

Evaluating the Educational Impact of the Gulf Nuclear Energy Infrastructure Institute (GNEII)'s Novel 3S Approach

Adam D. Williams¹, Alexander Solodov^{1,2}, Philip A. Beeley², Saeed Al-Ameri², Amir H. Mohagheghi¹

¹*Sandia National Laboratories*, Albuquerque, NM, USA, [adwilli; ahmohag; aasolod]@sandia.gov;*

²*Khalifa University of Science & Technology, Abu Dhabi, UAE, [philip.beeley; saeed.alameri]@kustar.ac.ae*

ABSTRACT

The Gulf Nuclear Energy Infrastructure Institute (GNEII) aims to develop a responsible nuclear energy culture and institutionalize key nuclear energy safety, safeguards and security ('3S') and nonproliferation norms in the future decision-makers of the Gulf-region nuclear power programs. During its first 6 years of operations, GNEII conducted an annual, semester-long professional development Fundamentals Course based on a novel integrated nuclear energy 3S curriculum that produced 99 graduates from five Gulf-region countries. Hosted at Khalifa University in Abu Dhabi, United Arab Emirates, GNEII's underlying educational paradigm couples the interaction of technical and operational elements with the complexity of real-world challenges to responsible nuclear energy programs. In support of GNEII's vision to be a regional capability for human resource development for peaceful nuclear power programs, the institute's key implementers conducted an analysis of its educational impact. First, the utility and benefit of GNEII's novel, integrated 3S (safety, security and safeguards) curriculum is evaluated in terms of its ability to improve the learning process. In-course weekly evaluations of instructional aptitude, course material appropriateness and overall topic effectiveness are compared from the 2011 and 2016 Course Fellows to address this question. Second, the topical breadth, analytical sophistication and increasing use of the GNEII Fundamentals Course Capstone projects are evaluated as possible evidence of the institute's impact. Content analysis, focused on the academic maturity and range of research topics, is conducted on the 45 GNEII Fundamentals Course Capstone projects to address this question. Analysis of the weekly topic evaluation data indicates a sustained utility and benefit of GNEII's novel 3S curriculum, whereas analysis of the capstone project data describes how the increasing sophistication of research conducted demonstrates GNEII's educational impact. Ultimately, these data suggest that GNEII's educational approach is developing an internationally-knowledgeable, regional cadre of nuclear professionals with whom the world can discuss (and develop solutions for) safety, security and safeguards challenges to global nuclear energy expansion.

INTRODUCTION

The fast pace of the nuclear power program in the United Arab Emirates (UAE)—and associated interest in nuclear power across the region—resulted in a growing demand for a regional mechanism for developing human resources across the varied, complex areas of expertise to support a responsible nuclear energy program. In 2011, The Gulf Nuclear Energy Infrastructure Institute (GNEII) was established to increase understanding of nuclear energy infrastructure among professionals in regional nuclear energy programs. Hosted at the Khalifa University of Science and Technology (and supported by the university's Nuclear Engineering department), GNEII's mission is to develop a responsible nuclear-energy culture and institutionalize safety,

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security and safeguards norms in decision makers from Gulf-region nuclear-energy programs.[1] Phase I of the institute’s operational history ran 2011 to 2016 and resulted from a strategic partnership between the UAE and the U.S.¹, typified by the main implementers of Khalifa University, Sandia National Laboratories (Sandia) and Texas A&M University’s Nuclear Security Science and Policy Institute (NSSPI). GNEII is built on three interdependent, frequently interacting pillars [2], which include:

- **Research**, both applied and longer analytical studies related to nuclear energy infrastructure topics that share the thoughts, ideas and talents of regional professionals with the greater nuclear energy community;
- **Technical services**, wherein the educational and research pillars are augmented with hands-on experience with associated technologies and systems in the assistance of target needs; and,
- **Education**, various offerings that provide a comprehensive understanding of the interacting technical, operational and political aspects of responsible nuclear energy programs and emphasizes the overarching goal of, benefits from and challenges to an integrated ‘3S’ approach to responsible nuclear energy programs (Figure 1).

