–2013 stresses the importance of considering existing capacities at international, regional, and national levels when creating nuclear security academic programs [8].

Safeguards as applied in the nuclear industry assist to provide the accuracy and wholeness of information given by states on the sole use of their nuclear material for peaceful purposes, thereby reducing the risk of the proliferation of nuclear weapons. This information is vital in the process of providing the necessary security for a facility because waste facilities and other storage facilities may be called on in the quest to develop more nuclear weapons. Nonproliferation in the nineteenth century saw some major developments that helped to curb proliferation activities by individual states following an evaluation on how to provide effective safeguards by the IAEA in May 1997. Monitoring of this nature for facilities offers continuity of knowledge and the prime assurance that nuclear material is not diverted from peaceful use [9].

With nuclear security being a national and international responsibility, the IAEA developed an *Integrated Nuclear Security Support Plan* (INSSP). This plan serves as an essential tool that enables countries to approach nuclear security in a comprehensive way to strengthen and provide a viable system for their national nuclear security. The plan begins with dealing with legislative and regulatory frameworks within a state. Important sites in nuclear facilities such as research reactors in which highly enriched uranium is used require further physical protection measures to ensure that efficient security is provided against acts of sabotage. Other radioactive materials, such as nuclear gauges and sealed radioactive sources used in radiotherapy machines in various health centers for cancer treatment, need to be well-monitored and accounted for to prevent them from theft. As parts of the plan, the INSSP identifies responsible entities and organizations within the concerned country taking into consideration timelines for the execution of approved activities. The INSSP is confidential and not legally binding but is a signal of a strong obligation to pursue the establishment of nuclear security improvements in a state. Developing a competent and sustainable nuclear security regime requires an adequate and effective regime. The costs of nuclear

terrorism present a grave threat to every nation that holds nuclear materials and power plants.

To help curb the risk of nuclear material theft or sabotage at Ghanaian nuclear facilities, education on nuclear security plays a major role in the country's protection of nuclear materials. Indicators of performance that might be used to evaluate the nuclear program include states creating comprehensive human resource development programs and a number of training courses with help from agencies. Ghana appreciates the need to intensify the knowledge base for nuclear security, and as a result, Ghana has established a strategic policy requiring increasing capabilities in nuclear security training and education. The country has therefore committed significant resources to ensure the long-term viability of the system. This study's goal is to emphasize Ghana's efforts to develop, sustain, and promote nuclear security training and education in light of this policy, as well as to analyze future obstacles.

This paper first provides background information and highlights objectives of nuclear security education in Ghana. Through an analysis of global practices, the next section offers a more comprehensive review of the situation. The third section gives the exceptional structures of nuclear security training and education in Ghana within primary institutions. The influence of nuclear security knowledge is examined in the fourth section and also presents a well-structured curriculum in nuclear security for a master's degree program. The final section describes challenges and suggested recommendations to improve nuclear security knowledge in the country.

The significance of nuclear security training and education is emphasized in this research about Ghana, demonstrating how Ghana places great importance on nuclear safety and security. This paper focuses on advances that Ghana as a country has made toward nuclear security training and education programs with the aim of realizing its nuclear ambitions. This paper also makes a brief analysis of international practices. It will also elaborate on Ghana's activities to impart nuclear security training and education within the region. It will further highlight various institutional setups and activities adopted by Ghana to realize its nuclear security training and education program, which is now gaining global recognition.

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Please include all figures in the manuscript where you would like them to be placed in the final publication. Please include it in line with the text and *not* anchored in the text.

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2. View on the Significance of Nuclear Security Education on a Global Scale

The issues that may occur at a nuclear facility with regards to workers, the public, and the environment are relatively similar, regardless of the source of the issue being related to safety or security. This similarity means that the safety-related initiating actions, such as human and/or equipment failures and internal and/or external hazards, should pose similar jeopardy as the security-related initiating actions, such as theft of nuclear material, an event of malicious origin, or a terrorist attack on the facility. Because of these conditions, the IAEA offers basic principles, advice, implementation, and technical assistance materials for member states through the Nuclear Security Series to support member states in realizing robust nuclear security programs. Additionally, IAEA will assist members in reviewing and enhancing their current nuclear security arrangements if necessary. Following an assessment on how to toughen the effectiveness and improve the efficiency of IAEA safeguards, in May 1997, the IAEA Board of Governors implemented a Protocol Model, which became a part of the agreements between states and the IAEA for the application of safeguards. Safeguards serve the purposes of validating the correctness and wholeness of declarations made by states about the exclusiveness of the peaceful use of their nuclear material and activities, thereby reducing the risk of the proliferation of nuclear weapons.