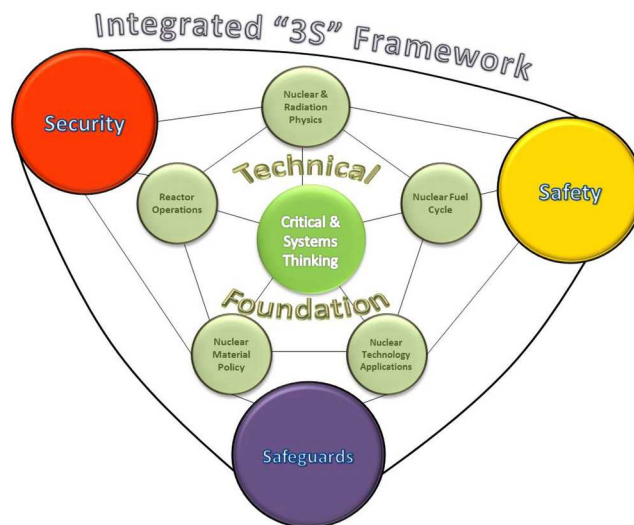


Figure 1. Graphical summary of GNEII's novel, integrated '3S' framework and pedagogical approach.

Over the six years of Phase I, GNEII offered a semester long ‘Fundamentals Course’ that coordinated experts from the UAE, U.S. and international collaborators across the range of nuclear energy infrastructure illustrated in Figure 1. Per Table 1, 99 Fellows completed the rigorous Fundamentals Course. Given the longevity of the course, the number of successful graduates and plans to expand this educational offering [2], this paper seeks to more rigorously

¹ More specifically, the UAE Stakeholders include the Federal Authority for Nuclear Regulation (FANR), the Emirates Nuclear Energy Corporation (ENEC), Nawah Energy Company (Nawah), the Critical Infrastructure and Coastal Protection Authority (CICPA) and the U.S. Sponsors included the US Department of Energy’s National Nuclear Security Administration Office of Nonproliferation and International Security and the US Department of State’s Partnership for Nuclear Security.

evaluate the effectiveness of this novel integrated '3S' framework and pedagogical approach 3S-based educational approach.

Table 1. Summary of GNEII Fundamentals Course Fellows 2011-2016

Year	# UAE Fellows			# Non-UAE Fellows	Yearly Total	Countries Represented
	ENEC/ Nawah	FAN R	CICPA			
2011	4	5	1	0	10	UAE
2012	3	9	2	8	18 (22) ⁱ	UAE, Kuwait, Saudi Arabia, Qatar, Jordan
2013	4	6	3	7	20	UAE, Saudi Arabia, Qatar
2014	6	3	3	0	12	UAE
2015	7	4	5	2	18	UAE, Jordan
2016	2	16	3	0	21	UAE
TOTAL	26	43	17	17	99	5

ⁱDue to modular structure of the course in 2012 not all international participants were able to finish all required modules due to logistical complications.

Methods & Data

A mixed methods analytical design was selected—and is appropriate—for evaluating the effectiveness of this novel pedagogical approach because of the ability to incorporate different data sources and triangulate findings.[3] To help organize this evaluation, two focal points were selected. The first focal point is to understand if (and to what extent) the 3S pedagogical approach improved the learning process of the Fundamentals Course Fellows. Here, the goal is to see if there is evidence suggesting the sustained utility and benefit of GNEII’s 3S framework. The second focal point is to analyze the ‘end of term’ Capstone projects to understand the depth and breadth of the applied knowledge of the Fundamentals Course Fellows. The goal of this focal point is explore the evidence regarding the level of sophistication in the applied research project requirement of the Fundamentals Course.

The data to support the investigation of focal point 1 consists of two different week topical feedback forms—one from the 2011 course and the other from the 2016 course. These feedback forms were submitted to the Fellows (and completed by them) after each topic of the Fundamentals course. For both the 2011 and 2016 feedback forms, the Fellows responded to each question using a 1 to 5 Likert scale. In 2011, there were 12 weekly topics and 8 questions on the feedback form. In 2016, there were 10 and 13, respectively. Because of these slight differences, the feedback questions were collapsed into three major categories (Table 2): instructor effectiveness, course structure effectiveness and overall topic effectiveness. The unit of analysis for focal point 1 is the individual (e.g., each Fellow who completed the feedback forms) and helps capture the ability of the GNEII Fundamentals Course to meet the professional education needs of the Fellows. The analytical goal of focal point 1 is to measure the difference in these feedback forms between 2011 and 2016 (the first and last Fundamentals Course offering during Phase I). Further, the degree to which the responses are the same (or improve) supports the sustained utility and benefit of the 3S pedagogical approach—specifically indicating that the GNEII Fundamentals Course instructor effectiveness, course structure effectiveness and overall topic effectiveness were judged by Fellows as (at worst) consistent and (at best) improved.

Table 2. Summary of the evaluation categories for the GNEII Fundamentals Course 2011 & 2016 weekly topic feedback forms.

Overall Evaluation Category	Specific Course Evaluation Question: <u>2011</u>	Specific Course Evaluation Question: <u>2016</u>
Instructor Effectiveness	<ul style="list-style-type: none"> • The instructor was well prepared for the presentation? • The instructor demonstrated a thorough knowledge of the subject matter. • The instructor interacted well with the participants? • The instructor clearly expressed interest in addressing all questions raised by the participants? • The instructor’s response to questions was clear and understandable? 	<ul style="list-style-type: none"> • The instructor’s activities/exercises and slides helped me achieve the learning outcomes • The instructor kept good discipline in the classroom • The instructor showed enthusiasm for the subject matter • The instructor was available for help outside of class • Assessment and feedback was fair and prompt by the instructor • The instructor include sufficient relevant examples
Course Structure Effectiveness	<ul style="list-style-type: none"> • The materials (handouts, on-screen visuals, videos, job aids, etc.) provided and reviewed were easy to understand? • The materials (handouts, on-screen visuals, videos, job aids, etc.) provided and reviewed offered valuable information that will help me in the future. 	<ul style="list-style-type: none"> • The instructor presented material clearly and lectures were well organized • The instructor’s activities/exercises and slides helped me achieve the learning outcomes • The instructor kept good discipline in the classroom • The instructor showed enthusiasm for the subject matter • The instructor was available for help outside of class • Assessment and feedback was fair and prompt by the instructor • The instructor include sufficient relevant examples • Overall I am fully satisfied with the module content
Overall Topic Effectiveness	<ul style="list-style-type: none"> • The materials (handouts, on-screen visuals, videos, job aids, etc.) provided and reviewed offered valuable information that will help me in the future. • The length of the presentations was sufficient to deliver the subject matter? 	<ul style="list-style-type: none"> • The module was informative and helped me develop an interest in the subject • I believe I achieved the learning outcomes of the module • The content of this module is relevant to my needs/interests/job responsibilities • The instructor presented material clearly and lectures were well organized • The instructor’s activities/exercises and slides helped me achieve the learning outcomes • The instructor kept good discipline in the classroom • The instructor showed enthusiasm for the subject matter • The instructor was available for help outside of class • Assessment and feedback was fair and prompt by the instructor • The instructor include sufficient relevant examples • Overall I am fully satisfied with the module content • Overall I am fully satisfied with the module delivery • Overall, I am fully satisfied with this module

Similarly, the data to support focal point 2 is found in the collection of 45 Capstone Projects generated by GNEII Fellows from 2011 to 2016. The Capstone Project served as the culminating requirement for the GNEII Fundamentals Course in which Fellows completed a practical research project related to one of the institute's three core competencies (integrated 3S methodologies, nuclear infrastructure development and Gulf/Middle East regional nuclear interactions).² Using elements of content analysis [3], the Capstone Projects were evaluated in terms of technical complexity, methodological sophistication and ability to address GNEII's research areas. The unit of analysis for focal point 2 is the individual Capstone Project, which provides insights into a 'beyond educational effectiveness' measure of impact. Specifically, the higher the technical complexity, methodological sophistication and ability to address GNEII's research areas, the better the knowledge transfer from GNEII's Fundamentals Course.