Certain unforgettable events creating terrifying memories, such as September 11, 2001, in the United States, spread fear throughout the world, including concern about nuclear weapons. Given the loose nuclear security procedures in numerous nations, the threat of a terrorist attack using a radiological dispersal device or an improvised nuclear device was regarded as an urgent hazard. Understanding the growing alarm, a nuclear security plan was adopted by the IAEA governing body [10]. The idea was to underline the value of human resource development and how it may help IAEA member states become more capable of establishing and maintaining adequate nuclear security. As a result, it will be easier for member states to stop, identify, and react to harmful activities involving nuclear and other radioactive substances. The documents produced by the IAEA concerning education were to develop a nuclear security education curriculum that can serve as a reference for its member states with the determination of developing and keeping up with pertinent information and abilities and sustaining competent personnel that can handle future nuclear security problems [11]. Because of insufficient investment into establishing special institutes for the training and education of all features of nuclear security, the IAEA took the initiative to establish an international program for teaching nuclear security. To fill any knowledge gaps and assist member states in modernizing their nuclear security training systems, the agency established technical recommendations for graduate and certificate course programs. Since then, the involvement of nuclear specialists and member nations has produced the successful development of an active training system. The IAEA cooperates and collaborates with leading academic institutions to come out with curricula and train personnel. By creating, disseminating, and supporting excellence in nuclear security education, the

International Nuclear Security Education Network (INSEN) is enhancing global nuclear security [12]. The IAEA also came out with International Network for Nuclear Security Training and Support Centers (NSSCs), which make up a cooperative network of nuclear security training and support facilities to enhance nuclear security capacity building. Member states now have the chance to create their own nuclear security, safety, and safeguards centers.

3. Assessing Contributions to Nuclear Security and Education at the National Level

When assessing the importance of nuclear security and its education in a country, it is necessary to consider the inputs made at the national level. The state has the entire responsibility for the level of nuclear security provided in the country with regards to the set standards of the IAEA. The state is accountable for safeguarding all nuclear and radioactive materials, related infrastructure, and related operations that fall under its purview. This responsibility is accomplished by the state creating a nuclear security program unique to that state. A country determines the legal and regulatory framework, as well as the policies required for the construction of an effective security program. The IAEA encourages member states to train and educate people to help establish threat mitigation and risk reduction procedures that contribute to an effective nuclear security regime.

Defining what is considered to be a crime or violations pertaining to nuclear security under the laws of a country is very important because the state seeks to avoid unauthorized acts involving or directed at nuclear material, radioactive material, and its associated facilities. Laying down the appropriate disciplinary measures according to the level of harm that can be caused by an offender is vital for the establishment of an effective nuclear security regime. This definition may be achieved by stating clearly the jurisdiction of the state over such offenses and giving out prosecution or, as suitable, extradition of alleged offenders [13].

a. International Nuclear Security Education Network

A few years ago, the IAEA agreed to improve the present Nuclear Security Plan [14], which aims to increase global collaboration in terms of nuclear security and safeguards. The plan's primary objective is to encourage initiatives that would make it possible to use nuclear energy and its uses with radioactive materials in a safe, secure, and peaceful manner [8]. The nuclear security plan projected by the IAEA in 2010 was based on four vital elements: needs assessment, information collation, and analysis; contributing to the enhancement of a global nuclear security framework; providing nuclear security services; and risk mitigation and improving security. Providing nuclear security services was stressed owing to the necessity of supporting nuclear-inclined states in developing educational programs on nuclear security. This development would further enhance the sustainability of nuclear security culture. The IAEA recorded 26 universities from member states, which Ghana happens to be part of, and two international organizations, which joined forces in the INSEN program with the target of promoting quality in nuclear security training and education [15]. The plan has the basic actions to realize the nuclear security ambitions, which are the following:

- Reducing the use of highly enriched uranium
- Strengthening security at nuclear facilities by implementing the best national regulations practices
- Establishing ways to detect and prevent the illegal movement of radioactive and nuclear materials
- Capacity building, developing new technologies, and coordinating support efforts with regards to nuclear security

The IAEA is providing support in diverse ways to countries such as Ghana to develop these programs, which also includes human resource expansion and related methodologies. Other support includes the development and engagement of innovative human resource delivery mechanisms for computer-based instruction, self-paced training, and instructional materials that typically include activities and supplies for lab work. To improve multilateralism and information exchange, the approach also conducts joint research and development projects to share scientific expertise and infrastructure. Eligible participants have the opportunity to participate in these projects through student exchange programs. These programs keep in mind the quality and standards of the IAEA [16].

b. World Institute for Nuclear Security

The World Institute for Nuclear Security (WINS) brings together security experts in government, nuclear security professionals, and international organizations to share and encourage the best security practices necessary for safeguarding nuclear and radioactive materials that may be vulnerable. The internal body focus their attention on the physical protection of radioactive materials and related facilities around the world, as well as sustainable improvement of security. The services provided by WINS focus on professionally moderated workshops and training, which are organized by providing innovative practical exercises and presentations. The activities are designed in a way to make the training very interactive and to engage participants for improving on their knowledge and skills. They also provide the chance for participants to connect with each other while sharing best practices and knowledge acquired. The WINS Academy perceives the acquisition of knowledge in security as a fundamental aspect of risk management and corporate reputation, as well as providing an internationally recognized certification program for nuclear security management. The knowledge center of the institute helps in the production of numerous published documents on nuclear security and the management of nuclear and other radioactive materials. The institute helps in evaluation by making available the resources needed to evaluate the maturity of their security arrangements, measure the efficacy of their security culture, and pinpoint areas where they can improve.

c. Ghana Atomic Energy Commission

The Ghana Atomic Energy Commission (GAEC) can be traced as far back as 1952, when the use of radioisotopes began to gain attention in Ghana, as did the intention of exploiting nuclear science and related technologies, which foster national development peacefully. GAEC has the responsibility to assist the government of Ghana in making

decisions concerning nuclear-related developments and the commercial application of nuclear research in the areas of health, agriculture, industry, and commerce. This commission fulfills the state's duty to ensure nuclear security, safety, and environmental protection and helps to create a sustainable nuclear energy future for Ghana.

Over the years, Ghana has successfully operated a nuclear research facility and has gained good experience with the nonpower applications of nuclear technology, including the medical and industrial sectors. GAEC also took interest in environmental radiation monitoring and the advocacy for the nonproliferation of nuclear weapons. The commission has a number of institutions, including the School of Nuclear and Allied Sciences affiliated to the University of Ghana, which seeks to educate and train prospective personnel stakeholders of nuclear facilities and its associated activities. Figure 1 describes the institutions involved in nuclear security training and education and how it flows.

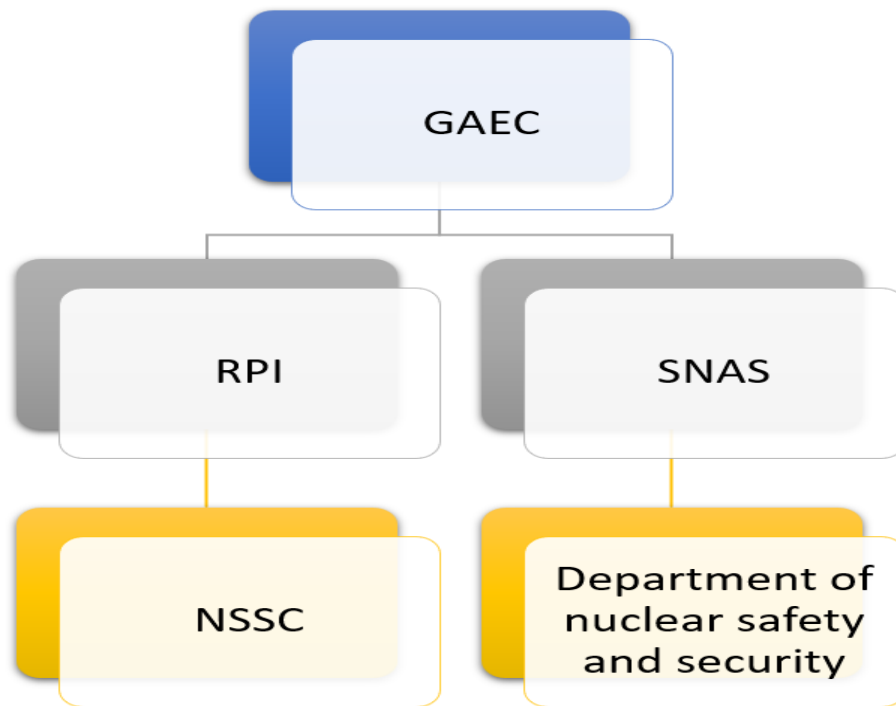


Figure 1. The flow diagram of nuclear security training and education in Ghana.

Radiation Protection Institute

The safety and security of nuclear and other radioactive materials are paramount to every nuclear-related facility, and this concern integrates various types of physical barriers to prevent theft and unauthorized access. The Radiation Protection Institute (RPI) enhance scientific infrastructure to boost research, growth, and innovation through protection against radiations. The institute also provides radiation and waste safety services with the goal of effectively managing nuclear waste. NSSCs such as the RPI have the responsibility of designing physical protection regimes and the assessment of those regimes. Professionals in the field of nuclear security assist research facilities, government institutions, and industrial companies in the safe use of radioactive sources

and implementing the best physical protection practices that correspond with their radiological risk. NSSCs focus on human resource development, as well as technical and scientific support, that helps a country's nuclear security to be sustainable. NSSCs often assess existing physical protection systems against existing threats to facilities to make recommendations. This effort comes with offering training to the companies if there is a need to inform the employees. They join forces with the Radiation Safety Assessment and Training Center to take on training programs in nuclear safety, security and safeguards for stakeholders in nuclear safety, and security and safeguards. The RPI conducts research into physical protection design, nuclear security, safeguards, and nonproliferation to create effective designs for any nuclear and radiologically related facility. The RPI has the capability to manage and assess a radiological crime scene and emergency response to nuclear safety and security incidents.

Graduate School of Nuclear and Allied Sciences

The School of Nuclear and Allied Sciences (SNAS) was established in 2006 through the collaborative effort of the GAEC and the University of Ghana, with the support of the IAEA. Its aim is to improve nuclear knowledge in Ghana and Africa in general. The graduate school seeks to promote and build human capability and capacity in the fields of radiation protection, nuclear safety, and security. SNAS's programs address national, regional, and international human resource development needs.

The Department of Nuclear Safety and Security is one of the five departments of SNAS with a vision to be recognized nationally and internationally as the first-choice center for human resource growth in radiation protection, radiation health and safety, nuclear security, and safety. SNAS's Department for Nuclear Safety and Security aims to deliver well-structured and organized instruction on how to safeguard people, communities, and the environment against the harmful consequences of ionizing radiation. Graduate students acquire practical experience on the physical security of nuclear material and nuclear facilities, as well as nuclear security knowledge and guidelines for radioactive material and related facilities.

The department offers accredited master of philosophy (MPhil) and doctor of philosophy (PhD) programs in radiation protection. Additionally, the department also runs the IAEA-sponsored Postgraduate Educational Certificate (PGEC) in radiation protection and safety of radiation sources, which began in 2011 after the department was endorsed as an IAEA Regional Designated Centre for Radiation Protection in October 2011.

Currently, the department is the only university department in Ghana educating the next generation of professional radiation protection specialists for nuclear and other industries in Ghana and neighboring member countries. This program seeks to train health physics and radiation protection practitioners who would spearhead the beneficial use of radiation while protecting workers and the public from potential radiation hazards.

d. African Centre for Science and International Security

The African Centre for Science and International Security (AFRICISIS), partnering with the University of Ghana's SNAS and other great universities in Africa, contribute to the nuclear security training and education in Ghana. The major goal of AFRICISIS is the promotion of a systemic approach to nuclear nonproliferation and arms control (as well as chemical, biological, and radiological weapons and delivery vehicles) in Africa and increasing transparency in peaceful nuclear activities. The organization holds professional development courses intended to develop and launch educational courses in nuclear security, safeguards, and safety for nuclear-related universities and research institutions. The organization does policy-relevant, evidence-based analyses of Africa's security concerns and releases independent research on the strategic dimensions and ever-changing patterns of global security threats, best security practices, and lessons learned. Local and foreign speakers are invited to address themes relating to science, technology, and security at conferences and regular seminar series held by the organization. The organization applies its knowledge to pressing security issues that require solid technical and scientific data and analysis, and AFRICISIS makes its findings available to policymakers, the press, and the general public.