ANALYSIS

Comparing the 2011 and 2016 GNEII Fundamentals Course feedback forms yielded several key trends and insights (Figure 2). First, the Fellows responses show high levels of effectiveness reported for each effectiveness category in both 2011 and 2016, with the lowest average score being 3.8 (for the overall topic effectiveness of 'Basic Nuclear & Reactor Physics' in 2011) and 4.8 (for the instructor effectiveness of 'Critical, Systems & 3S Thinking' in 2011, 'Safety I' in 2011 and 'Security II' in 2016 and the course structure effectiveness of 'Security II' in 2016). That all averaged responses across the three evaluation categories for all weekly topics in both 2011 and 2016 range from 3.8 to 4.8 illustrates a high level of consistency to meet the professional education needs of the Fellows.

Second, several trends emerged in the data. For example, the responses for the instructor effectiveness were static for the 'Nuclear Fuel Cycle, History & Policy,' 'Safety II,' and 'Security I' weekly topics, and increased (by an average of 0.275) for the 'Basic Nuclear & Reactor Physics,' 'Safeguards I,' 'Safeguards II,' and 'Security II' weekly topics. These illustrate that, overall, the Fundamentals Course instructors were able successfully adjust to Fellow concerns and suggestions. Similarly, for the 'Basic Nuclear & Reactor Physics,' 'Nuclear Fuel Cycle, History & Policy,' 'Safeguards I,' 'Safeguards II,' 'Safety II,' 'Security I' and 'Security II' weekly topics, the course structure effectiveness increased by an average of 0.33. This trend shows that the materials and delivery mechanisms designed into the Fundamentals Course successfully transferred knowledge across this broad set of topics and improved over time. Lastly, similar trends are seen for overall topic effectiveness as the data show no change for the 'Safety II' and 'Security I' weekly topics and an average increase of 0.36 for the 'Basic Nuclear & Reactor Physics,' 'Nuclear Fuel Cycle, History & Policy,' 'Safeguards I,' 'Safeguards II' and 'Security II' weekly topics.

An additional trend of note was that across all three evaluation categories, there was a decrease in all three effectiveness categories for the 'Critical, Systems & 3S Thinking,' 'Nuclear Power Operations & Systems,' and 'Safety I' weekly topics. Despite high levels registered in both 2011 and 2016, the data show a decrease (averaging 0.35) over Phase I inconsistent with the

² For more details on the Capstone project, please see A.D. WILLIAMS, et al., "Expanding in Research Opportunities: Gulf Nuclear Energy Infrastructure Institute (GNEII) in Year 5," Proc. 56th INMM Ann. Mtg, Indian Wells, CA (2015).