4. Program Learning Objectives for Nuclear Security Education in Ghana

An academic curriculum in nuclear security is designed for educational purposes but can also be regarded as a resource to facilitate the development of a comprehensive national nuclear security and human resource development program by a state. The nuclear security training and education course is necessary to develop and maintain relevant knowledge and skills in qualified personnel dealing with nuclear security challenges. Master's degree programs in nuclear security can be designed and implemented with the objectives stated in the following list. Graduates from the program should acquire the following professional training.

- Fully understanding the concept of a nuclear security regime, its importance, components, and how they interact
- Identifying the differences in nuclear and radiological infrastructure
- Awareness creation and the knowledge buildup of international legal frameworks governing nuclear security, as well as relevant national regulations and procedures
- Recognition of the importance of the human factor in nuclear security, including security culture and the insider threat
- Recognizing the existence of the threat associated with nuclear and radioactive materials out of regulatory control, as well as knowledge of the tools necessary to address them
- Knowledge about protecting nuclear and radioactive materials and their related facilities

5. Course Planning for a Master's Program in Nuclear Security

The kind of resources that are used to construct blended learning courses is very important and must be analyzed to confirm if it will help students progressively. A course planner can play a major role when developing a course syllabus to know what objectives, goals, and assessments are necessary for the course [17]. The course planner shown in Figure 2 considers the course goals, objectives, and different forms of assessment suitable for nuclear security training and education.

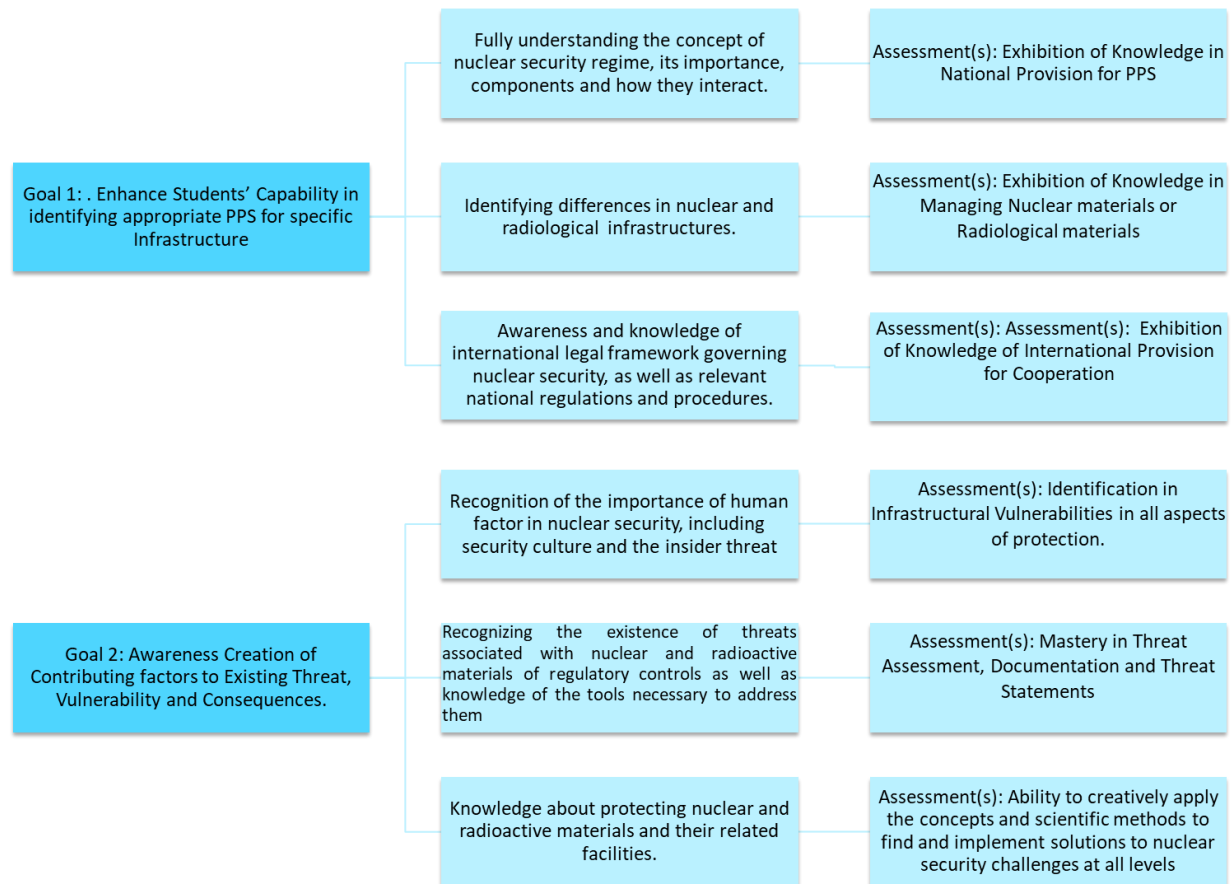


Figure 2. The course planner for nuclear security with different forms of assessments.

6. Master's Degree Curriculum Module for Nuclear Security Course

The academic curriculum presented in this work is a model that accurately describes the current knowledge in the field of nuclear security around the world. Elective courses enable students to specialize in a particular direction of nuclear security and serves as supplementary to the core courses.

Table 1. Designed elective and core course for master's degree in nuclear security [18]

Core subjects	Elective subjects
International and national legal, regulatory, and institutional framework for nuclear security	Interface of nuclear security with safety and safeguards
Risk-informed approach to nuclear security	Legal drafting for nuclear security
Coordination and cooperation of stakeholders at national and international levels	Nuclear material accounting and control for nuclear-related facilities
Nuclear security management at facility level	International cooperation on nuclear security
Security of sensitive nuclear information	Radiological crime scene management
Nuclear security culture	Nuclear forensic analysis
Threat assessment	Conducting computer security assessments
Physical protection systems design and evaluation	Developing and implementing a design basis threat
Physical protection technologies and equipment	Nuclear security framework for major public events
Use of nuclear material accounting and control for nuclear security	Designing physical protection systems for nuclear and radiological facilities
Security of nuclear and other radioactive materials in transport	Information/computer security incident response
Detection of criminal or unauthorized acts involving nuclear and other radioactive materials out of regulatory control	
Preventing and protecting against insider threat	
Computer security for a nuclear world	
Response to criminal or unauthorized acts involving nuclear and other radioactive materials out of regulatory control	

7. Training and Education in Nuclear Security and its Effects on Ghana's Nuclear Program

Ghana is currently making important advances toward developing its nuclear program through instruction, training, and information dissemination among pertinent stakeholders. The nation is fostering a culture of nuclear security responsiveness. The influence of training in several aspects is assessed recurrently to guarantee that it meets anticipated national standards and needs. In this regard, the Ghana Nuclear Power Programme Organisation, which is spearheading the nuclear power advancement in the country, is preparing evaluation methodologies, including the education of anyone involved in the program, to assess how effective training is to achieve the ultimate goal of realizing nuclear power infused into the national grid. Feedback from these evaluations helps to improve on areas that fall short with regards to the nuclear power program. Many pertinent organizations, notably those with direct responsibility for nuclear security, including nuclear regulators, operators, decision-makers, security services, and law enforcement organizations of the state, are becoming more capable as a result of nuclear security awareness. Experts from the IAEA, as well as trained professionals in the fields of nuclear energy, nuclear security, and nuclear safety, typically carry out these programs. The GAEC continually organizes training for law enforcement agencies and other stakeholders of the nuclear technological field to create the necessary awareness for the program. Figure 3 shows an image of training provided by the US Department of Energy Office of Radiological Security for Ghanaian security forces.



Figure 3. US Department of Energy Office of Radiological Security training: International Response Training Course organized for security services in Ghana, December 6–9, 2022.