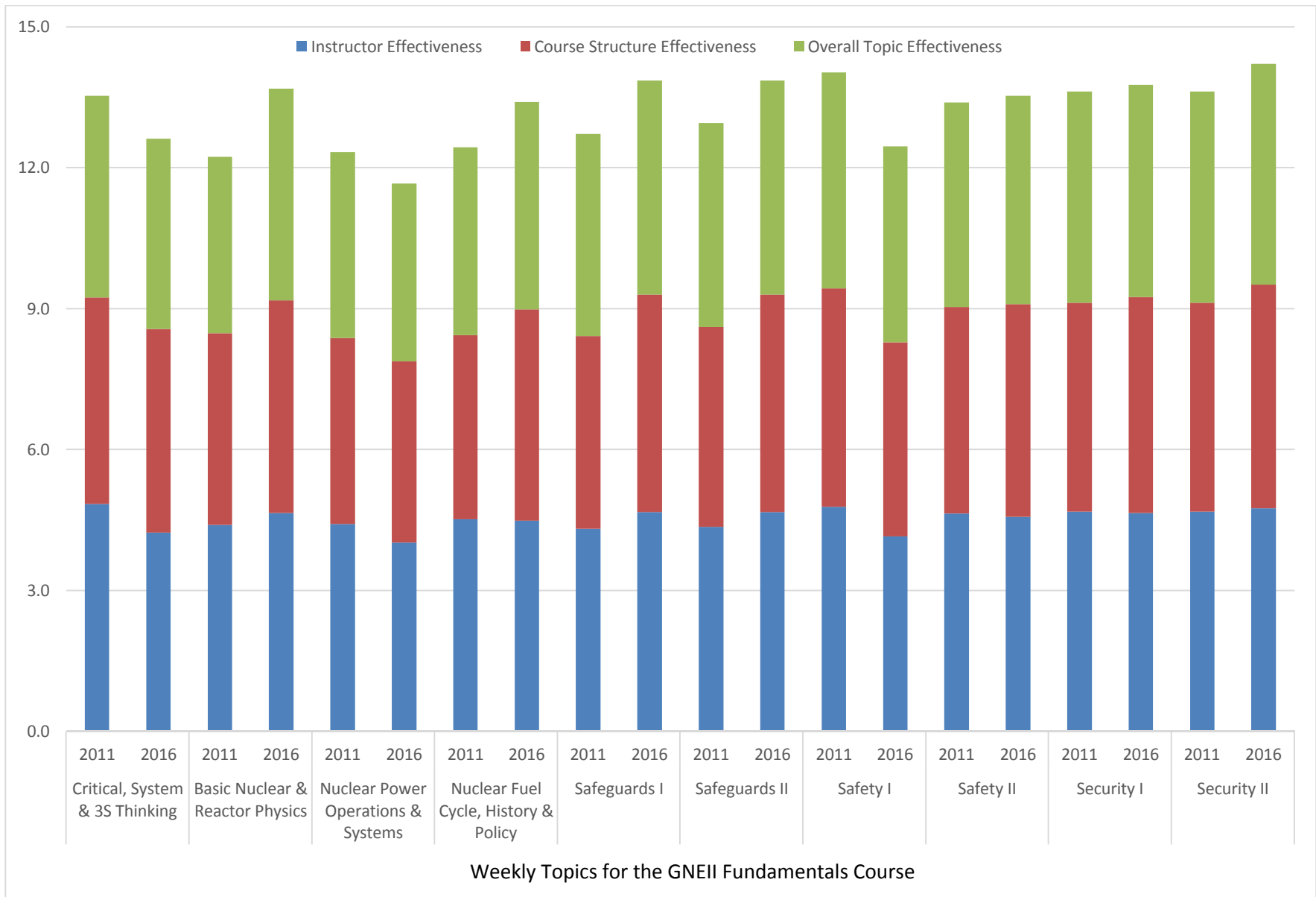


Figure 2. Analytical results from the evaluation categories for the GNEII Fundamentals Course 2011 & 2016 weekly topic feedback forms

other trends and hypothesized results. Though not explicitly investigated in this study, one possible cause for this categorical decline in the effectiveness of these three weekly topics is the increased expertise and experience of the Fundamentals Course Fellows between 2011 and 2016.

Overall, the data supporting focal point indicate a both a high level of consistency across the three evaluation categories—instructor, course structure and overall topic effectiveness. In addition, aside from the ‘Critical, Systems & 3S Thinking,’ ‘Nuclear Power Operations & Systems,’ and ‘Safety I’ weekly topics, the data showed improvements across most of the other weekly topics for each of the three evaluation categories between 2011 and 2016. This is evidence that GNEII’s novel, integrated ‘3S’ framework and pedagogical approach is both useful and beneficial for meeting the professional education needs of GNEII Fellows.

The content analysis of the 45 Fundamentals Course Capstone Projects provides additional evidence. For example, there is a clear increase in the technical complexity and methodological sophistication of these research efforts. Early Capstone Projects can be categorized as thought pieces that provided basic conceptual mapping of topics of interests—exemplified by the ‘Integrations of Safety, Security & Safeguards’ (2011) and ‘Transparency in Nuclear Security’ (2012) projects. The next level of depth and sophistication emerged with a series of topical literature surveys which included the ‘A Qualitative Assessment of Fuel Fabrication Options in the UAE’ (2013) and ‘Survey of the Current Spent Nuclear Fuel Storage Technologies & Assessing Safety Approaches of Existing Systems for Barakah Nuclear Power Plant (BNPP)’ (2014) projects. The highest level of complexity and sophistication included studies based on real data collection via surveys and interviews (e.g., ‘Mitigation of national cultural differences effects during safety, security emergency at an NPP site’ in 2016) and actual experimental results (e.g., ‘Measurements of radionuclides concentration in UAE cucumber’ and ‘Neutron activation of living insects for safety and security applications’ in 2016).

The data also support the ability for the Capstone Projects to support GNEII’s core research areas (Table 3). Despite only addressing 3S methodologies and regional nuclear interactions in 2011, Fundamentals Course Fellows have consistently completed applied projects to expand and refine GNEII’s research areas. For example, 2014’s ‘Evaluation of Safeguards and Security Options for the Dry Cask Storage in the UAE’ and 2016’s ‘Neutron activation of living insects for safety and security applications’ support the 3S methodology research area. Likewise, ‘Evaluation of Security and Safeguards Measures for the Transportation Security in the UAE’ (2014) and ‘Evaluation techniques for degradation of reactor containment building’ (2016) supports the infrastructure development research area, which ‘An Initial Radiation Baseline Study of Urban Environment in Abu Dhabi’ (2014) and ‘Evaluation of Cosmic-Ray Dose in the UAE’ (2016) support the regional nuclear interactions research area.

Table 3. Categorization of GNEII Capstone Projects by core research area.

Core Competency Research Area	2011	2012	2013	2014	2015	2016
Integrated 3S methodologies	1	1	4	4	2	3
Nuclear infrastructure development	0	6	4	4	4	3
Gulf/Middle East regional nuclear interactions	1	4	3	1	4	3

Likewise, the data suggest that two particular topics are iteratively revisited and the resulting Capstone Projects provide increased depth and breadth. For example, the conclusions from 2014's 'Development of Recommendations for the Nuclear Security Culture in the UAE' were incorporated into the design of the interviews and surveys of 2016's 'Mitigation of national cultural differences effects during safety, security emergency at an NPP site.' Here, deeper insights for and the importance of responsible nuclear energy culture and clear communications were reinforced. A similar thread can be seen from the basic conceptual analysis in 2011's 'Integration of Nuclear Safety, Security & Safeguards' to nuclear fuel cycle application in 2013's 'Safety, Security, and Safeguards Challenges for Building a Final Repository for Spent Fuel in the UAE' to the active integration of 3S concepts into operational realities in 2015's 'Operational Security and Information Protection in the Areas of 3S.' Lastly, several GNEII Capstone Projects provided the 'seed' for additional, more in-depth research efforts. For example, the 2015 'Evaluation of Threats by Drones to a Nuclear Power Plant' resulted in expanded analysis in both a term paper at Khalifa University [4] and a published article in *Security Journal* [5]. In addition, the Capstone Project 'Investigation on the Sensitivity of UAE Domestic Agricultural Production to Radiological Contamination Following a Hypothetical Severe Nuclear Accident at Barakah NPP' (2015) spurred a presentation at the 2015 'International Conference on Energy, Water and Environmental Sciences' and a published article on natural occurring radioactive material (NORM) in date palms in *Health Physics Journal* [6].

Ultimately, the content analysis of the 45 GNEII Capstone Projects completed from 2011 to 2016 indicates an increased technical complexity and methodological sophistication of research conducted and broader, more nuanced set of topics covered—illustrating a positive effect of the GNEII Fundamentals Course.

SUMMARY

Data from both Fundamentals Course weekly topic feedback forms and Capstone Projects during Phase I of GNEII operations provide evidence that support the utility and benefit of GNEII's novel, integrated '3S' framework and pedagogical approach. In addition, efforts are underway to more fully characterize GNEII's institutional impact, including a survey of past GNEII Fellows. Further, Phase II of GNEII was officially launched with the signing of a second MOU³ between the implementers that emphasizes the evolution and expansion of peer-to-peer collaboration across the institute's education, research and technology demonstration pillars. Future GNEII operations will focus on leveraging the institute's strong reputation for producing high-performing graduates and maintain (and expand) its role as a leading entity through which Gulf and Middle East voices can be introduced into global nuclear discourse.

³ This MOU is entitled 'Establishing a Framework for Continuing Collaboration with the Gulf Nuclear Energy Infrastructure Institute (Sandia MOU Number 16-2-706)'

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