In accordance with the IAEA's mandates to make sure that nuclear technology is used for peaceful purposes, states also have the responsibility for providing and applying safety and security standards to protect life and property against the negative consequences of radiation. The PGEC is a well-structured and multidisciplinary program that last for approximately 6 months and was created for young people who may advance to high management or top decision-making positions with duties for radiation security and protection. The program was expanded to include IAEA Regional Training Centers in Africa, Latin America, Asia, and the Caribbean after the initial training took place in Argentina in 1981. One of the nations chosen to host participants from Africa is Ghana. An impact evaluation performed on the training course (shown in Figure 4) confirmed that it plays a vital and remarkable role in training competent professionals in nuclear radiation protection and in consolidating the radiation safety setup at institutional and state levels.

1 YEAR			3 YEARS			5 YEARS			More than 5 years (historic evaluation)		
RTC	No. of participants (No. of courses)	Response rate	RTC	No. of participants (No. of courses)	Response rate	RTC	No. of participants (No. of courses)	Response rate	RTC	No. of participants (No. of courses)	Response rate
ALG	23 (1)	74%	ALG	20 (1)	70%	ARG	11 (1)	82%	ARG	482 (29)	33%
ARG	12 (1)	92%	GHA	20 (1)	80%	MAL	27 (1)	70%	BYE	142 (7)	38%
BRA	1 (1)	100%	BYE	13 (1)	92%	MOR	20 (1)	75%	GRE	57 (3)	69%
GHA	18 (1)	100%	MAL	47 (2)	58%				MAL	145 (7)	52%
GRE	13 (1)	100%							MOR	121 (6)	48%
MAL	61 (2)	72%							SYR	171 (10)	33%
Total of surveyed participants (courses): 128 (7)			Total of surveyed participants (courses): 100 (5)			Total of surveyed participants (courses): 58 (3)			Total of surveyed participants (courses): 1118 (62)		

Figure 4. Impact evaluation conducted over some years after training completion [19]. IAEA Regional Training Center hosted in Algeria (ALG), Argentina (ARG), Brazil (BRA), Belarus (BYE), Ghana (GHA), Greece (GRE), Malaysia (MAL), Morocco (MOR), and Syria (SYR).

With the gathered experience from PGEC and support from the IAEA, several approaches and mechanisms can be applied to internationally accepted security standards through the education course in nuclear security. This course can prepare students to offer radiological protection services and technical assistance, promote education and training, foster information sharing, and encourage knowledge management and networking. The program will be beneficial to member states because participants can apply their acquired knowledge and skills during the training to make significant contributions toward strengthening the security and safety of nuclear and radioactive substances in their home country or institution.

8. Challenges Toward Providing Effective Nuclear Security Education

The IAEA has listed approximately 28 countries as being involved in nuclear power programs, with a few of these countries being in Africa [20]. Even though it is projected that the first nuclear plant that can be developed will be in decades away from now, countries, especially in Africa, are seriously looking for potential international partners to start their nuclear power programs. However, the drive and preparation of African nations, including Ghana, toward nuclear power are challenged by some obstacles [21].

Nuclear security is not taught in public or private universities in the republic. This lack of teaching makes it difficult for people to comprehend the importance of security in general. Adding nuclear security to the programs studied in the universities will be beneficial to the country as a whole because it can help to improve national security. Institutionalizing a nuclear security program, as well as nuclear security education,

comes with challenges such as building the necessary infrastructure and employing adequate, highly skilled human resources to help in the training of personnel in the field.

This paper makes some recommendations for bringing together all relevant stakeholders to refocus attention on nuclear security.

- The continuous focus is placed on nuclear security training and education with regard to all stakeholders involved by adhering and putting into practice the laws governing nuclear security and making reviews. This focus enhances the development of a stronger nuclear security regime for the state.
- Governments must continuously lead in efforts to make meaningful changes in policy and regulation to nuclear security and its education in the country.
- The nature of nuclear security training requires the establishment of well-equipped technological laboratories. Simulation and animation-based techniques should be readily made available for tasks during training of nuclear security experts because these tools will provide them with hands-on training.
- International cooperation and collaboration are important to create diversity, hence the need to create connections with institutions with good records when it comes to nuclear security through student and research exchange.

9. Prospects of Employment at Stakeholder Facilities: Understanding Employers

Employers in the nuclear energy industry engage prospective employees with experience in a broad range of disciplines. These disciplines include engineering, technical skills, trade work, and technology. An emphasis on security of the facility, health, and safety is very important for the management of facilities in this industry; thus, a good record of security and safety consciousness on the job is often an advantage for candidates seeking jobs on the job market. The nuclear industry presents both temporary and permanent employment benefits. Some of the temporary employment opportunities, which can also be classified as periodic contracts of nuclear facilities, include carpenters, electricians, operators of heavy equipment, masons, pipefitters, sheet metal workers, welders, mechanics, and project managers. The need for these personnel to understand and believe in the security culture that exists at the working environment of nuclear facilities is held paramount. Some of the permanent employment opportunities include accountants, financial managers, entrepreneurs, policy analysts, subject matter experts, lawyers, communicators, cybersecurity specialists, chemical engineers, chemists, radiation protection specialists, scientists, reactor operators, nuclear engineers, safety and environmental impact specialists, civil engineers, and mechanical engineers.

It is therefore helpful for prospective employees to gain some level of education and, if possible, a certification in nuclear security training and education programs as evidence of their achievement. This education is a crucial component of the specifications that direct the licensing procedure for nuclear facilities. A huge benefit to the industry is realized in the fact that this cycle of training and education allows the system to also produce experienced and qualified experts across the various temporary and

permanent nuclear-related job opportunities within the many decades of operation of nuclear facilities.

Because of the strong global growth projection for the use of clean energy such as nuclear technology, the job demand in the nuclear industry among developing countries, especially in continents like Africa and Asia, is expected to be very large. One of the key reasons for this high demand is that the nuclear energy industry also presents promising high-paying jobs for many qualified personnel across the numerous fields of expertise mentioned previously.

With the known fact that nuclear power plants can operate out to approximately 60 to 80 years or even more, a certain acceptable level of guaranteed job security is provided for the various expertise. The long period of operation of this equipment and all associated facilities and activities provides reputable platforms for research and documentation to support the training and education of generations yet to venture into the nuclear industry.

10. Future Work to Promote Nuclear Security Training and Education in Ghana

The introduction of a postgraduate course or certificate program in nuclear security, which might be administered similarly to the IAEA's postgraduate education program in radiation protection and the safety of radiation sources (PGEC), is one suggestion for improving Ghana's nuclear security education. The scope of the plan for implementation is geared to involve simulation exercises of various forms, which will fit many forms of budget allocations. Relatively low-cost fit budget requisites such table-top exercises can be upgraded to appreciably high-cost modern computer simulation tools, which arguably provide more efficient benchmark results. IAEA considers effective management and sustainability measures as key to attaining success in nuclear educational programs. As part of sustainability culture for nuclear security training and education, the state, stakeholders, and institutions must help provide the needed infrastructure and management systems to ensure the continual effective delivery of training. Train-the-trainers programs are an effective way of making sure that the trainers of nuclear security courses are always well-equipped to perform their responsibilities. The leaders of these institutions have a significant effect on culture through their leadership and management strategies, which include encouraging employee motivation and pursuing continuous improvement.

11. Conclusion

Nuclear technology has evolved into a multifaceted field over time, and the advantages of atom splitting have made it a compelling choice for safe energy in the future. Because of these facts, Ghana needs to form a strong base of knowledgeable and well-trained experts in nuclear security to increase the nation's faith in the peaceful application of nuclear technology as a reliable power source. The designed master's program curriculum presented in this work can help to produce the skilled professionals the country needs to provide security for nuclear-related facilities and radiological facilities. Ghana consistently emphasizes the need of nuclear security education and

training in keeping with global initiatives to address new security threats. As Ghana decides to go nuclear, this article focused on the steps the government, stakeholders, and voluntary organizations have taken to enhance nuclear security training and education. Ghana has achieved significant advancements in nuclear security training and instruction through programs such as the PGEC and SNAS and is gradually gaining earned global credit for its practices in accordance with world standards. Considering the fast advances in the new technology, a continued sustainable effort to share the knowledge in the field and research will make Ghana's vision of using nuclear power a reality.

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